NSRP/ASE Surface Preparation and Coatings Panel (SP-3)

Study to Determine the Level of Salt Mitigation as related to the Accuracy of the Measurement and Cost Benefits

Final Report

Prepared by Lydia M. Frenzel, Ph.D.
Fat Squirrel 22, LLC

February 18, 2011

Advanced Technology Institute
5300 International Blvd.
North Charleston, SC 29418
Support Services Agreement No. 2010-385

NSRP Surface Preparation and Coatings Panel (SPC)
Study to Determine the Level of Salt Mitigation as related to the Accuracy of the Measurement and Cost Benefits

Submitted to: Judie Blakey, Steve Cogswell, Madeleine Fincher- ATI
Copy: Peter Ault, Elzly Technology Corporation, participant
Prepared by Lydia Frenzel,

List of Tables

List of Figures

Project Goals and Objective:

There is concern that the costs outweigh the benefits for salt mitigation in surface preparation. This cost in hidden in line items for surface preparation as part of normal operations.

This project will study the cost versus benefits and evaluate risk assessment for a given level of salt mitigation. It is not intended to generate new laboratory data, but rather to build on existing information.

The goal is to re-examine the level of mitigation of salts and to determine if there is justification to relax this level in limited areas after repeated attempts to remove the salt. This NSRP work would serve as the basis to look at the practical issues.

Another goal is to define whether the current method of obtaining the extract provides the accuracy in the field at the lower levels of detection. The objective is to identify situations where the potential for spending money to clean off salts at a lower concentration is not justified.

Another goal is to establish uniform preservation process instructions for salt mitigation to reduce variance requests, decrease mitigation costs, and delay time.

Summary:

1. The US Navy's requirement for salt level in 009-032 or 3 and 5 μg/cm^2 chloride or the conductivity of 30 to 70 μS/cm (based on a Bresle cell patch of 12.5 cm^2 and 3 ml of de-ionized water) are in agreement with the IMO PSPC levels based on sodium chloride for water ballast tanks.

Tator (2010, ref 141) summarized the European Commission (2004, ref 108) and the ISO Technical Report 15235 (ref 80) results that for marine immersion, a zinc-rich, three coat system can tolerate 40 μg/cm^2 chloride; an organic three coat system can tolerate 5 to 50 μg/cm^2 chloride. These two reports are based on first-hand data and on coatings manufacturer's recommendations.

The coatings manufacturer's guidance levels, as proffered for this study and as reported in ISO TR 15235, range from 3-10 μg/cm^2 chloride for immersed conditions, and 5 to 25 μg/cm^2 chloride for atmospheric conditions.

Thus the requirement could be relaxed. However, based on the Shipyard survey results, the Shipyards are achieving the Navy's limits without, at this time, major non-compliance issues that result in extensive rework or a halt in production time.

2. The Commercial shipbuilding industry has acceptance criteria based on NaCl, with the primary measurement being conductivity, but no set frequency except a minimum of one per block, unit, or plate. This can result in less total measurements than the US Navy.

On the other hand, the US Navy accepts either specific ion or conductivity measurements with acknowledgement that the conductivity will measure total soluble salts. With the dual measurements, there appears to be few areas for re-work.

3. No single source of a significant cost saving is apparent, except in the difference between quality assurance between commercial and US Navy practices.

The largest single cost savings without loss to performance would be to adopt a practice of Graduated Quality Assurance for those contractors who consistently provide superior products. Essentially the measurements are being taken during the building stage or repair operations by the SY, and again at government inspection points, resulting in a doubling of the costs associated with salt measurements.

The most significant difference between US Navy and commercial work, is that the salt measurement is almost always a "G-Point", that is, a inspection point where a government inspector has to be notified that the shipyard is performing the test and has to opportunity to oversee the inspection. The "G-point" is not just a "paint" requirement but is part of US government standard items. This call-out procedure will involve a minimum of two people, shipyard and US Navy, for a minimum of one hour, or a combined two man-hours. Interviews with SY imply that at least one hour is involved, and sometimes up to a half-day.

Commercial ship building practices adopt quality assurance using a level of effort of the shipyard working alongside the coating supplier and client/owner's representative. The shipyards have integrated the surface preparation parameters, such as profile, salt measurement, and film thickness into their process control so that when the government inspectors of the Navy come on site, the module meets the build criteria.

A study by the Naval Metalworking Center (ref 137, appendix 3) described a major lost production cycle that was attributed to salts on incoming steel.

None of the SY reported any major disputes or slow downs during the survey. One shipyard, clearly had an issue, based on the amount of out-of-compliance readings, that took about two weeks to resolve. The contact could not discuss any details.

4. Only one shipyard had a written mitigation procedure because out-of-compliance happens seldom. The Preservation Process Instruction issued in December 2010 is serving as a standard mitigation procedure.

5. On accuracy and field retrieval, the inspectors realize that the results can vary from spot-to-spot depending upon whether they located a salt crystal. Individuals get adept and very consistent results.

Spot tests side-by-side in the field validated that the variance in the field is far greater then the precision or standard deviation of the instruments. While the laboratory methods can establish precision, the same comparison requirements cannot be transferred into the field. (see appendix 6)

NACE Standard Practice (SP) 0508 provides the basis for comparison of extraction methods in the laboratory at 3, 5, and 8.5 $\mu g/cm^2$ total soluble salts (not defined as NaCl or chloride anion).

The numerous references, on the question of extraction efficiency, are mixed with both ranges from 25% to higher than theoretical. During the preparation of NACE SP0508, the task group realized that the extracted results were higher than theoretical, so a baseline conductivity had to be established.

5. All reports agree that extraction and measurement of salts on rusted steel is difficult. The extraction methods are for surface soluble salts.

6. The findings of the survey can be summarized as:

- Out of 2543 measurements, only 95 were out of compliance. Of those, 23 came from an NSRP shipyard who had a single instance of multiple cyclic blast, wash, reblast; and 23 came from a commercial contractor who was reporting all their test measurements during their daily operations to meet the specifications. As an analogy to SY operations, the latter would reflect the level of effort during the "building" stage before release of the unit. This study did not capture the shipyard daily measurements, we captured just the required inspection points.
- No major disputes were reported that required resolution.
- US Shipyards other than Navy very seldom conduct salt tests unless required by the bid documents.
- Percentage rework (out-of compliance measurements) for New Build is 1%. Percentage rework (out-of- compliance measurements) for Navy repair is 5%. Combining all the samples, the percentage rework (out-of-compliance measurements) is 3.7%

7. The summary of the coating manufacturer comments to date are:

- Navy, IMO are conservative, and within coatings guidelines.
- The Navy guidelines require too many measurements.

8. Combining the DIRECT cost of equipment, expendables, and labor with the average number of salt measurements per week results in annual costs for salt measurements of $66,000 for Naval activities. The full details of the assumptions are in appendix 4.

These costs DO NOT include the 1-4 hours of SY or US Naval personnel time associated with the G-Point inspection which would add an additional $100 to $400 per week. See Appendix 4

Table 1 Cost of Salt Measurements with Amortization of Equipment

	Cost of Salt Measurements/ per site				
	Ave Test/week	Weekly costs		Annual costs	
		Low of $6.24	High $27.00	52 week	52 weeks
Mixed Commercial-Navy NB	18	$112	$486	$5,841	$25,272
Commercial New Build Avg	51	$318	$1,377	$16,546	$71,604
Commercial Repair offshore	20	$125	$540	$6,490	$28,080
Navy New Build	20	$125	$540	$6,490	$28,080
Navy Repair	20	$125	$540	$6,490	$28,080

Including the labor, the Navy Repair including $150/week labor, for 6 yards, would then be $30,680 * 6 or $185,000.
Additional comparisons are in Appendix 4

Table 2 Cost of Test including Initial Setup/Equipment Cost

	Type	Datalogger	Time/test	Cost/test
Chlor*Test sleeve	conductivity	X	5 – 10 min	$23.7 to $27.5
Chlor*Test sleeve	Chloride		5-10 min	$23-$27
Bresle	Conductivity	X	4 to 17 min	$9.4 to $18.6
Bresle	Chloride	X	8 to 17 min	$14 to $21.6
RPCT SSM	Conductivity	X	3 to 4 min	$8.4 - $9.2
DKK-TAO SSM	Conductivity	X	3 to 4 min	$6.2 to $7
NST SaltSmart	Conductivity	X	2.5 to 10 min	$15 to $21
Elcometer 130 Paper absorbance	Conductivity		4-7 min	$11 to $14
Chlor*Test portable chloride meter	Chloride	x	In Development	

Table 3 Cost of Tests After Equipment is Amortized

Comparison Cost after initial equipment purchase is amortized			
	Type	Time/test	Cost/test
Chlor*Test sleeve	conductivity	5-10 min	$23 to $275
Chlor*Test sleeve	Chloride	5-10 min	$22-$25
Bresle	Conductivity	4 to 17 min	$8.9 to $18
Bresle	Chloride	8 to 17 min	$13 to $20.6
RPCT SSM	Conductivity	3-4 min	$2.5 - $3.3
DKK-TAO SSM	Conductivity	3-4 min	$2.5 - $3.3
NST SaltSmart	Conductivity	2.5 to 10 min	$14 to $20
Elcometer 130 Paper absorbance	Conductivity	4-7 min	$5.6 to $8
Chlor*Test portable chloride meter	Chloride	In Development	

9. There is a large cost factor that is missing in this study, it is the in-process level of effort required to insure that when the governmental inspector is called out for a G-point, the module will meet the specifications. The shipyards document the time and cost for the G-Point. The in-process cost for the preparation for the inspection might or might not be available from the SY proprietary data.

Recommendations:

1. Based on the coatings manufacturers' data, there is an argument that the level of salts could be raised without harm to performance. There also exist extreme accelerated laboratory studies that indicate no salt level is safe. There is no clear cost benefit associated with changing the level either lower – as the level is already lower than coatings manufacturers or higher- as the percentage of out-of-compliance is achievable. Removal of all the Governmental Inspection points for salts would result in a potential maximum savings of **$180,000 a**nnually based on average salt measurements, or **$360,000** annually, based on the maximum number of salt measurements.

2. To conform closer to commercial practices, the Navy should consider adopting a strategy of graduated quality control. This might produce huge cost savings with a low risk to benefit because each shipyard already has a hidden in-process cost to insure that they meet the G-points. The US Navy could recapture some of the G- inspection time.

3. Each Shipyard should consider contacting the Naval Metalworking Center concerning the potential savings of $265,000 per hull to see if the methodology would be applicable. However, the large savings includes the removal of lost time during production during the final blast and paint stage. None of the shipyards, either in the survey or during

phone interviews, indicated that they were experiencing the multiple test-wash-blast cycle as described during a phone discussion.

Task 1 – Bring Together the Studies already available on Salt Levels and Performance and Accuracy.

For consistency, the values for salt density are reported in $\mu g/cm^2$ in this report, rather than switching between mg/m^2 and $\mu g/cm^2$.
$10\ mg/m^2 = 1\ \mu g/cm^2$

It is noted that reports and guidance levels might refer to either NaCl or Cl^-. In this report, the salt values are normalized to Cl^-, the chloride ion.

When referring to conductivity, it is imperative to know the volume and the surface area; these vary considerably. The Navy conductivity values are based on 3 ml and a 12.5 cm^2 (1250 mm^2) Bresle patch.

Many papers deal with laboratory studies with immersion, or accelerated testing with condensation as the basis. None of the papers are presented as a risk assessment versus cost benefits issue. However, the key to threshold limits for performance is reflected in the coatings manufacturers' data. (see later topic)

Between the 1997 and current date, there have been several laboratory tests that would seem to advocate lower and lower amounts of salts can have detrimental effects.

When considering coatings performance, the reader is cautioned to look at studies that reflect the conditions under which the coating is to be exposed, not accelerated conditions. O'Donoghue et.al. (JPCL, May, 2010, p.30, The Dark Side of Misreading the Relevance of Coating Testing) succinctly states "faster tests mean the results are less likely to correlate with real-life performance."

However, these catastrophic results of salt can be interpreted in great measure by setting up conditions to accelerate water absorption and using the presence of salt as an indicator that the water has reached the metal/coating interface. When considering the Risk of failure with a salt concentration, the testing criteria should be close to the operating environment. Accelerated testing allows you to compare coatings performance, but not to predict lifetime.

The bibliography includes papers that discuss salts and additional 8 papers by C. Hare that discuss the movement of water and oxygen through the paint film and blistering. (See Appendix 1)

Discussion of the Parameter that the Studies are measuring:
Migration over the coating should be uniform. The rate of migration of water (vapor) through a permeable coating is predicted to increase with temperature. When the water reaches the substrate, it will finds its way to non-uniform sites such as salt crystals, grain boundaries, pockets of air, gaps/crevices in the steel under lips formed during the blast cleaning, or crevices/pits in the steel.

Ionic materials or soluble salts cause problems by facilitating, in the presence of water and oxygen, corrosion on exposed steel or blistering on painted surfaces.

There are many laboratory and field studies concerning the level of salt concentration and resistance to blistering. The typical result of these studies is predictable from thermodynamic principles. The studies are measuring the absorption of water liquid or vapor (or oxygen gas) into a coating; transport through the coating to the metal/coating interface; and the subsequent interaction between the water and initiation defect sites. This migration takes place over the entire surface that is under the same condition. Placing salt crystals on the substrate is the same as creating initiation defect sites on the substrate.

As the studies are based upon water penetrating the coating film, all the studies thus show the same results.

- It takes longer for water to penetrate a thicker coating.
- Immersion, condensing or ponding of water against the plate has a greater absorbance rate than a humid atmosphere with a partial pressure of water vapor.
- Wetting and drying cycle tests will take longer for water to penetrate to the substrate as the water is absorbed and then dries off.
- Temperature and pressure differentials between the outer surface and the coating/metal substrate affect the absorbance rate.
- An increase in temperature will generally increase the rate of absorption if the coating doesn't change its polymeric structure.

In simple terms, when the water (oxygen) starts to absorb on the outer surface and penetrate into the coating film, it does not have a direct connection with the inner substrate unless there a direct channel or void through the pigment/resin film such as a pinhole. However, when the water reaches the coating/metal interface, it will accumulate, form a lateral split, and end up at microscopic initiation points, such as areas where the film adhesion never occurred because of wetting difficulties, or microscopic cracks, voids, irregularities caused by the blast process, or salt crystals. The defects lead to continued disbondment as a layer of water can form at the metal/coating interface and blister growth as the water concentrates at the salt crystals. Clive Hare (ref 142-150) discusses this absorption and subsequent problems in detail.

Morcillo (ref 112 2006) states that the painted surface has to be wetted and water has permeated through the paint coatings, for there to be an osmotic force generated by the solution of either side of the film.

Both water and oxygen are of concern and can permeate polymer coatings. In terms of size, the molecular diameter of oxygen (2.34-2.96 angstrom units) is close to water (2.26-2.88 angstrom units) ("Physical Chemistry," Walter J. Moore, 3rd Edition, Prentice-Hall, 1964, p.229). Based on molecular diameters, the rate of diffusion would be similar. However, water has a dipole moment; oxygen molecule does not. This difference in dipole moment will affect the rate of diffusion through the coating. Clive Hare (ref 142-150)

One observes, in cases of high humidity (condensing, immersion), that the absorbance of water (subsequent blistering) would occur faster than in the case of water vapor, the blistering at substrate forms based on the number of salt crystals,, and then as the coating is saturated, the extent of defects, reflective of the initiation sites on the substrate, becomes static.

This behavior can be seen in the blistering data and figures of 1995 Ocean City Research Corp. (OCRC) Report (ref 41) to NAVSEA. The blistering level is higher for 5 $\mu g/cm^2$ than for zero salts. Also, as the hot distilled water test progressed, the coatings became saturated with water. There was a distinct difference at 2 weeks exposure; but by 10 weeks, the blistering difference between 5, 10, and 25 had no clear relation (Page I-11- I-20.) OCRC found that water absorption peaked in 5 days for coating panels, and about 10 days for free films. When films were dried, there was weight loss, due to both water and solvent loss.

Summary of Effects of Water Absorption:

The more defects on the substrate, the more sites there are for the accumulation of water under the coating and the more numerous or larger blisters can be observed.

It is predictable that for wet-dry cycles, it will take longer for water to reach the metal/coating interface.

When water penetrates to the substrate, it is predictable that substrates with "zero" defects will always perform better than substrates that have defects with 5 $\mu g/cm^2$ which will perform better than substrates with 10 $\mu g/cm^2$.

Whether the coating blisters or lifts from the substrate will depend upon the wet adhesion and the elasticity of the coating. In theory, there is no safe minimum; in practice, coatings do perform over less than perfect substrates.

Limits on Upper Values of Chloride Concentration

Organizations have adopted different values of salt and the conductivity as their acceptable upper limit. These are the values that ship builders must meet.

Table 4 Soluble Salt Levels Navy and IMO

		Cl^- µg/cm^2	NaCl µg/cm^2	Conductivity microSiemens/cm note (1)
US Navy (all critical areas)	Immersed	3		30
US Navy	Non-immersed	5		70
IMO	(ballast tanks/voids)	3.2 (calc)	5	**12.5 (calc)**
Ocean City Res. (1995. ref 41) NAVSEA		<5		

The Navy's adoption of 3 µg/cm^2 Chloride ion preceded the adoption of IMO of 50 mg/m^2 (5 µg/cm^2) of NaCl for primary or secondary surface prep for ballast tanks.

Note (1): Bresle method using a 1250 mm^2 Bresle Sample Patch, 3 ml water, and a HORIBA B-173 meter or equivalent NAVSEA approved test equipment . Conductivity is measuring total soluble salts. An assumption is made that NaCl is the primary, or only, source of ions.

For a Conversion of sodium chloride to chloride:

58.5 µg NaCl is composed of 23 µg Na and 35.5 µg Cl ; 64.6% by weight is Cl^-
Thus the IMO standard of 50 mg/ m^2 corresponds to 3.2 µg/cm^2 of Cl^- or 32 mg/m^2 of Cl^- and is in agreement with the NAVY level of 3 µg/cm^2 of Cl^-.

See Appendix 2 for further calculation discussion.

Ocean City Research, report to NAVSEA, 1995 (Ault, Kuljian, Ellor) (ref 41)
For the limits, the authors of many of the interim studies could have gone immediately to the NAVSEA report of 1995. Their conclusions included:

- The propensity for test panels to blister in the tests conducted was influenced by less than 5 µg/cm^2 of chloride contamination on a steel panel surface. The tests conducted are accelerated laboratory tests and represent severe exposure conditions, so further investigation is needed to identify a threshold value for chloride contamination which effects coating performance in service.
- Over a long period of time, low surface contamination levels may be as detrimental as higher surface contamination levels.

The results of laboratory Studies by commercial persons other than coatings manufacturers have ranged from recommendations for **ZERO** tolerance and upwards. Some of the more recent findings are given below.

Table 5 Literature Safe Values for Salt Limits

Compilation of "Safe" limits of salts from recent papers				
		Cl^- µg/cm^2	NaCl µg/cm^2	Conductivity microSiemens/cm
Baek (2006, ref 112)	Epoxy, water ballast tank	5-7		
Lee & Baek (2010 ref 136; 2008 ref 124)	Epoxy, water ballast tank		7-10	
Al-Monsour (2010 ref 134)	High solids, polyamide epoxy	20		Note (2)
European Commission (2004, ref 108 Tator, ref 141))	Zinc rich primer system immersed and atmospheric	40	65 (calc)	Note (3)
European Commission (2004, ref 108 Tator, ref 141)	Fusion bonded epoxy system-fresh water immersion	10	15 (calc)	Note (3)

Note (2) As with Ocean City Research paper Ault, Kuljian, Ellor ref 41), Al Monsour (Saudi Aramco) compared several methods of exposure and testing for performance. Al Monsour recommended to establish a detailed methodology in conduction these test under different conditions and also establish guidelines on how to interpret the data that is derived from these tests.

Note (3) The doping method used to determine soluble salt limits was a worst case method and the limits suggested by the work and reported are likely to be conservative:

Task 2- Solicit data and comments from coatings manufacturers

Several coatings manufacturers were contacted for their primary data and recommendations. The coatings manufacturers became interested in the level of salts because of waterjet cleaning in Europe. The primary electronic data base for performance reside with the companies such as: International Paint, Hempel, Jotun, PPG, and Sherwin Williams.

The typical comments are that the levels adopted by IMO or by the US Navy are conservative relative to what the coatings manufacturers could accept.

- Navy, IMO are conservative to these values.
- Some coating manufacturers have not tested over salts. Their position is that there should be zero salts
- The US Navy is requiring too many measurements.

Specific Comments and current Limits on Salts:

Manufacturer 1

The Coating manufacturer (CM) normally only includes soluble salt levels in tank coating specifications for commercial customers. These areas are where salt levels are routinely measured.

The CM is not currently looking at level of salts and evaluating risks. Their work in this area was accomplished some time ago (circa 1985) when they became involved in hydroblasting (HB) in the European community. HB brought salts to mind and they were seeing very good results with removal of salts. Their paint inspectors were seeing some infrequent failures because of immersion in tanks and condensation.

They looked at salt levels with tests involving: Condensation and immersion test, Cyclic Weathering- wet-dry; Different films and formulations, Different temperatures, and permeability of water through the coatings. They use for example, ASTM 1653- Standard Test Method for Water Vapor Transmission of Organic Coatings Films.

Manufacturer 2- doesn't test over deliberately contaminated coupons. Their testing regime of new formulation is a comparison of what they produce now compared to the test coatings.

Manufacturer 3: Is using ISO 8502-9 (Conductivity Analysis, Sample obtained by Bresle 8502-6) for measurements
Note: Manufacturer cited Equivalent sodium chloride mg/ m^2. Author converted to other units for comparison

Table 6 Acceptable Salt Levels - Coating Manufacturer

Location	Equivalent **Sodium**	Conductivity (V=15 ml Bresle)	Equivalent **Chloride**

	Chloride		
Cargo Tanks	6 µg/cm^2	10.0 µS/cm	4µg/cm^2
Immersed areas	8 µg/cm^2	12.3 µS/cm	5 µg/cm^2
Dry cargo holds	10 µg/cm^2	16.7 µS/cm	6.6 µg/cm^2
Atmosphere exp	10 µg/cm^2	16.7 µS/cm	6.6 µg/cm^2

Water Ballast Tank area- they follow (IMO MSC 215 #82) The manufacturer accepts 50 mg/m^2 NaCl. For mitigation of salts, this manufacturer includes further notes:. "Prior to treatment the substrate should be high pressure washed with fresh (clean) water. As a guidance we recommend that the conductivity of the abrasive prior to treatment should not be higher than 250 µS/cm (ISO 11127-6)

Manufacturer 4:

Acceptable salt levels on steel to be coated. Based on experience, we specify the following maxima for salt contents on steel surfaces prior to coating application:

Table 7 Acceptable Salt Levels - Coating Manufacturer

Ballast tanks	8 µg/cm^2 NaCl	
Cargo tanks	5 µg/cm^2	
Cargo tanks	2 µg/cm^2	Elevated temperatures
Submerged outside hull	8 µg/cm^2	
Fresh water tanks (Continued below)	Low salt level- risk of osmosis No fixed acceptance value	
Fresh water tanks	5 µg/cm^2	Ambient temp
Fresh water tanks	2 µg/cm^2	Elevated temperatures

In comparison, the NORSOK standard M-501 "Surface preparation and protective coating" specifies max 20 mg/ m^2 NaCl for "offshore installations and associated facilities".

Manufacturer 5

We were asked for comment by ISO TR 15235, and our input was as follows:

Cargo Tanks (chemical immersion) 5 µg/cm^2
Fresh water tanks 5 µg/cm^2
Ballast tanks and outer hull (sea Water immersion) 10 µg/cm^2
Atmospheric exposure 25 µg/cm^2

These values were for sodium chloride as measured by Bresle Patch method.

We normally only include soluble salt levels in tank coating specifications for commercial customers. These areas are where salt levels are routinely measured.

ISO 15235 Compiled Data from Multiple Coating Manufacturers

"Soluble Salt Contamination on Blast Cleaned Surface and the Effect on the Durability of Subsequently Applied Coatings.

The data in this ISO report remains valid. Some coating manufacturers sent their ISO 15235 data in response to the NSRP query. This document reflects the polling of 30 coatings manufacturers, the majority of whom manufacturers coating systems for ships and the marine industry. This reflects their opinion on performance versus level of ionic contamination.

Table 8 Acceptable Salt Levels - Coating Manufacturer
Exposure- **SALT WATER IMMERSION-**

		Highest Salt Level Tolerated	Comments
Source	Conductivity µS/cm	Equi, Cl- µg/cm^2	1 µg/cm2 = 10 mg/m2 1mS/m =10 µS/cm
A	53	6.9 µg/cm^2	#1 Bresle, cond calc salt
B		10 µg/cm^2	#1
C		8 µg/cm^2	#1
D		10 µg/cm^2	#2 Bresle, titrate chloride
E		5 µg/cm^2	#1
F		3 µg/cm^2	US Navy
G		10 µg/cm^2	#1
H		5 µg/cm^2	DIN 28 (accept higher)
I		5 µg/cm^2	DIN working paper 28
J		3 µg/cm^2	#1
K		7 µg/cm^2	

Table 9 Acceptable Salt Levels - Coating Manufacturer
Exposure- Marine Atmosphere

		Highest Salt Level Tolerated	Comments
Source	Conductivity µS/cm	Equi, Cl- µg/cm2	1 µg/cm2 = 10 mg/m2 1mS/m =10 µS/cm
A	150	19.5	#1 Bresle, conductivity calc salt
G		25	#1
H		5	DIN working paper 28
I		5	DIN working paper 28
J		5	#1
K		7	
L		7	Total Salt Level

ISO 15235 Data from Coating Manufacturer

One coating manufacturer had compiled laboratory data over a period of 4 years

“These test data were not necessarily collated at one and the same time but over a period of years. The company has been using a test to determine coating performance over “salt contaminated” surfaces for over 4 years. However, in each test a control was used of known and recognized performance which allows the correlation of systems or schemes tested at different times. The “low risk of failure” figures are relatively well defined. The company has used internal information and knowledge of products in some cases to predict the “high risk of failure” figures.

The tests were carried out around the company's group laboratories by a standard test method.

The method ensures that correct levels of contamination were deposited on the test panels and control determinations were made of the contaminated levels via Bresle patch testing and also from “clean” panels. The panels were then coated with the appropriate test coatings and/or schemes for their resistance to osmotic blistering either under permanent immersion or under wet/dry cycling.

Since the commencement of such detailed work on contamination levels, the company has not carried out any specific testing to attempt to correlate laboratory data against actual practical vessel outturns.”

Table 10 Acceptable Salt Levels - Coating Manufacturer- Salt Water Immersion

Salt Water Immersion				
Paint	DFT um	No. Coats	Low Risk ug/cm2	High Risk chlorides
Epoxy; epoxy-polyamide	>225 >200	2	<10	>25
Tank lining epoxy	250	2/3	<5	>15
Epoxy mastic	200	2	<10	>25
Chlorinated rubber	>225	3	5	10

Table 11 Acceptable Salt Levels - Coating Manufacturer- Marine Atmosphere

Marine Atmosphere				
Paint	DFT um	No. Coats	Low Risk ug/cm2	High Risk chlorides
Epoxy	>150	1/ 2	<25	>50
Epoxy polyamide	>150	1 / 2	<25	>50
Alkyd	>180	2/3	<15	>25
Chlorinated rubber	>150	2/3	<25	>50
Epoxy/polyamide	>150	1/ 2	<25	>50
Zinc silicate/chlorinated rubber	>225	3	<5	>15

Coating Manufacturer 6

The following table was proffered by a major paint manufacturer- it was prepared in 2008. The presence of excessive chloride or sulfur residual contaminants on steel surfaces can cause failure of coatings by blistering. The maximum allowable level of contaminants is a function of service conditions, coating type, and coating thickness. While it is impossible to cover all the possible variables, below is some guidance on residual chlorides for a limited set of circumstances for paints and coatings manufactured by this company.

A typical disclaimer accompanies the guidance. The company does not accept liability from the use of the contents of the data sheet(s). One company stated that it did its own testing and also analyzed the data sent to the ISO task groups. Newer measurement devices for conductivity are available.

Table 12 Acceptable Salt Levels - Coating Manufacturer

Exposure Condition		Maximum Permissible Chloride Level µg / sq cm	Coating Types	Minimum Dry Film Thickness	
				µ micron	mil
Atmospheric	All Except Ponding Water	30	Epoxy, Moisture Cured Polyurethane, and Zinc Rich Coatings	200	8
Atmospheric	All Except Ponding Water	20	Alkyd, Acrylic	200	8
Ambient Temperature Immersion to 50^{o}C (121^{o}F)	Salt Water, Crude Oil, Refined Products.	8	Epoxy, Epoxy Novolac, Epoxy Phenolic	300	12
Ambient Temperature Immersion to 50^{o}C (121^{o}F)	Potable Water, Fresh or River Water, or De-mineralize Water	3	Epoxy, Epoxy Novolac, Epoxy Phenolic	300	12
Immersion Above 50^{o}C (121^{o}F)	Salt Water, Crude Oil, Refined Products. Potable Water, Fresh Water, or De-mineralize Water	1	Epoxy, Epoxy Novolac, Epoxy Phenolic	300	12

For ponding water in atmospheric service, use 8 µg / sq cm as the Maximum Permissible Chloride Level.

Higher thickness of epoxy, epoxy novolac, epoxy phenolic and vinyl ester tank linings increases their resistance to osmotic blistering caused by chloride contamination. Using leafing pigments like glass flake, mica flake, or micaceous iron oxide also increases the resistance of tank linings to osmotic blistering caused by chloride contamination.
For buried pipelines and other underground or underwater equipment, use limits for immersion service in either fresh or salt water, depending on the exposure.

Chlorides – Measurement Method – Most field measurement techniques do not detect 100% of the chlorides that are present. The limits shown for Maximum Permissible

Chloride Level assume the field test method detects at least 50% or more of the total chlorides present.

Field test methods to detect chlorides include:
ISO 8502-6:1996 Preparation Of Steel Substrates Before Application Of Paints And Related Products – Tests For The Assessment Of Surface Cleanliness – Part 6 – Extraction Of Soluble Contaminants For Analysis – The Bresle Method.
KTA Scat Kit - 800-582-4243 or 412-788-1300 www.kta.com
CHLOR*TEST – Test Kit 800-422-3217 www.chlor-rid.com

Measurement Units: Some test methods yield results in μ / sq cm (micrograms per square centimeter) while others yield mg / sq m (milligrams per square meter). Since 100 mg / sq m is the same concentration as 10 μ / sq cm, a serious error can occur if the technician is not careful with the interpretation of the mathematics.

Corrosion scale or other barriers often mask high levels of chloride and sulfur contaminants. For immersion service, surfaces to be tested should be cleaned to a minimum of SSPC-SP6 Commercial Blast prior to testing. For atmospheric service, surfaces should be cleaned to a minimum of SSPC-SP2 Hand Tool Cleaning or SSPC-SP3 Power Tool Cleaning prior to testing.

The following procedure will frequently remove enough chloride and sulfur contamination from tank bottoms to achieve acceptable levels:
Abrasive blast to SSPC-SP-6, vacuum up the abrasive and debris.
Power wash with potable water at 2500 to 3000 PSI, allow to stay wet and flash rust over night.
Then abrasive blast to at least SSPC-SP10 Near White Metal Blast.

Commentary Notes:
The limitations on chloride content in the above table are the result of an engineering analysis of the available data and do not represent any position or recommendation by the International Standards Organization.

Task 3 – Solicit data from private and public shipyards on salt measurements

Cost Drivers

These cost drivers for salt mitigation have been identified. Each area allows a little increment for cost savings. No single issue for large costs savings within the US Navy's protocol is apparent.

However, if the US Navy is able to consider adopting commercial practices where the operations inspection by the ship builders is accepted, then there are realized cost savings.

- Handling, transport, storage of bulk steel plate
  - Savings have been found in washing bulk plate.
- Operations Prior to third party inspection points
  - Working with the SY during operations, rather than at a separate inspection point is the norm for commercial operations.
- Third Party Measurement
  - Level of Ionic contaminants

    Could be increased according to coatings manufacturers, but the current level is achievable and within IMO guidelines
  - Frequency

    Navy frequency is per area; commercial is per block or unit. Number of test could be decreased and not compromise quality.
- Cost of Equipment or expendable supplies
  - Labor of SY and Government for tests; Time to record /verify/ document results

    Based on 1000 tests, the costs of the individual measurement range from \$6.20 to \$25 per test. There is a steady move to test methods that are less expensive, but still consistent in extraction.
- Resolution of Disputes
  - Disputes do not occur. The measurements are not questioned. The SY measures conductivity, and moves to specific ion measurements if needed.
- Procedure to reduce Ionic contaminants to specifications
  - The cleaning is infrequent. Shipyards are typically following the Navy Preservation Process Instruction.

Handling, transport, storage of bulk steel plate

Comment from a European Shipyard:
When you get steel parts from other shipyards, you wash them fully to remove salt from all areas, even those which will not be coated. There is a difference between secondary prep and re-work. All areas to be coated will get the second preparation, but not all areas

to be coated will get a re-work due to salt. During this winter, we made checks due to the snow and the de-icing salt.

The PPI would seem to indicate that bulk steel plate **must** be washed down prior to blasting.
PPI NBR: 63101- 000 (REV 26) DATE: November 30, 2010
PRESERVATION PROCESS INSTRUCTION (PPI) CORE

5.3 DEGREASE / FRESH WATER WASH DOWN: Prior to surface preparation by dry abrasive blasting, remove all surface contaminants in accordance with SSPC-SP1 with 3,000 psi minimum at the nozzle fresh water wash down. Use vacuum to remove standing water followed by an adequate period of time to allow the surface to dry prior to surface preparation.

However, only two shipyards reported that they wash their steel plate before placing it in the blast room. A poll at the November, 2010 NSRP-SPC meeting in Providence showed that washing the plate prior to initial blasting was NOT a wide spread practice.

The Japanese, Koreans, and European shipyards noted the effect of winter salt on the bulk plate steel. They have adopted the practice of washing plates as they are transported to or stored in the yard.

As a specific, Lee, and Baek et al., Hyundai Heavy Industry (ref 124, 2008) discovered that the ship's blocks, before secondary preparation, varied from 2.8 $\mu g/cm^2$ to 150 $\mu g/cm^2$ during the year. Most were in the 3 to 12 $\mu g/cm^2$. This variation led them to check and clean ship's blocks. Lee and Baek also stated the maximum allowable limit of soluble salts in the IMO's PSPC specification should be designated to be 8 $\mu g/cm^2$, since 8.3 $\mu g/cm^2$ TSS (Total Soluble Salts) corresponds to 50 $\mu g/cm^2$ NaCl.

As another example of salt mitigation by washing:
Chad Scott, CTC, Navy Metalworking Center, reported at the November, 2010, NSRP SPC meeting on their projects related to painting. The NMC is operated by Concurrent Technologies Corporation, under contract No. N00014-06-D-0048.

"Mitigation of Conductive Contaminants." was funded by ManTech under Improved Preparation Methods for Coating Tanks and has a direct impact on this project. The report documents have a Distribution Statement D on them, which limits distribution to DOD and US DOD contractors. The NMC report contains cost information and pictures information was deemed sensitive to the participating shipyard.

Mr, Scott emphasized that the project was shipyard and vessel hull specific. This project estimated a saving of **$265,000** per hull if their recommendations are followed.

It is recommended that each NSRP shipyard contact Chad Scott and determine if the methodology and findings can be applied to their yard or if they have already identified sources of salts.

NMC identified that the primary contamination sources were from incoming material and the river. There was a huge cost associated with delay due to multiple blasting and washing at the final blast and paint cycle. The objective was to remove the salt contaminants upstream from that point.

When NMC identified that there was salt on the incoming plates, they realized that salt on the incoming plates is partially removed during the blast, but also salt remained on the plate. NMC recommended washing stations before the initial pre-construction primer blast and also for structures in-process that have pre-construction primer on them.

More discussion is in Appendix 3.

Operations Prior to third party inspection points

There is a Duplication of Effort in surface preparation measurements.

The NSRP survey only shows the measurements points when the third party (government, Navy) inspector is called as the block is released or sold to the client. It does not include any of the in-house points that the SY makes during the production process. These measurements are taken as the plates/blocks/modules are being constructed to insure that the block will be acceptable to the client. The US Navy is paying for two sets of numbers while recognizing only the data from the “inspection” points.

Commercial Practice
According to ABS, and the comments at the NSRP-SPC meeting in Providence, Nov. 2010, coating inspections are left to the builders and the Certified Coating Inspector, mutually appointed by the 3 parties involved, i.e the builders, the owner and the coating producer. This is integrated into the daily operations.

Third Party Measurement

In the presentation by Hyundai Heavy Industries. the authors (ref 112, 124) state: One critical issue, yet to be clarified on this subject, is that it is impossible to measure exact NaCl content following ISO 8502-9 method, even though the IMO PSPC specified “NaCl” content as the concerned salt. The accurate chemical analysis for the extracted solution is required to differentiate the chemical elements contributed to the electrical conductivity and to clarify IMO’s PSPC criterion for soluble salts.

Level of Ionic Contaminant

The current levels appear to be conservative from the coatings manufacturer’s viewpoint, and, according to the survey results, achievable.

In this NSRP survey taken during July, August, and September, only nine measurements out of 865 for Commercial New Build were out of compliance. This one percent failure does not lead to large cost savings from re-work.

Initially Japan- Korea shipyards were concerned about the levels and the costs for the IMO requirements. They found 95% are within compliance (private communication). They adopted a practice to routinely wash incoming plates.
Safinah, in a private communication, said Safinah had conducted two studies for costs on all the requirements for IMO. Their results were

- Study Korea showing 20-25% increase in costs
- Study Japan showing 8 – 12% increase in costs

The author takes this to mean the increase in costs on the water ballast tanks and voids, not on the entire vessel new-build costs.

Frequency of Measurement:

The frequency of measurement will depend on the specific hull, the unit size, and the shipyard. Because this is a public study, the author did not try to get specifics for an individual hull. This table lists the frequency of measurements for large flat surface such as underwater hulls, and the same surface area as found in a typical tank of 2000 sq feet.

To get the costs of measurement, multiply the number of measurements with the cost for the selected method. Cost range \$6.20 to ca.\$20 for conductivity. Cost is approximately \$22-28 if chloride specific.

Table 13 Frequency of Measurements Based on Area

	Frequency of Measurements			
5 in first 1000 ft2; then one per 500 ft2				
Formula = 5 + (Total area-1000)/500			Lot cost	High Cost
			$2.50	$27.00
	Large Surfaces as underwater hull			
Underwater Hull Sq Footage	Sq Feet	No. of Measurements		
Misc Hull Repair	2,000	7	$17.50	$189
Typical Smaller Craft	30,000	63	$158	$1701
Aircraft Carrier	150,000	303	$758	$8181
	Tanks			
assume that tank is 2000 sq feet with 4 sides and top and bottom- 6 sides.				
Each wall, top, bottom is 350 sq feet. 2 readings/surface or 12 readings per tank				
		No. of Measurements		
1 tank	2,000	12	$30.	$324.
15 tanks	30,000	180	$450	$4,860
75 tanks	150,000	900	$2,250	$24,300
Number of measurement reported by Baek on tank				
400 m2 tank	3600	20		
No. of Measurements by US Navy requirement				
Assume ft2 area = 9 x m2	3600	11		
	VLCC (Very Large Crude Carrier)			
	WBT Total Coating Area 240,000m2			
	No. of Measurements by US Navy requirement			
ft2 area = 9 x m2	2160000	4323		
Lee and Baek report 1 to 3 readings for each block or steel plate.				
ABS indicates minimum of 1 reading for block, unit, plate.				

The US Navy, and Coast Guard establishes a frequency of measurements based on area; commercial work is generally based on block, section, or unit.

Commercial Work

One NSRP yard reported that adoption of IMO specifications for their Military Sealift Command (MSC) resulted in a major change order and pricing. However, the increase in pricing came from the edge preparation and the coatings technical file, not from the salt measurement requirement.

The salt results are taken as needed as the work progresses with agreement between representatives of owner, coatings supplier, and shipyard. Inspectors are certified by agencies such as NACE, SSPC, NOROSK. If they find a reading that is out, then they will continue to take measurements until the area is defined. If measurement is within specifications, they progress to other areas.

One NSRP SY noted a requirement for state agency vessels. Five measurements shall be taken every 100 m^2 (ca 1000 ft^2) and for areas less than 100 m^2. Measurements shall be made randomly over the prepared surface. If it can be demonstrated to the Supervisor that material stored, transported, and erected in a similar manner to the material to be coated has consistently **passed** the soluble salt test, then a **single** soluble salt test for each 100-m^2 (ca 1000 ft^2) to be coated shall be sufficient.

Lee and Baek (2008, ref 124) noted the use of Bresle patches with a conductivity meter and a frequency of 1-3 tests for each of 14 blocks and 22 steel plates.

Commercial Work- ABS

ABS discussed commercial practice. There is no specific number on salt contamination in any specific application, as that would imply that there is an agreed performance and risk scenario. Each situation is different, and each situation can absorb a different level of risk. If there is a limit to funds available, a higher risk might be justified. It's a matter of defining a set, well-defined group of reasonable numbers that the market can price, and that a proper risk/cost analysis can be made in each situation.

ABS monitors the work. With regard about 'monitoring'; it is their experience that in general salt measurements are taken as required by IACS PR34 2.3 copied below :

> Common Interpretation
>
> The conductivity of soluble salts is measured in accordance with ISO 8502-6 and ISO 8502-9, and compared with the conductivity of 50 mg/m2 NaCl. If the measured conductivity is less than or equal to, then it is acceptable.
>
> Minimum readings to be taken are one (1) reading per block/section/unit prior to applying coating or one (1) per plate in the case of manually applied shop primer. In cases where an automatic process for application of ship primer is used, there should be means to demonstrate compliance with PSPC through a Quality Control System, which should include a monthly test.

Military

US Navy

009-032 ITEM NO: 009-32 FY-10 (CH-1) DATE: 09 MAR 2009

3.10.7.3 Accomplish surface conductivity or chloride checks using available field or laboratory test equipment on the freshly prepared surface. One reading shall be taken for every 200 square feet for the first 1,000 square feet. One determination shall be conducted for every additional 500 square feet or less.

PPI NBR: 63101- 000 (REV 26) DATE: November 30, 2010
PRESERVATION PROCESS INSTRUCTION (PPI) CORE
6.5.2 (Soluble Salt Measurements Conductivity Testing**):** Conductivity samples shall be collected using a product that meets the requirements of NACE SP0508-2008, "Methods of Validating Equivalence to ISO 8502-9 on Measurement of the Levels of Soluble Salts" (such as the Soluble Salt Conductivity Measurement according to Bresle Method, ARP Soluble Salt Meter model RPCT-07-001, or SaltSmart from Innovative Productivity, Inc.) Enclosure 1 provides the procedure for the Bresle method using a 1250 mm^2 Bresle Sample Patch and a HORIBA B-173 meter or equivalent NAVSEA approved test equipment. Measurements shall be made randomly over the prepared surface. **Take 1 reading for each 200 ft^2 for the first 1,000 ft^2. Take 1 additional measurement for each additional 500 ft^2 or less**. For immersed applications, conductivity due to soluble salts (total ionic) shall not exceed 30 µS/cm (microSiemens/cm). For non-immersed applications, conductivity due to soluble salts (total ionic) shall not exceed 70 µS/cm (microSiemens/cm).

Coast Guard:

A.1.1.1.1 "Soluble salt conductivity measurements. Measure and document conductivity due to soluble salts, randomly over the prepared surfaces (take 5 measurements every 1,000 square feet or **five** total measurements for surfaces less than 1,000 square feet), using a suitable surface contamination analysis equipment, in accordance with ISO 8502-9."
The Coast Guard has a more frequent requirement than the US Navy. The CG ships are generally smaller than US Navy vessels. There is a person on board each vessel who has responsibility for the coating repairs. Based on all interviews, this responsible party involved in quality assurance will know the history of the vessel.

Cost of Equipment, labor to take the tests

The detailed table is Appendix 4. SY's are opting to purchase more expensive equipment that requires less measurement labor hours rather than tie up labor.

The tabulated data shows the cost to buy the equipment, expendables, and estimated time to take the measurement. It is assumed that one person is present, not two. The formulas are given. It is noted when an individual test might consume 10 minutes, then several test can be run at the same time to reduce the labor costs.

Table 14 Overview of Salt Methods and Costs including Start up costs

	Type	Datalogger	Time/test	Cost/test
Chlor*Test sleeve	conductivity	X	5-10 min	$23.7 to $27.5
Chlor*Test sleeve	Chloride		5-10 min	$23-$27
Bresle	Conductivity	X	4 to 17 min	$9.4 to $18.6
Bresle	Chloride	X	8 to 17 min	$14 to $21.6
RPCT SSM	Conductivity	X	3-4 min	$8.4 -$9.2
DKK-TAO SSM	Conductivity	X	3-4 min	$6.2 - $7
NST SaltSmart	Conductivity	X	2.5 to 10 min	$15 to $21
Elcometer 130 Paper absorbance	Conductivity		4-7 min	$11 to $14
Chlor*Test portable chloride meter	Chloride	x	In Development	

Note: Some kits contain conductivity meters that are not data loggers. The pricing in this study includes purchase of meters that can store and transfer data and can comply with paperless quality assurance. For example, the non-data logger conductance meter supplied with a kit has a purchase price of ca. $400; The data logger conductance meter has a purchase price of $1500.

It is assumed that all the methods require gloves. De-ionized water was not included in the expenses. Syringes were included if needed for each test. Syringes were not included if they were used just for an occasional calibration.

It is assumed that there are 1000 measurements in the first year and that the equipment and start-up costs have been amortized, then the following table is the estimated costs for only the test time and obvious expendables.
Water and gloves are not included. The cost for syringes have been included, where appropriate.
Additional Assumptions are in Appendix 4

Table 15 Overview of Salt Methods and Costs only with consumables

Comparison Cost after initial equipment purchase is amortized			
	Type	Time/test	Cost/test
Chlor*Test sleeve	conductivity	5-10 min	$23 to $27
Chlor*Test sleeve	Chloride	5-10 min	$23-$25
Bresle	Conductivity	4 to 17 min	$8.9 to $18
Bresle	Chloride	8 to 17 min	$13 to $20.6
RPCT SSM	Conductivity	3-4 min	$2.5 - $3.3
DKK-TAO SSM	Conductivity	3-4 min	$2.5 - $3.3
NST SaltSmart	Conductivity	2.5 to 10 min	$14 to $210
Elcometer 130 Paper absorbance	Conductivity	4-7 min	$5.6 to $8
Chlor*Test portable chloride meter	Chloride	In Development	

Once the equipment is expensed, then it is obvious that the two salt meters that are magnetic, automatically come to equilibrium, and record the conductivity have a distinct price advantage because there are no significant expendables associated.

The claims of accuracy of the equipment and the extraction efficiency were examined for the equipment. Over all the equipment manufacturers are very comfortable with the current level of contaminants. Each instrument reports a low standard deviation and a high accuracy over a specified range.

The Bresle sleeve and the flexible membrane are general methods of collecting water (liquid) samples. The extract solution can be used for various tests.

There are various types of commercially available portable conductivity meters available as “pocket’ types that are operated by placing the probe into the liquid; or “cup” types where liquid is placed in a cup that is part of the meter.

For example, The Kitagawa ion detection tube for chloride that is described in ISO 8502-5 can detect chloride levels from 1 to 2000 PPM, using tubes with varying ranges of detection. The tube most commonly used for surface testing of chlorides has a detection range of +0 to 60 PPM (parts per million). The precision reported by a supplier of the tubes is +/- 8%. Further information is needed to convert from PPM to $\mu g/cm^2$ with respect to volume extract per surface area.

The field titration method (drop) method in 8502-6 and is separated into low concentration **(0-10μg/cm2) , and higher concentrations.** It requires a conversion for surface area. The precision is reported +/- 3%.

The laboratory titration method ISO 8502-2 is reported to be +/- 0.1 PPM.

The Quantab paper chromatography test strip is available from Hach that changes color as the extract wicks up on the paper. The range is 30 to 180+ PPM chloride ion, with a precision of +/- 5 PPM. This test strip was originally included in the KTA SCAT kit. Currently, this test strip is not commonly used in the paint industry because the range is high; the paint industry is testing for lower detection limits.

The details of the Elcometer paper method include calibration curves for various salts and salt mixtures; with a removal rate around 70% for coarse profiles and >95% for smooth machined surfaces. The technical literature provides caution about salts remaining in the pitted areas.

SSPC Guide TU15, give further details.

The question of accuracy and extraction efficiency continues to be studied under laboratory conditions. Every author has a different opinion on extraction efficiency.

All of the above methods are being used by inspectors in the field. The major variation in the laboratory is the skill of the individual operator. The standard methods reflect consistency of a specific operator.

NACE SP0508-2008, "Methods of Validating Equivalence to ISO 8502-9 on Measurement of the Levels of Soluble Salts"

> 1.1.5 The range of variance in ISO 8502-6 and 8502-9 has been demonstrated by extensive laboratory tests.["Bresle Patch Evaluation Report," Corrosion Control Consultants and Labs, Inc., May 8, 2008. This report is available from the NACE Technical Activities Division upon request.]
>
> The precision of a single ISO 8502-9 test result was determined to be ± 8.2 mg/m^2 in the salt level range of 30 to 80 mg/m^2. The absolute variance, and not the relative or percent variance, was found to be constant in this range.

In the field, salts will be deposited on the surface in crystals. Thus there will be high readings when the measurement is on a crystal; and low readings when the measurement is not on a crystal. The result is averaged over the area that the measurement contacts. For example, the measuring surface is 12.5 cm2 for one of the Bresle patches and for the RPCT SSM, 10 cm2 for Chlor*Test flexible sleeve, and the Elcometer paper covers 94.5 cm2.

The NST SaltSmart has a smaller contact area, so it could give a higher reading when it hits a crystal because the site is more localized; i.e. you are averaging the same amount of salt deposited over a smaller area as compared to the larger area measurement devices.

The Elcometer 130 does not appear to directly conform to an ISO method, but it has been widely used and much of the earlier field data is based on this method. Al-Sulaiman (ref 135 2010) concluded that the Extraction method with absorbent paper even at controlled atmosphere found giving insignificant or low readings. This variation is due to the evaporation loss of the water content from the absorbent paper.

Pang and Schultz (ref 127) compared the Bresle with the RPCT SSM. Rather than try to dope a full panel, they doped the panel just where the reading was to be taken so that all of the salt would fall within the extracted area. The Horiba B 173 was just with the Bresle extraction.

Calibration Standards and Horiba Readings of 30 µS/cm KCl Solution

Table 16 Extraction Efficiency

Conductivity Meter	Calibration Solution	1406 µS/cm KCl	30 µS/cm KCl	Deviation from 30 µS/cm (%)
Jenway 4020 Laboratory reference	99.1 µS/cm	1389.0 µS/cm	30	–
Horiba B-173 Unit 2	1406.0 µS/cm	1410 µS/cm	38	27.7
Horiba B-173 Unit 2	1406.0 µS/cm	1410 µS/cm	35.7	19.0
SSM	84.0 µS/cm	Capable to 300	30.7	2.3

The Pang and Schultz study contains other calibration solutions.
The SSM appears to be capable of producing more accurate and consistent readings with less scatter than the Horiba meter used by the Bresle method.

The SSM method clearly gives conductivity readings closer to the theoretical values of the diluted doping solutions. Both Horiba meters consistently read conductivity values much higher than the SSM and theoretical conductivity numbers.

Morcillo (ref 108, 111, 112, 115) reported extraction efficiency in various publications including the European Commission Report of 2004. (ref 108, 111, 112, 115). Morcillo developed a new method for extraction during that time. The two numbers i.e. 34 (45) reflect that the extraction coefficient was reported as 34 in one journal article and 45 in another journal article.

Table 17 Extraction Efficiency

Morcillo		Extraction Efficiency		(ref 108, 111, 112, 115)	
Contaminant		Standard boiling (ref) 100%	ISO Swabbing Is 34% of 100 8502-2 8502-5	Elcometer 134S (Chlor*Test) 8502-6	New Method developed in CENIM Morcillo
Chlorides	Before Cleaning	100	34 (45)	8 (10)	56 (64)
	After cleaning	100	58 (54)	14.5 (19)	71 (68)
Sulfates	Before cleaning	100	15(21)	-	38(41)
	After Cleaning	100	45(49)	-	54 (66)

Field Variance

In 2008, J. Eliasson, formerly of Stolt Nielson and currently with ABS, (ref 124a) and a Korean Shipyard conducted measurements under normal in-situ conditions to establish the variance in pairs of measurement about 100 mm apart. This report is part of the committee who drafted NACE SP-0508.

The Korean shipyard documented what they had been observing: The Variance of the extraction solution in closely spaced patches is large. In practice, a user of any of the extraction methods becomes very consistent and adept. In practice, salts are discrete crystals. There can be high concentrations and zero concentrations in close proximity. The report is appendix 7.

Testing of Salt Levels about 100 mm apart

Table 18 Field Measurements on Paired Samples

Salt Reading in Pairs			**Readings in mg/m2 NaCl**	
Reading #	**Panel I**	**Panel II**	**Block**	**Deviance**
1 **2**	**30** **18**			**Very Large**
3 **4**	**6** **24**			**Very Large**
5 **6**	**30** **18**			**Very Large**
7 **8**		**24** **24**		**0**
9 **10**		**6** **6**		**0**
11 **12**			**54** **12**	**Very Large**
13 **14**			**42** **30**	**Large**
15 **16**			**12** **30**	**Very Large**
17 **18**			**54** **60**	**Large**
19 **20**			**36** **30**	**Very Large**

Bresle Patch, NaCl, HANNA conductivity meter.

The salt reading was done using a ISO8502-9 method adopted in Korea, It involved using a larger volume of water, part of which was used to extract salt with a Bresle patch. The test solution then added back to the container with the remaining water, and the conductivity measured on the larger volume using a HANNA conductivity meter.
The Conductivity meter gave only whole numbers and not decimals, hence there was an added deviance in the system only for that fact – but the deviation was much larger than for this to be the main issue.

For the NACE TG 392 committee who was examining how to prove that techniques were equivalent, Gossen (2008. 124b) has determined that the minimum dwell time of liquid in the Bresle patch was **90 seconds in the laboratory**. In this SY study, the dwell time for the de-ionized water was about 1 ½ min (90 seconds); with the water being syringed in-and-out 4 times and with finger rubbing between the syringe movement.

ISO 8502-6 “The Bresle Method” says to use a suitable time. It further notes “ On unpitted, blast cleaned areas, a period of **10 minutes** has been found satisfactory, as by then more than 90% of the soluble salts have usually been dissolved.” ISO 8502-6 further talks about SURFACE soluble contaminants. It does not claim to get into cracks and crevices.

The SY consistently applied this method of extraction to determine the variance in the field of dual patches within 100 mm of each other. The distance between the patches were not measured to be exactly 100 mm, but were close enough for this evaluation.

$E = (0.5)\ S\ V/A$

where, E is surface concentration of total soluble in µg/cm^2, S is conductivity measured due to soluble salt in µS/cm, A is measurement area in cm^2, V is volume of extracted solution in mL, 0.5 is the conversion factor, which depends on the chemical composition of the soluble salts and can vary from **0.54 to 0.96**. The conversion factor was selected to be 0.5, measurement area “A” was 12.5 cm^2, and volume “V” was 15mL in this study, Combining the fixed volume and area with the conversion factor leads to:

$$E = (5)\ S\ 15/12.5 \qquad = S\ 6$$

The constant is 5 when the surface concentration of total soluble is mg/m^2,

In this study, the combined multiplication factor is 6.
For Example: Conductivity = 2 µS/cm this corresponds to 12 mg/m^2
In pair 19 and 20
The measured conductivity 6 µS/cm = 36 mg/m^2
The measured conductivity 5 µS/cm = 30 mg/m^2

In this study, a difference of 1 µS/cm will make a difference of 6 mg/m^2 NaCl.

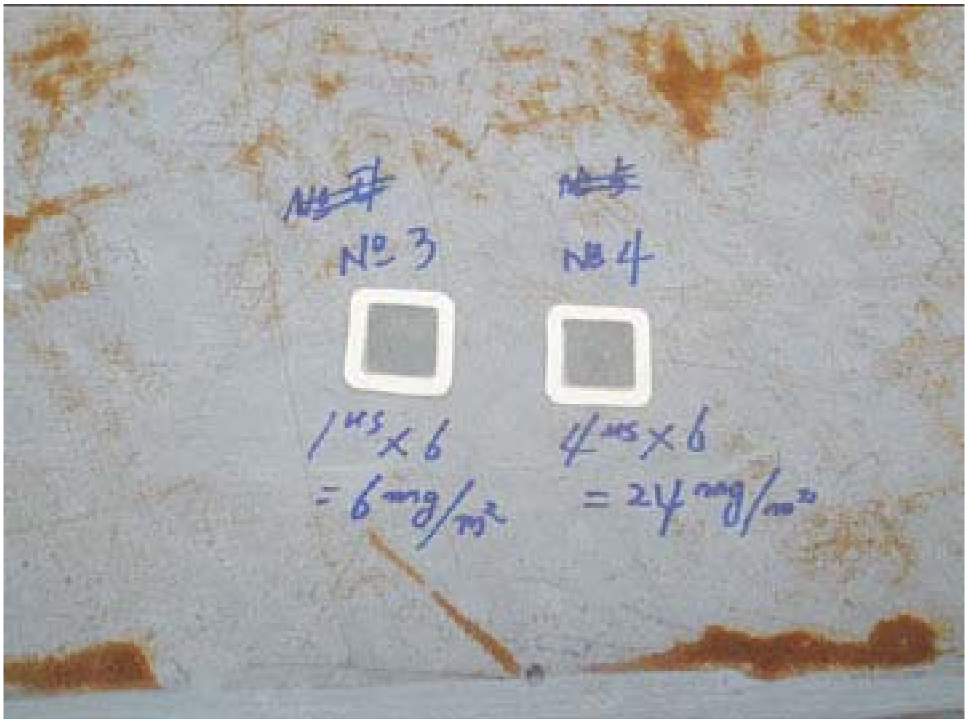


Figure 1 Duplicate Measurements
Panel 1 - Area that had been washed quite well by recent rain. Horizontal Surface

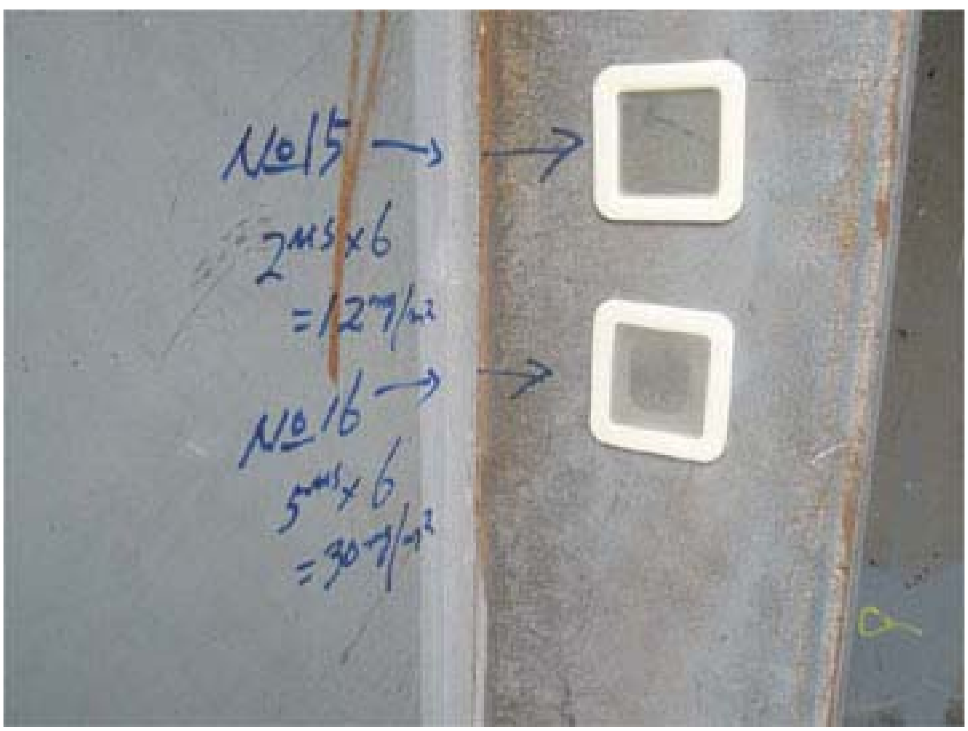
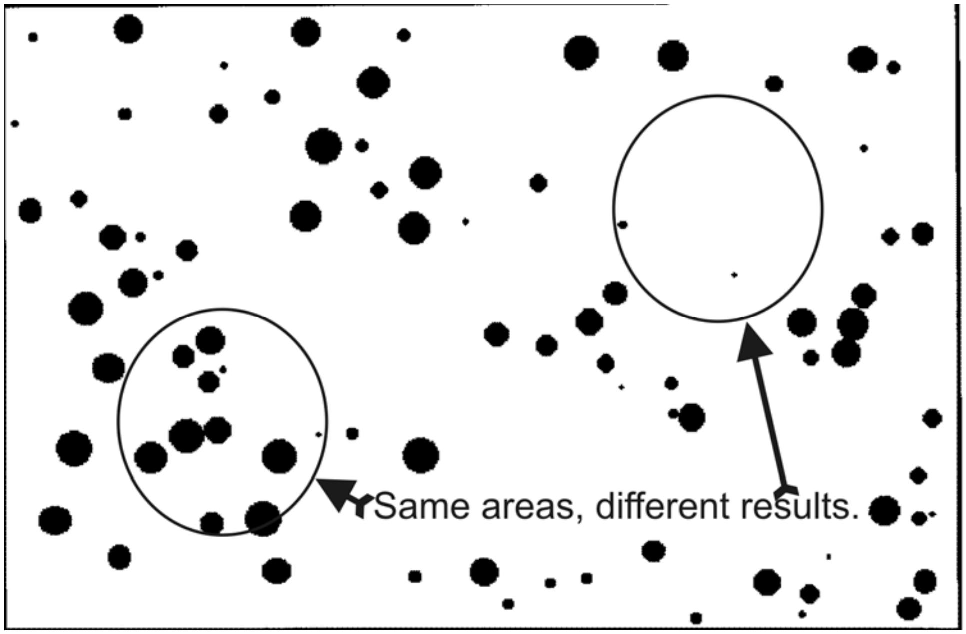


Figure 2 Duplicate Measurements
Block 2- On Bracket- Typically not an area touched much by hand.

Figure 3 Field Variation of Salts & Measurements



The above figure illustrates why two test patches might have large variations in the concentration of salts. This also illustrates why a specific chloride ion result might be small (or large) compared to the conductivity measurement.

The first time a patch is placed on the surface, it should extract most of the surface salts. Even if a specific ion extraction was then conducted on the same spot, there should be a lower amount.

At the February, 2001, SSPC meeting, Gary Tinklenberg, retired from CCCL, said at the meeting to develop standard language on "Frequency and locations for salt testing." "Tell me what you want to accomplish in the salt testing. I can go on site and give you the average readings, give you reading that are all in compliance, or give you readings that are all out-of-compliance." His point was the field variance is great enough that a certified inspector can bias the results.

Salts will collect in the last place to dry. The following figures show areas where surface soluble salt concentrations will be higher than the surrounding areas. A measurement taken at the defects will likely be much higher than the "average" reading.

Figure 4 Field Drying and Concentration of Salts

Figure 5 Field Drying and Concentration of Salts

Resolution of Disputes

There does not appear to be any major issues between the SY and quality assurance inspectors for the US Navy work. First the conductivity is measured. If the conductivity is out-of-compliance, then the specific ion is measured. Typically, the specific ion concentration resolves the issue.

Procedure to mitigate Ionic contaminants to specification

Develop a standard process

There are so few excursions from the specification that there appears to be pressing need or cost savings to develop a standard process for all shipyards. The SY are generally following the preservation process instruction. The estimated time to remediate is 1 to 2 man hours, based on getting equipment to site, washing/abrading, and re-testing. The exception to this time frame is the process delay noted by NMC.

The respondents indicated that they used:

- Pressure wash
- Wire Brush
- SP-1- solvent wipe, water wipe
- Sweep blast

Standard Item 009-032 and the Preservation Process Instruction can be invoked as a standard process for mitigation.

The out-of-compliance occurs so infrequently that most of the reporting shipyards do not have a written procedure. Most shipyards have no procedures or a very limited method to mitigate. They follow the US Navy Guidance.

Three shipyards said that they have no written standard process. Between conductivity and specific ion measurements, the out-of-specification measurements occur about 5% of the time.

One Coating Manufacturer gave guidance for mitigation:
The following procedure will frequently remove enough chloride and sulfur contamination from tank bottoms to achieve acceptable levels:

> Abrasive blast to SSPC-SP-6, vacuum up the abrasive and debris.
> Power wash with potable water at 2500 to 3000 PSI, allow to stay wet and flash rust over night.
> Then abrasive blast to at least SSPC-SP10 Near White Metal Blast.

Only one NSRP shipyard submitted a written Remediation process. It was noted that remediation does not occur often.

If any soluble salt conductivity measurement exceeds the specified limits, the affected area(s) shall be water washed with fresh water, dried, and the surface shall be retested until satisfactory levels are obtained. The fresh water washing pressure shall be maintained between 1000 and 2000 psi (48 and 96 MPa) and shall not contain corrosion inhibitors. If flash rusting occurs on steel surfaces as a result of water washing, the surface shall be re-cleaned to the originally specified visual cleanliness level.

One contractor who uses UHP WJ indicated that they clean again with UHP WJ when the salt level is above the specified limits.

009-032 ITEM NO: 009-32 FY-10 (CH-1) DATE: 09 MAR 2009

3.10.7.3 For immersed applications, such as tanks and bilges, chloride measurements shall not exceed 3 µg/cm^2 (30 mg/m^2); conductivity measurements shall not exceed 30 micro Siemens/cm. For non-immersed applications, chloride measurements shall not exceed 5 µg/cm^2 (50 mg/m^2); conductivity measurements shall not exceed 70 micro Siemens/cm.
Conductivity samples shall be collected using the Soluble Salt Conductivity Measurement according to Bresle Method**,** ARP Soluble Salt Meter model RPCT-07-001**,** or approved equivalent. Document on QA Checklist Form Appendix 4.

3.10.7.4 Because conductivity testing measures more than just chlorides, for any conductivity check that fails, a confirmatory chloride check may be conducted to confirm chloride levels. If the chloride levels do not exceed the requirements in 3.10.7.3, the measurement passes the conductivity/chloride check.

3.10.7.5 If a conductivity check fails and the confirmatory chloride check is not conducted, or if chloride measurements exceed the respective values, water wash (3000–5000 PSI) the affected areas with potable water. Dry the affected areas and remove all standing water. Accomplish surface conductivity or chloride checks on affected areas in accordance with 3.10.7.3. Repeat step until satisfactory levels are obtained.

PRESERVATION PROCESS INSTRUCTION (PPI) CORE

PPI NBR: 63101- 000 (REV 26) DATE: November 30, 2010

6.5.2.1 If conductivity measurements for surfaces prepared to an SSPC-SP-10 exceed the respective values, water wash the area exceeding the required limit with fresh water. Soluble salt conductivity limit of the fresh water shall not exceed 200µS/cm (microSiemens/cm). If low pressure, 3000 psi, water washing is used, in order to ensure it is effective, the operator shall maintain the wand within a maximum distance of 12 inches to the substrate. The angle of the wand relative to the substrate shall be maintained between 45º - 90º. Remove all standing water, dry the area, and retest. If flash rusting has occurred, or/and soluble salt conductivity still exceed limits rewash, dry the area and retest. If the soluble salt conductivity limit is not reached after 2 washes, then perform water wash to the affected areas using water that is below 30µS/cm (microSiemens/cm) for immersed applications or below 70µS/cm (microSiemens/cm) for non-immersed applications. Repeat water wash and retest until satisfactory levels are obtained. If flash rusting has occurred, reblast the area and retest.

Note: IF AFTER A FRESHWATER WASH, THE MEASUREMENTS EXCEED REQUIRED LEVELS, A SALT REMOVER MAY BE USED; HOWEVER, THE ONLY SALT REMOVER PRODUCTS THAT MAY BE USED FOR A COATING SYSTEM ARE THOSE SPECIFIED ON THAT COATING'S NAVSEA-APPROVED ASTM F-718.

6.5.2.2 If conductivity measurements for surfaces prepared to an SSPC-SP-12 exceed the respective values, repeat SSPC-SP-12 to the affected areas. Remove all standing water, dry the area, and retest. If flash rusting has occurred, reblast the area and retest. Repeat SSPC-SP-12 until satisfactory levels are obtained. If flash rusting has occurred, reblast the area and retest.

6.5.2.3 If conductivity measurements for surfaces prepared to an SSPC-SP-11 in an isolated area exceed the respective values, circle area and perform spot solvent cleaning (see table 631-2-1 in NSTM 631 for approved solvent for use) followed by retest

6.5.2.4 For surfaces prepared by Power Tool Cleaning to Bare Metal that are not practical for the spot cleaning method, water wash these surfaces with fresh water, and scrub with hand scrub brush. Soluble salt conductivity limit of the fresh water shall not exceed 200µS/cm (microSiemens/cm). Immediately remove all standing water and dry the affected area. Immediately remove all flash rust developed. Anchor profile shall be re-established as required. Perform an SSPC-SP-1 solvent wipe on all sanded areas and retest. If the soluble salt conductivity limit is not reached after 2 washes, then perform water wash to the affected areas using water that is below 30µS/cm (microSiemens/cm) for immersed applications or below 70µS/cm (microSiemens/cm) for non-immersed applications. Repeat necessary steps until satisfactory levels are obtained.

Results of Survey

Shipyards and contractors were solicited for data in July, August, and September, 2010. This does not cover the period for the annual cyclic results found by the Japanese, Koreans, and northern and European Shipyards where winter salts are a factor.

We surveyed shipyards and contractors during July, August, and September. There was a nominally 2540 measurements reported. Statistics were reported for the AVERAGE. Thus the total number of samples is recorded as 2543, but could be as high as 5100.

Included in the survey were:

Navy Public Shipyards	4 including surface and submarine vessels
Commercial Private Shipyards	11 (US)
Commercial Private Shipyards	3 (Japan, Korea, Germany)
Contractors- US	5
Contractors-Foreign	1 (offshore rigs, Australia. Co. has large US presence)

Research Center- US Navy 1 (developing a new Salt meter)

The findings can be summarized as:

- Severity and dispute is not great
- Frequency might be cut down because the work is being done during in-house production.
- US Shipyard other than Navy very seldom, if at all, conduct salt tests

The survey asked for number of measurements as

- None graphed as 0
- Less than 10 graphed as 5
- 10 to 50 graphed as 30
- 50 to 100 graphed as 75
- 100 to 200 graphed as 150

We graphed the AVERAGE. Thus the total number of samples is recorded as 2543, but could be as high as 5086.

The PERCENT RE-WORK means ABOVE Compliance limits. For example, If a SY reported 10-50 measurements and a re-work of <5%, then he number of measurements was graphed as 30, and 1 (rounded up from 0.6) measurements were "RE-WORK" or out-of-compliance.
The raw results were

Measurement/week distribution			**Percent re-work**	
100-200	1		Greater than 50%	4
50-100	12		5% to 25%	6
10-50	43		Less than 5%	16
less than 10	41		None	71
none	27			
total sample	124		total sample	97

The 27 responses where NO readings were taken were deleted from the percentage re-work; no readings always had no re-work (out-of-compliance).

The results were sorted into customer type (Navy or commercial) and new build/repair.
Mixed- This is a mix of US Navy and commercial work, both new build and repair.
Navy New Build
Navy Repair
Commercial New Build
Commercial Repair- All this data came from one contractor who was cleaning offshore rigs with UHP WJ.

The 100-200 measurement originates from a foreign new-build SY with a capacity for large construction volume.

The 50-100 points are from 2 foreign New-Build shipyard, except one report for a US contractor who works on Navy maintenance and repair.

Our conclusion was that during this time period, the actual measurements for salts was a minor consideration for cost savings compared to all other activities, with one exception.

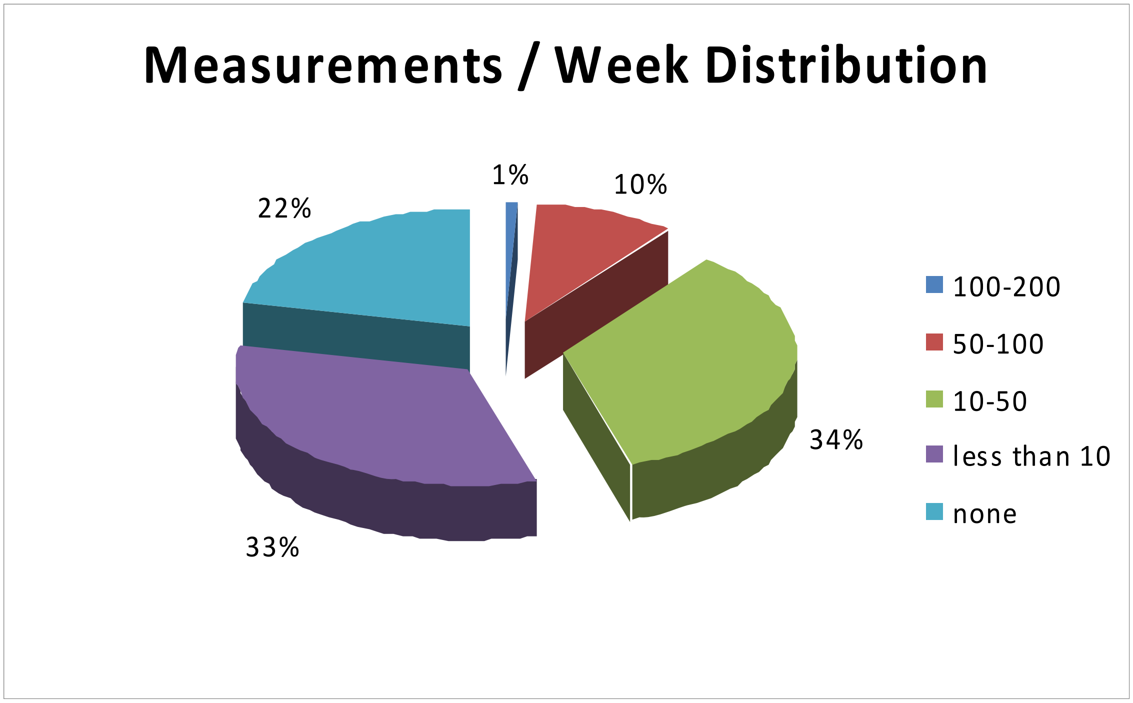


Figure 6 Salt Measurements/Week Distribution

The average re-work (out-of-compliance) on Navy and on commercial sectors was the same

Figure 7 Distribution of Out-of-Compliance

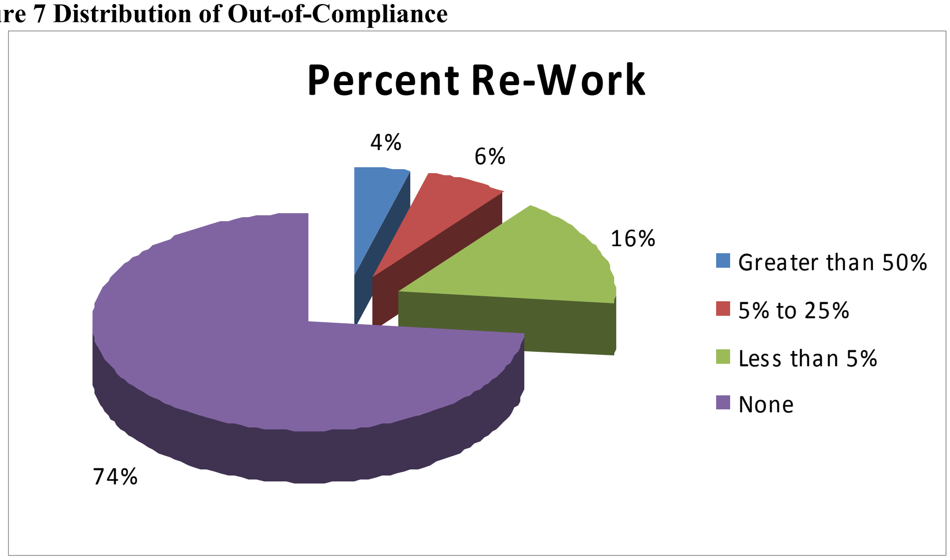


Table 19 Distribution of Repair and New Build

Categories of Repair and New Build			
	Avg tests/sample	Total Tests Ave.	Sample Frequency
Navy Repair (79)	16	1225	79
Navy New Build (19)	17	318	19
Mixed (4)	9.0	35	4
Comm Repair- offshore rig (5)	20	100	5
Comm New Build	51	865	17
		2543	124

The commercial new build high average originates from a foreign new-build SY with a capacity for large through-put volume.

Table 20 Distribution of Type and Re-Work

	Ave Test /week	Rework% Avg	Rework /week	Total Rework Survey Period
Navy Repair (79)	20	5	0.9	58
Navy NB (19)	20	1	0.17	3
Mixed (4)	18	3	0.5	1
Comm Repair- offshore rig (5)	20	23	4.5	23
Comm NB (17)	51	1	0.68	10
total		3.74%		95

The offshore rig contractor is reporting as the work is progressing. The contractor's numbers reflects the level of effort during production to get within compliance, not necessarily what third party or governmental inspector might detect when called for G-point. The contractor reported for ONE week that >50 % values were slightly higher than the specification of 50 mg/m^2 NaCl.

Figure 8 Type -Ave No. Test- % Out-of-Compliance

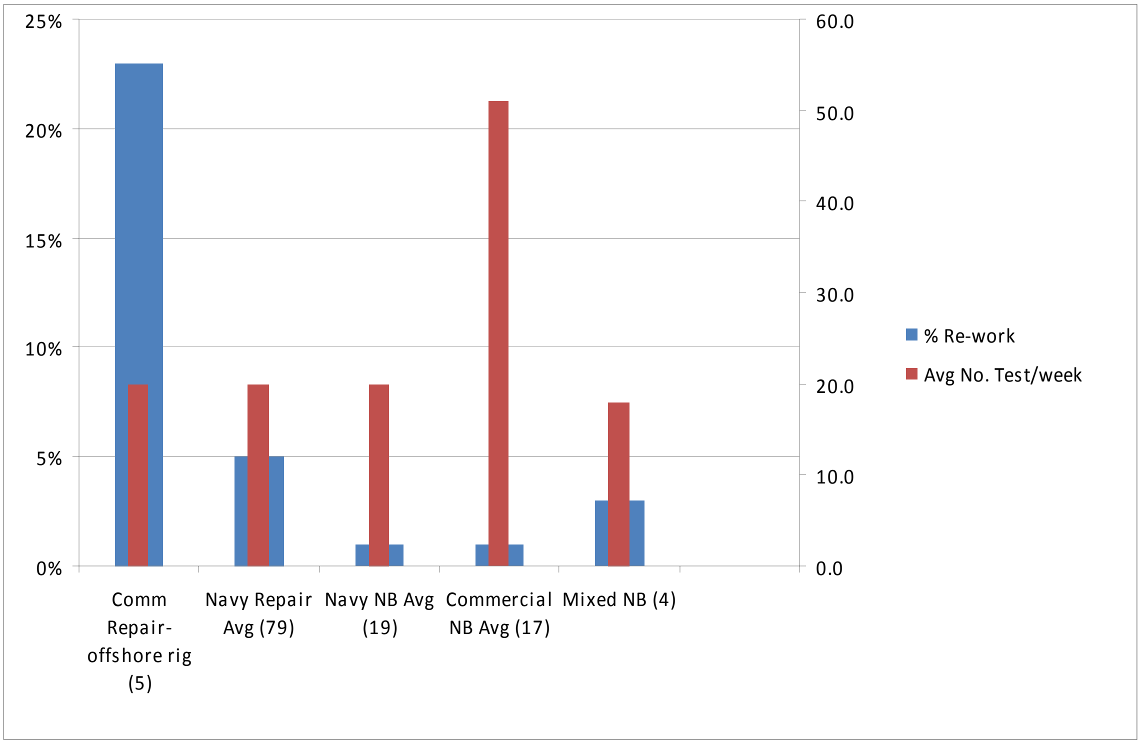


Table 21 Total Repair-New Build Frequency

All Repair and All New Build			
	Avg No. Test/week	% Re-work	Sample Frequency
REPAIR (84)	20	6%	84
NEW BUILD (40)	35	1%	40

New build has less rework (Out of compliance) than repair. This makes sense because repaired steel would have chlorides embedded in any extant corrosion. The rework (out-of-compliance) percentage for the Navy new-build tracks that of the commercial new-build.

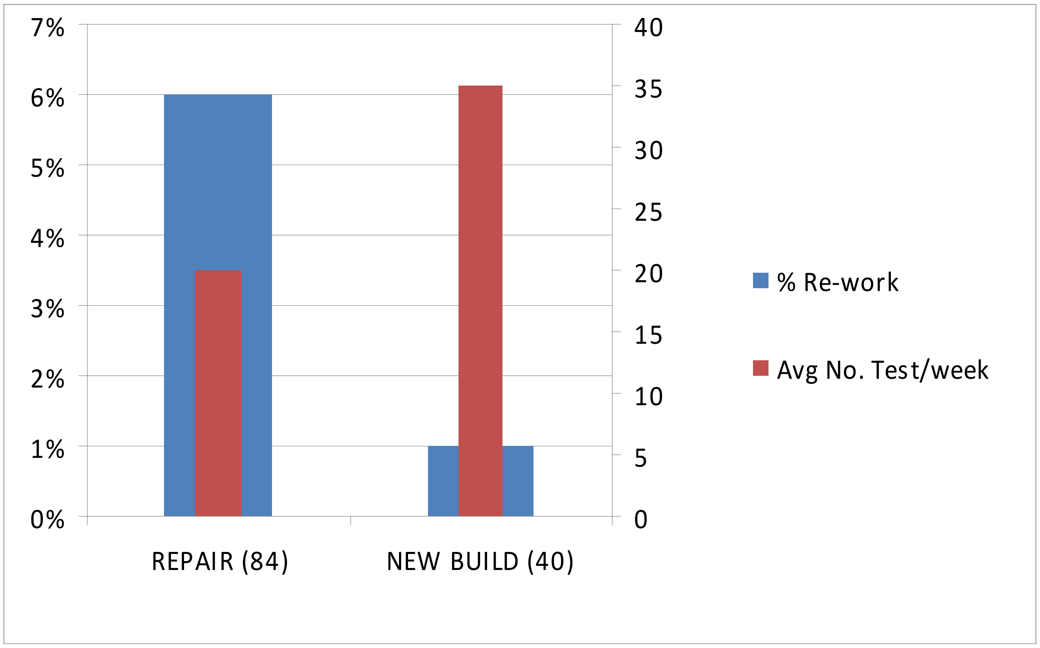


Figure 9 Comparison of Repair and New Build

Table 22 Comparison of Commercial and Navy

All Navy/Military and Commercial			
	Avg No. Test/week	% Re-work	Sample Frequency
Commercial (24)	44	4%	24
Navy/military (100)	20	4%	100

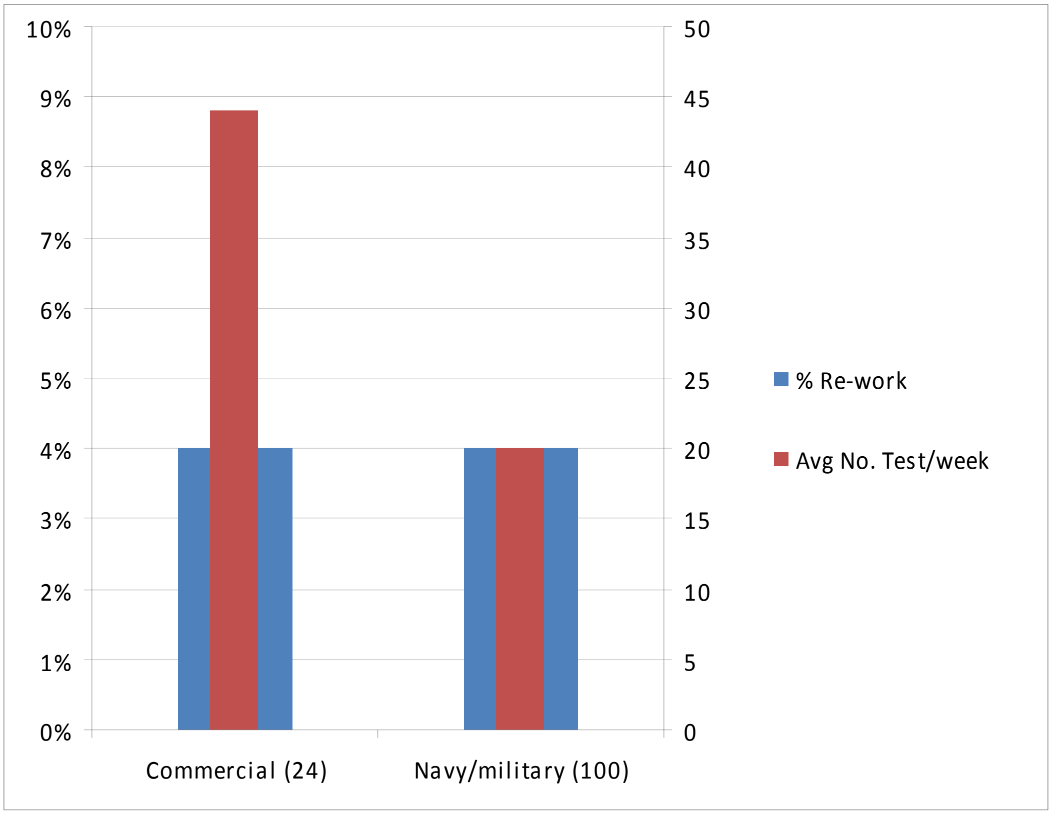


Figure 10 Commercial and Navy Comparison

During this period, there were 27 reports that no critical coatings, or commercial coatings was being done out of the 124 responses. Shipyards reported in interviews that they typically performed paint and blast periodically. Modular blocks might be held before inspection.

The 100-200 measurement originates from a foreign new-build SY with a capacity for large through-put volume.

All the 50-100 points are foreign New-Build SY, except one report for a US SY contractor who was working on a hull.

Our conclusion was that during this time period, the actual measurements for salts was a minor consideration for cost savings compared to all other activities.

The majority is no-re-work or out-of-compliance readings. The >50% came from the commercial offshore contractor who reported for ONE week that the values were slightly higher than the specification of 50 mg/m^2 ; they rewashed with UHP WJ; and from one NSRP shipyard who might have had a multiple blast-wash-blast cycle where the salts appear to be redeposited with the abrasive, but could not really discuss the incident.

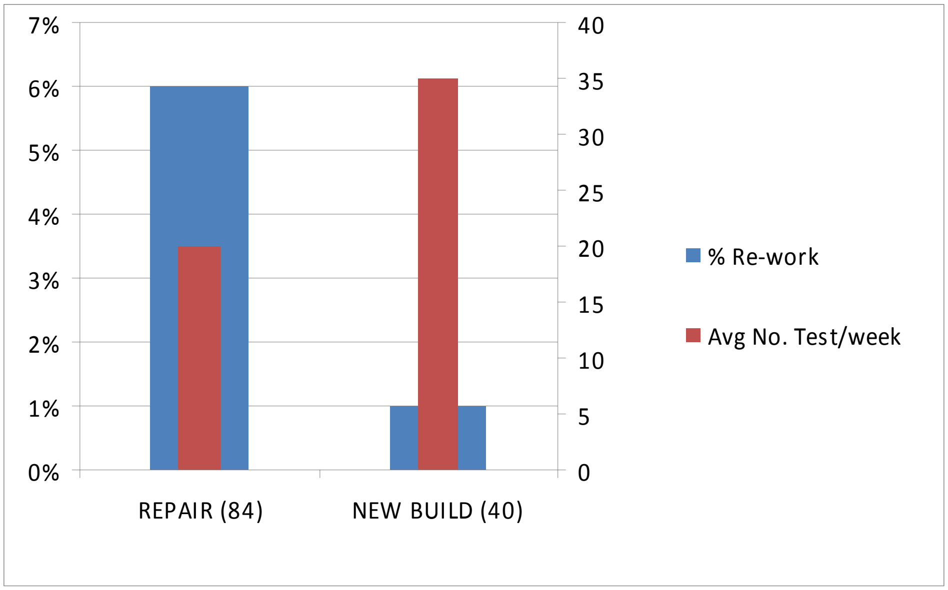


Figure 11 Repair vs. New Build Comparison

The percent re-work for repair is skewed by the offshore rig contractor.

Table 23 Type, No. of Test, Out-of-Compliance

2011 data	No. Tests	Sample Frequency	% Rework	Out of Compliance
Navy Repair (79)	1225	79	5	58
Navy NB (19)	318	19	1	3
Mixed (4)	35	4	3	1
Comm Repair- offshore rig (5)	100	5	23	23
Comm NB (17)	865	17	1	10
total	2543	124	3.75%	95

Table 24 All Out-of-Compliance Results

Compilation of all out-of-compliance Results			
	Avg tests/sample	Total Tests	Out of Compliance
Mixed (Navy-comm)	9	35	1
Navy Repair	16	1225	58
Navy New Build	17	318	3
Comm. Repair-offshore	20	100	23
Comm. New Build	51	865	10
		2543	95 (3.7%)

Findings:

- Repair has more rework than new build.
- The percentage of re-work for new build is 1%.
- The average percentage of re-work for repair is 6% The percentage of re-work for repair without the offshore contractor is 5%.
- The offshore commercial contractor work reflects the level of effort in taking readings as the work is done, not in a situation where the contractor makes sure that the surface is ready for inspection, and then calls in the inspector.
- There are not as many readings as we expected to find. Twenty readings per week average does not appear to be unreasonable.
- No readings generally meant no critical Surface Preparation that week. The SY might be coating non-critical areas.
- US shipyards doing commercial work are not performing salt readings on a routine basis, if at all. The customers do not required salt readings in the bid documents.
- US shipyards doing commercial work limit the salt reading to only those required by IMO.

Cost of Salt Measurements

Combining the cost of test with the average number of weekly tests results in the total costs.

Table 25 Cost of Salt Measurements with Initial Set-up

Cost of Salt Measurements

	Ave Test/week	Weekly costs Low $6.24	High $27.00	Annual costs 52 weeks	52 weeks
Mixed Commercial-Navy NB	18	$112	$486	$5,841	$25,272
Commercial New Build Avg	51	$318	$1,377	$16,548	$71.604
Commercial Repair offshore	20	$125	$540	$6,490	$28,080
Navy New Build	20	$125	$540	$6,490	$28,080
Navy Repair	20	$125	$540	$6,490	$28,080

From this tabulation, it appears that the direct costs of salt measurements are not a significant cost factor for any one single shipyard. However, if a labor cost for 2 to 4 many hours per week ($100 to $200) is added, there is an additional burden of $10,000 annually. Assuming that 6 shipyards are involved, the costs rise to $180,000.

See Appendix 4 for more comparisons

This is an area where small, incremental cost savings could be made.

Frequency and Location of Tests

Conductive measurements for US Navy vessels are required for “critically coating areas” (CCA), defined in Navy Standard Item 009-032, and not for all of the ship. The critically coated areas will depend on the vessel.

If we could reduce half of the readings, the cost saving is not over the entire ship, but just that critical coated area portion.

Table 26 Critically Coated Areas

Critically Coated Area (CCA) table submitted by a SY for their specific new-build vessel		
	30 µS/cm	70 µS/cm
	3µg/cm^2	5µg/cm^2
Description	Immersed	Non-Immersed
Underwater Hull	X	
Topside/Freeboard		X
Pot Water Tanks	X	
Seawater Ballast	X	
Fuel/JP5 Tanks	X	
CHT Tanks	X	
Non-skid Decks		X
Bilges		X
Uptakes/Plenums		X
Decks under EME's*		X
AFFF Decks		X
Decks for Heads		X

Estimated Percentage of Critical Coated Areas (CCA)

The exact critically coated area depends upon the specific hull design. As this documents is designed for public release, the specific vessel designs are not included.

One SY estimated that critically coated areas on their vessels could be up to **60%** of the total square footage.

Another SY provided a data table of their new build vessels from spring 2010 to fall 2010. The SY did not start their salt reading until Spring 2010. They concluded "Approximately **16%** of the total square footage we have prepped and painted to date is critical coated."

Unit	sq ft (CCA)	sq ft (Non-CCA)
4	**7,675**	**15,324**
5	**12,154**	**15,951**
1		**55,905**
6	**9,421**	**27,841**
7	**1,173**	**51,657**
2	**9,978**	**10,314**
8		**58,463**

Out-of-Compliance Measurements Deviation

We were requested to examine the difference between the actual readings from the specifications, i.e. How far off were the measurements?

One SY sent results from fall 2009 to spring 2010 as they were starting to locate areas of concern before it was time to officially start G- inspection points. The SY was looking at places near the outside doors, or in traffic areas. The upper limit was 70 µS/cm. The modules had a Preconstruction Primer for which the visible condition was fine. They measured the inside bulkhead module that was located close to outside elements. This is not a comprehensive survey of the geography of the SY.

The Bresle patch was used initially and then the SY acquired a soluble salt meter to avoid "half a day of measurements." The specific chloride ion from the Bresle extract was measured with an Orbecco-Hellige 942 photometer

Table 27 Specific Shipyard Survey to locate Trouble Spots

	Test Method	Cl- Content (µg/cm^2)	Conductivity (µS/cm) Limit 70
Pre-constr. Primer –OK cond	Bresle Patch	N/A	161
Pre-constr. Primer –OK cond	Bresle Patch	N/A	220
Pre-constr. Primer –OK cond	Soluble Salt Meter / Photometer	0.38	137
Pre-constr. Primer –OK cond	Soluble Salt Meter	N/A	32
Pre-constr. Primer –OK cond	Soluble Salt Meter / Photometer	0.31	108
Pre-constr. Primer –OK cond	Soluble Salt Meter	N/A	46
Pre-constr. Primer –OK cond	Soluble Salt Meter / Photometer	0.42	163
Pre-constr. Primer –OK cond	Soluble Salt Meter / Photometer	0.30	175
Pre-constr. Primer –OK cond	Soluble Salt Meter	N/A	84
Post blast	Soluble Salt Meter / Photometer	6.12	92
Post blast	Soluble Salt Meter / Photometer	5.81	76

It can be seen that the measurements are far above the allowable limits.

This table also illustrates examples of the field practice that if the conductivity is out-of-limits, then measure the specific chloride ion.

It should be noted that after the SY identified the problem areas where pieces were being exposed to the salt from outside elements, the inspection points starting February, 2010, were all within specification either by conductivity or specific chloride measurement, except for **two** points taken in **two** anomalous footprints.

The following table lists **all** 7 of the out-of-specification readings, over February 2010 to September 2010, for this SY.

Table 28 All Out-Of-Compliance Readings for one SY

All out-of-spec readings, February 2010 to Sept. 2010 for 1 Ship Yard		
Test Method	**Chloride Content (µg/cm2)**	**Conductivity (µS/cm)**
Soluble Salt Meter / Photo	0.48	110
Soluble Salt Meter / Photo	0.50	190
Soluble Salt Meter / Photo	2.80	198
Soluble Salt Meter / Photo	6.12	92 (footprint)
Soluble Salt Meter	n/a	* 0 after wash (footprint)
Soluble Salt Meter / Photo	5.81	76 (footprint)
Soluble Salt Meter	n/a	* 12 after wash (footprint)

Summary of All Survey Comments on Out-of-Compliance Readings

The following are the comments and tabulation of the “out-of-specification” salt readings from the other survey responders in July-September.

- Commercial New Build Deicing Salt contamination in winter likely- SY expected some problem when they started the painting application of the modules; 5-25% rework (50-100/week)
- Commercial Offshore- readings were just above 50 mg/m2; process is UHP WJ; >50% rework; just re-sweep the areas
- Navy Repair- Underwater hull- 3 dark area out of 75 areas; they range from 45-61 µS; use a wire brush; wash with DI water once; final reading < 30 µS
- Navy Repair- Underwater hull; 3 dark area out of 75; they range 44-68 µS; use a wire brush; wash with DI water once; final reading 17-24 µS

- Navy Repair-Underwater hull; 4 dark area out of 75
- Navy tank; suspect contaminated. Blast media even though the conductivity of blast media meets criteria; the conductivity is high after blast; then low after pressure wash; then the conductivity is high after sweep blast to remove light flash rust; then the conductivity is low after pressure wash; The contractor went through multiple cycles; they reported >50% rework
- Navy Repair- Bilge; init 100-250 μS; then the substrate is pressure wash; final 15-27 μS

Appendix 1 Bibliography

Bibliography

Listed in Chronological Order

1 Chandler, K.A. : The Influence of Salts in Rust on the Corrosion of the Underlying Steel :Brit. Corros. J., 1966, Vol. 1, July

2, Dasgupta, D. and Ross, T. K. : Cleaning of Rusty Steel for Painting :Brit. Corros. J., 1971, Vol. 6, Nov.

3. Sonntag, D. : discussion of German standards :Korrosion, 1973, Vol 4 (4), pp 3-10

4. Evans, U.R., & Taylor, C.A.G. : Critical Humidity for Rusting in the Presence of Sea Salt" :Br. Corros. J. (Quarterly), 1974, No. 1 , page unknown
Notes: If relative humidity is kept below 70%, there was little attack by atmosphere containing sulphur dioxide.; If any given salt contact, it decreases as the RH is reduced and becomes inappreciable below RH of about 40%.

5. Koehler, E.L. : The Influence of Contaminants on the Failure of Protective Organic Coatings on Steel :NACE, Vol. 33, No. 6, June, 1977

6. Whitby, K.T. : disucssion of rusting in atmospheric exposure :Atmospheric Environments, Vol 12, P 135 (1978)

7. British Ship Research Assoc. Rpt. (BSRA) : Salt Contamination of Steel Surfaces Before Coating :BSRA, 1982

8. Igetoft, L. : Coatings Systems for Bridges, :Proc. 2nd World Congress, Oct 26-276;, Missouri USA 1982

9. Gross, H. : Examination of salt deposits found under German painted Steel Bridge Decks :MP, Oct. 1983, p. 28
Notes: salt found under painted steel bridge decks

10. Johnson, W.C. : Detrimental Materials at the Steel/Paint Interface :ASTM STP 841,1984. pp28-43;D.M. Berger and R.F. Wint Editors, SSPC 83-01

11. Frondistou-yannas, S., Deanin R.D., Tator K.B., & Johnson W.C. : Coatings for Non-abrasive Cleaned Highway Steel :FHWA/RD86/053 Fed. Highway Admin., Dec. 1985

12. Weldon, D.G. & Caine T.A. : Salts" Their detection and Influence on Coating Performance :SSPC , May, 1985, (SSPC 85-06), P. 1-18

13. West, J. : The Relationship between Coating Thickness and Salt Contamination on Blistering of Coatings :UK Corrosion/85, Harrogate, Nov, 1985

14. Frondistou-yannas, S. : Evaluation of Rust-tolerant Coatings for Severe Environments :JPCL, Aug, pp. 26-35 1986

15, Appleman, B.R. : "Painting over Soluble Salts: A Perspective" :JPCL, Oct. 1987, p. 68-82

16. Cathcart, W.P. : Non-visible Contaminants in Railcar Interiors: Their Significance and Removal :JPCL, Dec., 1987, P. 64-69

17. Morcillo, M., Feliu, S., Galvan, J.C. & Bastidas, J.M. : Some Observations of Painting of Contaminated Rusty Steel :JPCL, September, 1987, p. 38-43

18. Weldon, D., Bochan, A. & Schleiden, M : The Effects of Oil, Grease & Salts on Coating Performance :JPCL,, Aug, 1987, pp 46-58

19. Brevort, Gordon H. : Abrasive Blasting and Salt Contamination: A Case History :JPCL, May, 1988, p 24,71

20. Trimber, K.A. : Detection and Removal of Chemical Contaminants in Pulp and Paper Mills :JPCL, Nov. 1988, p. 30- 37

21. anon, SSPC : Performance of Alternate Coatings in the Environment (PACE), Vol.2, 5 year Field Data and Bridge Data of Improved Formulation :SSPC 89-11, 104 pages
Notes: Comprehensive report on performance of coatings over abrasive, wet abrasive, etc. preparation regarding some rust FHWA-RD-89-235, 2800 test panels

22. anon, SSPC : Performance of Alternate Coatings in the Environment (PACE), Vol.3, Executive Summary :SSPC 89-12, 11 pages, 1989
Notes: Exec Summary- does not actually correspond to results within the data wrt wet abrasive blast, near-white performance. Comprehensive report on performance of coatings over abrasive, wet abrasive, etc. preparation regarding some rust FHWA-RD-89-236

23. anon, SSPC : Performance of Alternate Coatings in the Environment (PACE), Vol. 1, 10 year Field Data :SSPC 89-03, 182 pages 1989

24. Dekker, T.T., Bok, T.R., & Vergorgt, J. : Combating Corrosion by Fighting a Hidden Enemy- Soluble Salts :12th In. Conf. Of Organic Coatings, Athens Greece, 1989, p 164-170

25. Thomas, Noreen : The Protective Action of Coatings on Rusty Steel :JPCL, Dec. 1989, p. 8

26. Rex, Janet : A Review of Recent Developments in Surface Preparation Methods :JPCL, Oct. 1990

28. Appleman, B; Boocock, S.; Weaver, R., Soltz, G. : Effect of Surface Contaminants on Coating Life :FHWA-RD-91-011, SSPC 91-07. 256 pages

29. Phull, B. S. & Kirk, W. : Monitoring the Corrosivities of Atmospheric Exposure Sites :JPCL, Oct. 1991

30. Soltz, G.C. : The Effect of Substrate Contaminants on the Life of Epoxy Coatings Submerged in Sea Water :NSRP, NO. 0329, March, 1991, task 3-89-2

31. American Gas Association : Fusion-Bonded Epoxy Pipe Coatings :Midwest Research In., 1992

32. Boocock, Simon : SSPC Research on Performance Testing of Abrasives and Salt Retrieval Techniques :SSPC 1993 conference, p. 112

33. Boocock, Simon K. : SSPC Res. on Performance Testing of Abrasives & Salt Retrieval Techniques :JPCL, Vol. 11, NO. 3, March 1994, p. 28-

34. Brodar, John M. : Street Light Pole Corrosion :Salt River Project video, Nov. 1993

35. Morcillo, Manuel : The Detrimental Effect of Water-soluble contaminants at the Steel/Paint interface :12th International Corrosion Congress. Sept 19-26, 1993, Vol. 1. Coatings- p.87-98

36. Flores, S, Simancas, J.; Morcillo, Manuel : Methods for Sampling and Analyzing Soluble Salts on Steel Surfaces. A Comparative Study :JPCL, Vol 11, No. 3, March, 1994, p. 76

37. Van Der Kaaden, R. : Wet Blasting Studied to Replace Dry Blasting in Netherlands Shipyards (surf blast) :JPCL, May, 1994, pp. 29-86
Notes: Port of Rotterdam study to clean surfaces with water, grit, and slurry blast, 'surf'

blast. Compare salts with water and dry blasting.

38. Bresle, Ake : Conductimetric Determination of Salts on Steel Surfaces :MP/June 1995

39. Neal, D., Whitehurst T. : "Chloride Contamination of Line Pipe- It's Effect on FBE Coatings Performance" :NACE, MP, Feb 1995, p 47-52

40. Peart, John W., Hale, David, Hansink, James D. : Soluble Chlorides in Abrasive Media, :JPCL, Jan., 1995, p. 23-27

41. Anon Ellor, Kuljian, Ault Novel Coating Analysis Practices: Dec 1995, Ocean City Research Crop, Report prepared for NAVSEA Corrosion Control Div (Code 03M1) NAVSEA CONTRACT NO. N00024-92-C-4249, TI5C009 Year Published: 1995 Notes: Analysis of MIL-P-24441 epoxy coatings over steel in various conditions, doped with varying levels of sodium chloride. Performance is based on blistering. This report has NOT be sanitized.

42. Holder, Albert G, Juers, Raymond H. : Marine Coatings for Imperfect Substrates :NAWC-Carderock Div., NSWCCD-TR-64-96/15

43. Jackson, Donald : Chloride-Content Kit is a Bridge Saver :MP, Materials Performance (MP),Vol. 35, No. 6,June, p. 11; Roads & Bridges, Jan, 1996, p. 12
Notes: Describes field test kit for chloride in concrete.

44. Kuljian, Gordon : Comparison of 7 coatings over blasted steel panels, salt :private correspondence, August, 1996
Notes: Comparison of coatings of same formulation but different manufacturers over salt doped coatings. Same coating from different manufacturers behave differently. Depends on the manufacturing process (fineness of grind)

45. Alblas, Dr. B.P.; van Londen, A.M. : The Effect of Chloride Contamination on the Corrosion of Steel Surfaces: A Literature Review :PCE, February, 1997, p. 16-25
Notes: Comprehensive review of literature with effects of salts concentration and performance, includes atmospheric deposition; INCORRECT CHEMISTRY; '

46. Brodar, John; Colahan, Jerry : Extraction of Chlorides from Bridge Steel Debated :JPCL, Vol. 14, No. 5, May 1997, p 60-66

47. Carlson, Bo : Assessment of Surface Cleanliness by Use of the Bresle Method of Sampling :PCE, February, 1997, P. 12-15

48. Ellor, James A., & Farschon, Christopher L. : "Allowable Salt Contamination Levels for Industrial Painting :SSPC 1997, San Diego CA

Notes: Shows that drying the surface fast with a hot air gun led to blisters. Allowing the surface to rust with salt naturally did not lead to blisters.

49. Johnson, William C. : Cost-Effective Extraction of Chloride from Bridge Steel :JPCL, Vol. 14, NO. 1, January, 1997, P 82-92

50. Lever, Guy : Hydroblasting to Achieve Selective Coating Removal: Case Study of the USS Belleau and USS Duluth :US Navy & Ind. Corrosion Technology Conf., 1997, Louisville, KY

51. Morcillo, M. & Simanacas J. : Effects of Soluble Salts on Coating Life in Atmospheric Services :JPCL, SEP. 1997, pp 40-52

52. Morcillo, M., Rodriguqz, F.J. & Bastidas, J.M. : The Influence of chlorides, sulphates, and nitrates at the Coating- Steel Interface On Underfilm Corrosion :Elsevier, 1997

53. Morcillo, Manuel and Simancas, Joaquin : Water-Soluble Contaminants at the Steel/Paint Interface: Their Effect in Atmospheric and Marine Services :PCE Proceedings, Feb-Mar, 1997 Brighton, paper 12

54. Schmid, Richard : Advances in Ultra-High- Pressure Waterjetting :JPCL, Feb. 1997, p. 83

55. Schmid, Richard F. : Ultrahigh-pressure Waterjetting comes of age for Surface Preparation-It's Time to Get the Salts off (The 'Work') :NACE Corrosion97, paper 594, March, 1997, New Orleans

56. Ault, Peter; Farschon Christopher; & Chong, Shuang-Ling : Laboratory Investigation of Waterborne Inorganic Zinc Coating Failures :SSPC 1998 Proceedings, "increasing the Value of Coatings"

57. Bastidas J.M., Morcillo, M., & Rodriguez F.J. : Mild Steel Corrosion in Saline Solutions. Comparison Between Bulk Solutions and Steel-Coating Interfacial Solutions :J. Coatings Tech., July, 1998

58. Chong, Shuang-Ling, & Yao, Yuan : Performance Testing of Moisture-cured Urethanes on Power Tool-Cleaned Steel Surfaces :SSPC 1998 Proceedings "increasing the Value of Coatings,", p. 110-116

59. Garrabrant, Richard, Biesinger, James, & Jacinto, Glenn : A Practical Field Chloride Remediation Method :SSPC 1998 Proceedings, "increasing the Value of Coatings,", p. 62-67.

60. Johnson, James R. : Laboratory Test Parameters for Chloride Testing :SSPC 1998 Proceedings, "Increasing the Value of Coatings", p. 48

61. Johnson, James R. : A Primary Cause of Coating Failure :MP, Material Performance (MP), June, 1999, p. 48-49

62. Soltz, G.C. : Understanding How Substrate Contaminants Affect the Performance of Epoxy Coatings & How To minimize Contamination :SSPC 1998 Proceedings, "Increasing the Value of Coatings", p 208-219

63. Steinsmo, U. & Axelsen, Sten : Assessment of Salt Contamination and Determination of its Effect on Coating Performance :PCE 98 Conference, April, 1998, The Hague, Netherlands

64. Ackerman, Dr. Norbert : Coating Potable Water tanks on Board Ships :PCE, Sep., 1999, p. 24-27

65. Garrabrant,R.; Biesinger, J., Jacnto G., MeLampy, M. : "A practical field method for chloride remediation" :JPCL, Jan. 1999, p. 32-40

66. Johnson, Jim (Chlor*Rid) : Coatings on Dam Intact 4 years after Rehab, Salt Removal, Repainting :JPCL, Oct. , 1999, p. 56-71

67. Leng, et. al : :Corrosion Science, vol 41, (1999), 579-597
Notes: don't have; see EC paper reference

68. Leyland, David & Huntley, Rick : A Review of Shop Coating Failures :JPCL, June, 1999, p. 34-38

69. Morcillo, M. : :Progress in Organic Coatings Vol 36, 137-147, 1999

70. Richards, D.M. : Effects of Chloride Contamination of Abrasives on Performance of Long Life Coatings for Steel :Coatings for Asia 99, Singapore, August, 1999, p. 181-192

71. Richards, Dennis M. : EFFECTS OF CHLORIDE CONTAMINATION OF ABRASIVES ON THE PERFORMANCE OF LONG LIFE COATINGS FOR STEEL :ACA, 1999, Paper 39-084
Notes: Note: high pressure here means 1500 psi.

72. Dupuy, Richard : Ultra High Pressure Waterjetting for Maintenance Coating Applications :SSPC Conference, 2000, Nashville, TN

73. Forgren, A., Applegren, C. : Comparison of Chloride Levels Remaining of the Steel Surface After Various Pretreatments :PCE 2000, proceedings, March, 2000

75. Jeffrey, Jeremy; Johnson, Jim; Mills, G.; Eliasson, J.; Alveberg, Bjorn E. : Limiting Chloride Content in Ballast Tanks :JPCL, PCE, Nov., 2000, p. 17-24

76. Kline, Erik; Angeloff, Carl A. : Rapid Deployment: A potential Approach to Reducing the costs of Painting Steel overpass Bridges over Busy Highways :PCE, January 2000, p. 63-66

77. Mitschke, Howard : Effects of Chloride Contamination on Performance of Tank and Vessel Linings :SSPC 2000 Conference, Nashville TN SSPC#00-15, p. 304
Notes: extreme accelerated test to drive water through coating

78. Peacock, Curtis; Maire, Guy (France); Barton, Penny (W VA Div. Of Highways); Fleming, James (Canada); Taylor, Alan J. (Steel Protection Consultancy- UK); Castler, Brian (Ct DOT) : On Pressure Washing Structures before Abrasive Blasting :JPCL, PCE, April, 2000, p. 17-27

79. Towers, Rodney (Sigma) : Accelerated Corrosion in Cargo Tanks of Large, Double-Hull Ships: Causes & Countermeasures :JPCL- PCE, Mar. 2000, p. 30-42

80. anon; Tator, Ken- chair : ISO working Group 5 , Guidance Lavels of Water Soluble Salt Contamination Before Application of Paints :ISO/TR 15235, 2001

81. Johnson, Jimmy, Colahan, Jerry 'CHLOR*RID : Salts 101- An Overview :JPCL, Feb. 2001 advertisement supplement

82. Lambrakos, S.G., Paulette, Patricia : Evlauation of Desalting and Inhibiting Washes for Corrosion Control of Military Equipment operating in Marine Environments :NACE Corrosion2001, 01554,, 8 pages

83. Mitschke, Howard : Effects of Chloride Contamination on Performance of Tank and Vessel Linings :JPCL, Mar. 2001, p. 49-56

84. Ortega (Trotter) Luis : Comparison of Surface Preparation Using Different Methods :WJTA, 2001, 11th Conference, Minnieapolis, MN

85. Appleman, Bernard : Advances in Technology and Standards for Mitigating the Effects of Soluble Salts :JPCL, PCE, May, 2002, p. 42-47

86. Appleman, Bernard R. : The Effect of Soluble Salts on Protective Coatings" :"Good Painting Practices", SSPC, Vol. 1, 4th Ed., 2002, p 119-138

87. Cavallo, Jon : Concrete Contamination and Its Effects on Coating Work :JPCL, Feb. 2002, p. 33-38

88. Peters, Harry : Natural Surface Phenomena and the Impact of Corrosion Inducing Salts :SSPC 2002 Conference, 9pages
Notes: Attempt to again show that salts cause acid conditions, works at the hydroxide layer and disbonds it. They do not acknowledg that acid condition results because of oxidation and corrosion, not because of the salts.

89. Schnell, Don J. : Dehumidification Comes of Age :SSPC 2002 Conference, 9pages

90. Bartlett, D.J. : "Water and water soluble salts, The Scourge of Anti-corrosive Coatings :private communication, April 2003, Willie Mandeno, New Zealand; paper presented in Australia.

91. Chong, Shuang-Ling, Yao-Yuan : Intra-Laboratory Assessment of Commercial Test Kits for Quantifying Chloride on Steel Surfaces :JPCL, PCE Aug 2003, p 42

92. Colahan, J.J. : Surface Adsorption: Overcoming "Water-Soluble" Salts :MP, Dec., 2003, p. 32

93. Colahan, Jerry J. : "Standardization of Wash Water Quality in Specification for Surface Preparation" :MP (Material Performance), Feb, 2003, p. 46-49

94. Colohan, Johnson, Chlor*Rid : SSPC Workshop on" Stopping Salt Induced Coatings Failures" :SSPC Conference, 2003
Notes: workshop slides - there are errors.

95. Curran, J.J., Curran J.& MacDowell, Louis : Evaluation of Chemical Rinse Agents on Steels Exposed to an Atmospheric Marine Environment :Tri-Services Corro. Conf, Nov 2003

96. Frenzel, Lydia M : Water Additives-Do They Help Cleaning? :CleanerTimes, Aug, 2003 p 42-44

97. Frenzel, Lydia M : Dissolved Salts on Surfaces: Determining Amounts :CleanerTimes, June, 2003 p 22-23

98. Johnson, James, Kowalski, Gary : Is Plain Water Washing Effective Enough? Chloride, Sulfate, & Nitrate Salts on Bridges & Their Removal :JPCL, Sept., 2003, p. 48-54

99. Lambrakos, S.G., Tran, N.E., Cooper, Khershed P., & Paultette, Patricia : Properties and Effects of Rinse Water Additives on the Corrosion Rates of Structural Metals Used for Marine Corp Ground Vehicles :Naval Res. Lab, NRL/MR/6320--03-8680,2003, 42 pages

100. Lambrakos, S.G., Tran, N.E., Paultette, Patricia : Effects of Inhibiting Washes on the corrosion behaviou of metals in Diluted Seawater Enviornments :NACE Corrosion 2003, 03215, 8 pages

101. Needham, Bill : "Conductivity and Chlorides", Navy Special Study on Conductivity and Washing :April 14, 2003 by memo, NavSea

102. Tator, Ken B. : Levels of Salt Contamination on Steel Beneath Coatings :SSPC Conference, 2003

103. von Fraunhofer, J.A., and Davis G.D. : Tobacco Extracts as Pickling Inhibitors :MP, Dec., 2003, p. 38

104. Colahan, Jerry J. : Salt Contamination: Are There "Acceptable" Levels? :Coatings Pro, Sept. 2004, p. 18-

105. Curran, Joseph and Curran, Jerome, and MacDowell, Louis : Evaluation of Chemical Rinse Agents on Steel Exposed to an Atmospheric Marine Environment :NACE Corrosion 2004

106. Frenzel, Lydia M. : Popular Salt Removers, Current Chemical Rinse Aids (CRA's), Part 1 :CleanerTimes, Feb, 2004 p 24-29

107. Beech, A. : The Adverse Effect of Soluble Salt Contamination on the Durability of Subsequently Applied Paint Systems :quote in EC (Bohm) paper, MSc Thesis

108. Bohm, M. Longdon, P.J.; Garcia, D. de la Fuente; Morcillo, M.; Rohwerder, M.; Houyoux, C. : Soluble Salt Contamination of Blast-cleaned Surfaces and the Effect on the Durability of Subsequently Applied Coatings :Technical Steel Res, Eurpoean Commission, Final report, EUR 20910, 2005

109. Mobin, M., Malik, A.U. : Premature Failure of Repainted Epoxy on the Internal Bottom Plate of A Fuel Oil Tank :MP, Feb, 2005, .28-31

110. Richards, D. M. : Effects of Salt Contamination of Abrasives on the Performance of Long Life Coatings for Steel :ACA Journel "Corrosion & Materials", Feb, 2005

111. Schilling, Mark : JUNK SCIENCE IN CORROSION CONTROL: GIMMICKS GADGETS AND GIZMOS :Australasian Corrosion Asso, 2005, Brisbane

111. de la Fuente, Otero, Chico, M. Morcillo "'Painting over Soluble Salts: Field Extraction of Soluble Salts from Corrosion Products of Steel" Progress in Organic Coatings, Vol 54, Issue 3, Nov 2005, p 240-247 Elsevier Year Published: 2005

112. de la Fuente, Chico, M. Morcillo 'The Effects of Soluble Salts at the Metal/Paint Interface: Advances in Knowledge 'Portugaliae Electrochemica Acta, (2006) p 191-206

112. Baek, K.K., et.al : Effect of Blasted Surface Contaminants on Coatings Performance :NACE Corrosion 2006, paper 06014

113. Schilling, Mark S. : Soluble Salt Frenzy- Junk Science: Part 1 :Corrosion & Materials, ACA, Vol. 31, No. 5 Oct. 2006, p 10-15

114. Schilling, Mark S. : Soluble Salt Frenzy- Junk Science: Part 2 :Corrosion & Materials, ACA, Vol. 31, No. 6 Dec. 2006, p 12-17

115. de la Fuente, D; Bohn, M, Houyoux, C.; Rohwerder, M;, Morcillo, M. : The Steeling of Critical Levels of Soluble Salts for Painting :Progress in Organic Coatings, Jan., 2007, p 23-32

115a Lee, Hun-Kug (Samsung) "Effects of IMO PSPC Korea Shipbuilders' Assoc (KOSHIPA), Sep, 2007 Tripartite Meeting
Notes- PowerPoint presentation- detailed overview of effect of grinding edges, profile, and salts levels.

116. Hatle, Loren : Method for Removal of Surface Contaminants from Substrates :patent applicaton 20070065587

117. Hausmann, D.A. : Thress Myths about Corrosion of Steel in Concrete :MP, august, p. 70-73

118. Paul McBain : Effect of Soluble Salt Contamination of Steel Substrates on the Performance of Coatings :Protective Coatings, 24-25 October 2007 Amsterdam, The Netherlands

119. Peter J. Longdon* & M. Bohm : Soluble Salt Contamination on Blast Cleaned Surfaces and the Effect on the Durability of Subsequently Applied Coatings :Protective Coatings, 24-25 October 2007 Amsterdam, The Netherlands

120. Peters, H. : References: Salts and Their Role in Corrosion and

Coating Performance :NACE, Mar 2007, TIE on Salts

121. Schilling, Mark : Phlogiston and Modern Corrosion Junk Science :Material Performance (MP), Mar, 2007. p 32

122. Whitehouse, Nigel : Recent Progress in the Development of International Standards for the Surface Preparation and Painting of Steel :Protective Coatings, 24-25 October 2007 Amsterdam, The Netherlands

123. ISO : Laboratory Determination of Chloride :8502-2

124. Lee, C.H.; Son, S.M.; Shin, C.S.; Baek, Y.H., and Baek, K.K. : Technical Aspects of Soluble Salt Contamination Analysis in New Shipbuilding Yards :NACE Corrosion 2008, Paper 08020

124a. J. Eliasson, Report to TG 392 “Testing of Salt Levels about 100 mm apart” Private Communication-NACE

124b. Paul D Gossen, “Equivalence to ISO 8502-9_, NACE Presentation, to STG 44 TG 392, Sept 16, 2008
Notes: Gossen of National Surface Treatment Center performed several studies to establish the minimum time for extraction, a fallacy for bias, and the minimum numbers of tests that have to be conducted.

125. Lisa Detter-Hoskin of Georgia Tech Research Institute : sonic energy and manual brushing of specimens with the boiling extraction process :Private Letter email 2008-03-20

127. Pang, Yuan, Schultz, Paul B. : Improved Preparation Methods for Coating Tanks S2096, Comparative Evaluation of SSM and Bresle Methods for Salt Extraction Efficiency :CTC report, 01-May 2008, ONR Code 03T, Navy Metalworking Center

128. Yates, Ed : Salt Contamination Testing: Integrated Extract & Analyze Strip :NSRP, Johnstown PA Oct 2008

129. Chirgwin, G, Manamperi P, Moor M : A Global Study of Chloride Induced Corrosion within the RTA's Reinforced Concrete Bridge Stock :ACA, Corrosion Management & Protection of Infrastructure, Ballina, Australia May 15, 2009

130. Frankhuizen, N. : Measuring NaCl, Salt, and Soluble Contaminants with Bresle Patches- Part 2 :MP Nov. 2009 p 34-37

131. Frankhuizen, N. : Measuring NaCl, Salt, and Soluble Contaminants with Bresle Patches- Part 1 :MP Nov. 2009 p 36-39

132. G Chirgwin, P. Manamperi, Michael Moore, : A Global Study of Chloride Induced Corrosion within the RTA's Reinforced Concrete Bridge Stock :Corrosion Management & Protection of Infrastructure, Australiasian Corrosion Association, 2009

133. Hansel, Bill (Cal Trans) : Going Hollywood on the Vincent Thomas Bridge Tower :SSCP PACE, 2009, New Orleans

134. Al Mansour, Saudi Aramco; "'Effect of Water- Soluble Salt Contamination on Coating Performance"'13th Middle East Corrosion, Feb, 2010, Bahrain
Notes: done with Jerry Woodson-Sherwin Williams according to ISO guidelines, found that condensation and cyclic testing gave different results. Looked at adhesion, EIS, Prohesion Correlation between coating service life and amount of salt contamination is hard to establish.

135. , Al-Mithin, Sabri, Jarragh, Faisal, Kuwait Oil Co. "Soluble Salt Criteria of Epoxy Coatings for Ship's Water Ballast Tank" '13th Middle East Corrosion, Feb, 2010, Bahrain

136. Lee, Chui-Whan; Son, Sung-Mo; Baek, Yun-Ho; Kim, Dae-Young : Soluble Salt Criteria of Epoxy Coatings for Shp's Water Ballast Tank :NACE Corrosion 2010, Paper 10017

137. Chad Scott 'Navy Metalworking Center (NMC) Coatings-Related Projects Overview Presentation at NSRP SPC meeting, Nov. 2010

138. Swan, Tom : Myths about Salts, chlorides, and Coatings :MP, Mar, 2010, p.2

139. Swan, Tom Chlorides and Contaminants- Inspection and Sampling NACE Central Area Conf, Aug 2010, Corpus Christi TX

140. Woodson, Jerry 'Chloride- The Non-Visible Contaminant NACE Central Area Conf, Aug 2010, Corpus Christi TX

141. Tator, Ken : Soluble Salts Beneath Coatings- An Overview :JPCL, Feb, 2010 p 50- 63

142. Peters, Hap Measuring Surface Salts: Conductivity vs. Ion Specific Testing MP, Oct., 2010, p. 42

=====

As most of the performance of coatings over "salts" is based water penetration and what happens as water migrates along the surface, these papers by Clive Hare discussed what most of the other authors ignore.

143. Hare, Clive Blistering of Paint Films on Metal, Part 1: Osmotic Blistering JPCL, Feb., 1998, P. 45-63

144. Hare, Clive Non-Osmotically-Induced Blistering Phenomena on Metal JPCL, Mar. 1998, p. 17-34

145. Hare, Clive Adhesion: Part 1, p.77-87 JPCL, May 1996,;

146. Hare, Clive Adhesion: Part 2," JPCL, July, 1996, p 77-95 :

147. Hare, Clive Water Permeability in Pigmented Films, JPCL, Oct 1997 p.77; Water Permeability in Unpigmented Films JPCL, Sept., 1997, p. 67

148. Hare, Clive The Permeability of Coatings to Oxygen, Gases, and Ionic Solutions JPCL, Nov. 1997, p. 66

149. Hare, Clive "Metallic Corrosion JPCL, Dec. 1997, p. 74 and Corrosion Phenomena: Specific Forms: JPCL January 1998, p. 63

150. Hare, Clive Barrier Coatings JPCL, April, 1998, p. 17

Appendix 2 Relationship between Conductivity and Concentration of Sodium Chloride

See: ISO 8501-9
See NACE SP0508 Methods of Validating Equivalence to ISO 8502-9 on Measurement of the Levels of Soluble Salts

The precision of a single ISO 8502-9 test result was determined to be ± 8.2 mg/m^2 in the range 30 to 80 mg/m^2. (±0.82 µg/ cm^2 in the range of 3 to 8µg/ cm^2)

Specific Conductance (SC) is a measure of how well water can conduct an electrical current. In discussion of bulk material, it is convenient to talk of its specific conductance, now commonly called conductivity. Conductivity gives an indication of **TOTAL ion** concentration. Conductivity is the reciprocal of resistance (measured in ohm), and its basic unit is the "Siemens", formerly the mho. This is the conductance as measured between the opposite faces of a 1 cm cube of the material. This measurement has units of Siemens/cm. Conductivity increases with increasing amount and mobility of ions. Conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron.

The total conductance is the summation of each of the individual ion concentrations x the individual equivalent conductance constant.
I.E. a solution contains NaCl and KNO_3
Total Conductance = $c_1[Na^+] + c_2[Cl^-] + c_3[K^+] + c_4[NO_3^-]$

In the discussion on conductivity versus specific ion measurements, Swan (ref 139) provided lists of anions and cations that could be present and would contribute to conductivity. This long list of **POSSIBLE** contributors to total soluble salts or conductivity simply means that the inspector should be aware of environmental surroundings. What is likely to be present? In a marine environment- of course sodium chloride, but if there is chemical processing or refineries nearby- there could be other conducting species. So long as people understand that the equivalency conversion for conductivity to chloride is indeed a mechanism to get to a calculated basis focused on one ion there should be no obstacle in the concept. If you are in a phosphoric plant, the conductivity will be composed of phosphate anions and appropriate cations, not necessarily sodium chloride.

In 8502-9, an average constant C is adopted, with the stipulation that following ions are predominant in the water: Na^+, Ca^{2+}, Fe^{2+}, Cl^-, SO_4^{2-}, and HCO_3^- . The adoption of the value of C is the source of the difference between the following calculation based on fundamentals.

The following is a discussion by Dr. Frenzel used in workshops to provide the calculation of µg/ cm^2 Chloride or Sodium Chloride from conductivity.

The extraction Bresle patch cell uses 10 ml de-ionized water on a 12.5 cm^2 area.

The extraction Chlor*Test™ uses 10 ml liquid solution on 10 cm^2 area.

These tests will use different conversion factors as Conductivity will go down if more water is used to extract the same surface area. You must know the volume and the area.

The units of measurement used to describe Conductivity and resistivity are fundamental and are frequently misused. Conductivity gives an indication of **TOTAL ion** concentration.

The basic unit of resistance is the ohm. Conductivity is the reciprocal of resistance, and its basic unit is the "Siemens", formerly the mho. In discussion of bulk material, it is convenient to talk of its specific conductance, now commonly called conductivity. This is the conductance as measured between the opposite faces of a 1 cm cube of the material. This measurement has units of Siemens/cm. Since this unit is much too large for most solution, the units µS/cm and mS/cm are used instead. The corresponding terms for specific resistance (or resistivity) are ohm-cm, mega ohm-cm and kilo ohm-cm.
1 PPM is 1 mg/Liter.
10 mg/Liter = 10 PPM
1 µS/cm = 0.001 mS/cm = 0.000001 S/cm = 1 µ mho/cm

Typical Values	Conductivity	Resistivity
absolute pure water	0.055 µS/cm	18.3 M ohm cm
power plant boiler water	1.0 µS/cm	1 M ohm cm
good city water	50 µS/cm	Rarely used
Ocean water	53 mS/cm	Rarely used
31.0% HNO_3	865 mS/cm	Rarely used
11 mg/Liter NaCl	23 µS/cm	
33 mg/Liter NaCl	70 µS/cm	
215 mg/Liter NaCl	445 µS/cm	
15 mg/Liter 442	23 µS/cm	
300 mg/Liter 442	445 µS/cm	

A common solution to represent most applications for natural water is known as 442. It contains

40 % Na_2SO_4 (sodium sulfate)
40 % $NaHCO_3$ (sodium bi carbonate)
and 20 % NaCl (sodium chloride or salt)

The corresponding conductivity are given above for this calibration solution. A standard sodium chloride solution is used when testing brackish or **sea** water. 442 solution is used to calibrate in most other instances.

Sodium Chloride has an ionic weight of 59 of which 36 is Chloride and 23 is sodium. As an approximation, one assumes that sodium chloride is made up of 50% chloride and 50% sodium instead of 61% chloride and 39% sodium.

1 PPM is 1 mg/Liter.

You can see from the table that:
Conductivity in µS/cm **is approximately** 2 x (Dissolved solids in PPM of NaCl)
Conductivity in µS/cm **is approximately** 4 x (Dissolved solids in terms PPM of Cl).
For example a 200 µS conductivity is **approximately** 50 PPM of chloride and approximately 100 PPM of sodium chloride.

Let's look at the example of using the Bresle test cell, and CHLOR*TEST™ Let's assume that the collected sample measures 50 µS/cm (or micro mho) for each case.

In order to calculate the chloride concentration, the assumption is made that the conductivity is due to dissolved sodium chloride. **This is not necessarily true, but we are using a CHLORIDE EQUIVALENT.**
We will calculate back to micrograms of sodium chloride / unit area.

Bresle Cell:

$50\ \cancel{\mu S/cm} * \frac{33\text{ mg NaCl}}{\text{liter}\ \ 70\ \cancel{\mu S/cm}} = 23.5\text{ mg NaCl/Liter}$ (or 23.5 PPM).

$23.5\text{ mg NaCl}/\cancel{\text{Liter}} * 10\ \cancel{\text{ml}} * 1\ \cancel{\text{Liter}}/1000\ \cancel{\text{ml}} = 0.235\text{ mg NaCl or } 235\ \mu g\text{ NaCl}$

$235\ \mu g\text{ NaCl} * 1/12.5\text{ cm}^2 = 18.8\ \mu g\text{ NaCl / cm}^2$

This is an exact calculation, based on the **assumption** that NaCl is the conducting medium. But a good assumption is to use, for the Bresle cell, **0.4** as a conversion factor, which would give the answer **20 µg** instead of 18.8 µg.

ISO 8502-09 includes an equation where an empirical constant "c" is set at a value of 5.

Using 50 µS/cm, and 10 ml, and 1250 mm patch, the equation is:
Density = conductance * 5 * ml volume of solution/area of patch in mm

Density = 50 *5*10/1250 =20 µg NaCl / cm^2 or 200 mg NaCl/m^2

ISO 8502-9 starts with the conductance, and an empirical constant c = 5, that depends upon the salts that are present. For Bresle **10** ml over Area=1250mm, the calculated salt would be **20 µg**/cm^2 for 50 µS/cm. See later discussion on Lee and Baek paper for use of empirical constant.

NACE SP0508 uses 3 ml, instead of 10 ml.; then the conductance for this sample would be 167 µS/cm instead of 50.

$167\ \cancel{\mu S/cm} * \underline{33\text{ mg NaCl}} = 78.7\text{ mg NaCl/Liter}$ (or 78.7 PPM).

liter   70 ~~µS/cm~~

78.7 mg NaCl/~~Liter~~ * **3** ~~ml~~ * 1 ~~Liter~~/1000 ~~ml~~ = 0.236 mg NaCl or 236 µg NaCl

235 µg NaCl * 1/ 12.5 cm^2 =   18.8 µg NaCl / cm^2

Using the formula
Density = (conductance) x 5 x 3 ml/1250) = 167 x 15/1250 = 20 µg NaCl / cm^2 or 200 mg NaCl/m^2

If you use the same volume and area each time, just collect the constants and use a multiplication factor of 4.

The conversion to just chloride ion is:
18.8 µg NaCl / cm^2 * 61% Cl = 11.5 µg Cl / cm^2
Take the conductivity in micro mhos and divide by 2.5 to get micro gram sodium chloride/ square centimeter.

If we continued to use the **assumption** that sodium chloride contained 50% chloride, then this gives the answer 50 µS/cm x **0.2** = 10 µg Cl / cm^2 instead of 11.5.
Take the conductivity in micro mhos and divide by 5 to get approximate micro grams chloride / square centimeter.

In summary:
When using the Bresle cell of 10 ml liquid in a 12.5 cm^2 area, the conversion factor (a combination of the volume, surface area, and conductivity constant) is
measured µS/cm x **0.4** = µg NaCl/cm^2 i.e. 10 µS/cm = 4 µg NaCl/cm^2 = approx. 2 µg Cl/cm^2
measured µS/cm x **4** = mg NaCl/m^2 i.e. 10 µS/cm = 40 mg NaCl/m^2 = approx. 20 mg Cl/m^2

Chlor*Test™: The extraction solution is not de-ionized water. To use conductivity measurements, you MUST use de-ionized water
OR take the Final Conductivity minus the Initial Conductivity to find out how much is due to the extraction.

50 ~~µS/cm~~ * 33 mg NaCl   = 23.5 mg NaCl/Liter   (or 23.5 PPM).
liter   70 ~~µS/cm~~

23.5 mg NaCl/~~Liter~~ * 10 ~~ml~~ * 1 ~~Liter~~/1000 ~~ml~~ = 0.235 mg NaCl or 235 µg NaCl

235 µg NaCl * 1/ 10 cm^2 =   23.5 µg NaCl / cm^2

This is an exact calculation, based on the **assumption** that NaCl is the conducting ionic media.
The conversion to just chloride ion is:

23.5 μg NaCl / cm^2 * 61% Cl = 14.3 μg Cl / cm^2

Take the conductivity in micro mhos and divide by 2 to get micro gram sodium chloride/ square centimeter.

If we continued to use the **assumption** that sodium chloride contained 50% chloride, then this gives the answer 50 μS/cm x **0.25** = 12.5 μg Cl / cm^2 instead of 14.3.
Take the conductivity in micro mhos and divide by 4 to get approximate micro grams chloride / square centimeter.

In summary:
When using the **Chlor*Test™** cell of 10 ml liquid in a 10 cm^2 area, the conversion factor (a combination of the volume, surface area, and conductivity constant) is
measured μS/cm x **.5** = μg NaCl/cm^2 i.e. 10 μS/cm = 5 μg NaCl/cm^2 = approx. 2.5 μg Cl/cm^2
measured μS/cm x **5** = mg NaCl/m^2 i.e. 10 μS/cm = 50 mg NaCl/m^2 = approx. 25 mg Cl/m^2

NOTE: The **Chlor*Test™** is supplied with Kitagawa tubes to read **Cl^-** in PPM, so that a reading of 5 PPM Cl^- will correspond to 5 μg Cl^- / cm^2.

Calculations from Lee, Baek et al (2008) NACE Paper No. 08020

For ISO 8502-6 & 8502-9 method, the TSS in extracted solution was evaluated with measured conductivity and the following conversion equation;

$\rho A = C.V\ .\Delta\Gamma/A$ Eq.(1)

where, ρA is total surface density of the salts, C is an empirical constant approximately equal to 5 Kg/m2/S(0.5Kg/ cm^2/μS), V is original volume of water in the beaker, ΔΓ is the change in conductivity.

The equation can be simplified by unit conversion into the following Eq. (2).

$E = (0.5)\ S\ V/A$ Eq. (2)

where, E is surface concentration of total soluble in μg/ cm^2, S is conductivity measured due to soluble salt in μS/cm, A is measurement area in cm^2, V is volume of extracted solution in mL, 0.5 is the conversion factor, which depends on the chemical composition of the soluble salts and can vary from **0.54 to 0.96**. The conversion factor was selected to be 0.5, measurement area "A" was 12.5 cm^2, and volume "V" was **15**mL in this study, Combining the fixed volume and area with the conversion factor leads to:

$E = (0.5)\ S\ 15/12.5 \quad = S\ 0.6$

In this study, the combined multiplication factor is 6 for conversion to mg/m2 or 0.6 for conversion to μg/ cm^2

For example for measured conductivity of 20 μS; the Total Salt density would be 120 mg/m2 or 12 μg/ cm^2 NaCl, assuming that all the salt is NaCl.

This factor of 6 is often used without reference. As we have discussed, the inspector MUST use a factor that is based on the specific volume and area. If you know that you are expecting a specific ion, the C constant might also change.

Some companies use an extraction number. They assume a retrieval rate of 50% or 60% to estimate between the field method and the "real" number.

This leads into another discussion. What is the retrieval rate for a "swab" versus a "soak" method. Dr. Frenzel's experience and recommendation is that you do not complicate your field measurements by including a "retrieval rate". The operator should become proficient with the specific test.

Mr. Ault's experience is that the efficiency or retrieval rate varies with the way the salt is contained on the surface. Most tests of extraction efficiency are performed on doped panels where the salt is deposited as a crystal and readily dissolved. In the "real world", salts are often complexed with an oxide or physically dispersed in a pit. In this instance, the extraction efficiency has been shown to be worse versus boiling water extraction.

ISO 8502-6 does note that this retrieval is for **Surface** contaminants.

The **assumption** that conductivity is caused by sodium chloride alone is the fundamental variable. You should record: conductivity, surface area, amount of liquid, the beginning conductivity, and the ending conductivity.

Tables of Anions and Cations (Swan, ref 139)

Table 29 Common Cations

Common Anions

Simple ions:			
Hydride	H^-	**Oxide**	O_2^-
Fluoride	F^-	**Sulfide**	S_2^-
Chloride	Cl^-	**Nitride**	N_3^-
Bromide	Br^-	**Phosphate**	PO_4^{3-}
Iodide	I^-	**Hydrogen phosphate**	HPO_4^{2-}
Oxoanions:		**Dihydrogen phosphate**	$H_2PO_4^-$
Arsenate	AsO_4^{3-}	**Nitrate**	NO_3^-
Arsenite	AsO_3^{3-}	**Nitrite**	NO_2^-
Sulfate	SO_4^{2-}		
Hydrogen sulfate	HSO_4^-	**Iodate**	IO_3^-
Thiosulfate	$S2O_3^{2-}$	**Bromate**	BrO_3^-
Sulfite	SO_3^{2-}		
Perchlorate	ClO_4^-	**Hypobromite**	OBr^-
Chlorate	ClO_3^-	**Chromate**	CrO_4^{2-}
Chlorite	ClO_2^-		
Hypochlorite	OCl^-	**Dichromate**	$Cr_2O_7^{2-}$
Carbonate	CO_3^{2-}	**formate**	$HCOO^-$
Hydrogen carbonate or Bicarbonate	HCO_3^-	**Amide**	NH_2^-
Acetate	CH_3COO^-	**Peroxide**	O_2^{2-}
Cyanide	CN^-	**Oxalate**	$C_2O_4^{2-}$
Cyanate	OCN^-	**Permanganate**	MnO_4^-
Thiocyanate	SCN^-		
Hydroxide	OH^-		

Table 30 Common Anions

Common Cations

Name	**Formula**	**Other name(s)**
Aluminum	Al^{+3}	
Ammonium	NH_4^+	
Barium	Ba^{+2}	
Calcium	Ca^{+2}	
Chromium(II)	Cr^{+2}	**Chromous**
Chromium(III)	Cr^{+3}	**Chromic**
Copper(I)	Cu^+	**Cuprous**
Copper(II)	Cu^{+2}	**Cupric**
Iron(II)	Fe^{+2}	**Ferrous**
Iron(III)	Fe^{+3}	**Ferric**
Hydrogen	H^+	
Hydronium	H_3O^+	
Lead(II)	Pb^{+2}	
Lithium	Li^+	
Magnesium	Mg^{+2}	
Manganese(II)	Mn^{+2}	**Manganous**
Manganese(III)	Mn^{+3}	**Manganic**
Mercury(I)	Hg_2^{+2}	**Mercurous**
Mercury(II)	Hg^{+2}	**Mercuric**
Nitronium	NO_2^+	
Potassium	K^+	
Silver	Ag^+	
Sodium	Na^+	
Strontium	Sr^{+2}	
Tin(II)	Sn^{+2}	**Stannous**
Tin(IV)	Sn^{+4}	**Stannic**
Zinc	Zn^{+2}	

In 8502-9, an average constant "c = 5" is adopted, with the stipulation that following ions are predominant in the water: Na^+, Ca^{2+}, Fe^{2+}, Cl^-, SO_4^{2-}, and HCO_3^- . The adoption of the value of C is the source of the difference between the following calculation based on fundamentals.

The Standard Mineral analysis of water includes: chloride, Phosphate, carbonate, bicarbonate, nitrate, sulfate as anions and iron, sodium, magnesium, ammonia, calcium, potassium, and manganese as cations. It includes a specific conductance, and a cation/anion balance. The sum of individual cation and anion concentrations x their individual conversion factor should equal to the measured conductivity.

Appendix 3 Navy Metalworking Center - Mitigation of Conductive Contaminants

Chad Scott, CTC, Navy Metalworking Center, reported at the November 2010, NSRP SPC meeting on their projects related to painting. Concurrent Technologies Corporation operates the NMC, under contract No. N00014-06-D-0048.

"Mitigation of Conductive Contaminants." was funded by ManTech under Improved Preparation Methods for Coating Tanks and has a direct impact on this project. The report documents have a Distribution Statement D on them, which limits distribution to DOD and US DOD contractors. The report document can be distributed to organizations with a Joint Certification Program Number if the proprietary cost information is removed. The NMC report contains cost information and pictures information was deemed sensitive to the participating shipyard.

Mr, Scott emphasized that the project was shipyard and vessel hull specific. This project estimated a saving of **$265,000** per hull if their recommendations are followed.

It is recommended that each NSRP shipyard contact Chad Scott and determine if the methodology and findings can be applied to their yard. So long as the mathematical formulas for the cost basis are available, then these findings can be beneficial to the Shipyards and US Navy. By inserting individual shipyard cost information and layouts and the design of tanks and modules for the particular hull, the NSRP participating shipyards can determine if they can also gain this savings.

The Improved Preparation Methods for Coating Tanks included reports on
Conductive Contaminants and
Environmental Controls
NMC estimated savings of **$265,000** per hull if the conductive contaminants controls are implemented and:
NMC estimated additional savings of **$291,000** per hull if efficient environmental controls for painting are implemented.

The **Baseline Study Summary** included a view of conductive contaminants readings located around the Ship Yard:
The following table is a composite of the slide, presented at the November, 2010, meeting with the baseline data and site map.

Table 31 Location of Salts on Shipyard (NMC Study)

Location	Ave. Bresle Reading (µS/cm)	Min. (µS/cm)	Max. (µS/cm)
Incoming Plate (away from waterway)	43	8	210
Building 274 (next to plate yard)	15	6	32
Bldg 274 plate storage	26	9	337
Bldg 275 (next to plate yard)	25	8	83
Bldg 276 (Steel Production & Fabrication) Cut & Shape	11	4	24
Bldg 1745 Storage Yard (closer to waterway)	40	12	94
Bldg 1745 (Structural Fabrication & Assembly; Blast, grind, assemble)	42	19	76
Welded Plate	46	17	122
Buffer Zone (assemble, nearer to waterway)	86	6	380
Platen (assemble, blast, paint; one end is next to waterway	95	8	300
Dry-Dock (assemble, blast, paint; one end is next to waterway)	107	28	270

The findings and recommendations do not stretch the imagination from practical sense.

NMC identified that the primary contamination sources were from incoming material and the river.
NMC recommended washing station for incoming plate and shapes in-line with pre-construction primer line

- **Provided storage recommendations to avoid pooling of water**
- **Recommended washing procedures**
- **Reported savings from implementing recommendations on conductive contaminants is $265K/hull**

The following is a descriptive summary of the project.

The shipyard was just beginning to start salt measurements.
Based on the hull that the SY was building, there was a tremendous amount of critical coating and tanks. The Navy had said that all tanks were to be tested for salts.

The very large modules were being completed outside. In particular, SY was finding that in the final blast and paint on tanks, after assembly:
There were high salt readings after the final blast
They would wash and reblast, and still not meet the specs even though this was new build.
They had to repeat multiple times.

It was a significant schedule delay at a critical point in the construction schedule.

The objective was to get a process upstream so that the cost to mitigate contaminants was not so overwhelming near the completion stage. Get the contamination that was under the pre-construction primer off at the initial stage.

When NMC identified that there was salt on the incoming plates, they realized that salt on the incoming plates is partially removed during the blast, but also salt remained on the plate. They recommended washing before the initial pre-construction primer blast.

Then NMC identified that modules (steel) left outside
1 Rain would wash off salt from vertical surfaces and
2 Salt was being added in places where brackish river water (rain water) would pond and dry.
Not all surfaces are vertical. In the sites that were closer to the river- the pooling of river water could result in vey high levels of salts.

So NMC recommended areas in the production for sufficient washing before the final blast and paint.

At this latter stage-, there were two processes

1. Check for salts on the modules and just wash those areas
2. Assume that there are salts and just pressure wash everything.

There were two different costs associated with the two processes.

Between start and end of project, The Navy reduced number of tanks that were required to be measured. The study identified production areas that didn't have salts.

The total cost benefit includes the reduction in washing and blasting operations due to sufficient chloride mitigation prior to the final blast operation. Additional benefits can be realized from removal of the schedule delay that was present in the new build tanks.

Appendix 4 Comparison of Equipment and Test Pricing

Comparison of Equipment Pricing and Time For Test

TEST	Cost per Test	Time	Total	(Soluble) SALTS
Sleeve Test (Chlor*Test)	$19.00 per test	10 minutes per test		NO

CSN TEST $35.00 per test 15 – 20 minutes per test NO
Initial cost of $999.00 (5 TESTS)
This is for 3 separate analysis; so cost for each ion is ca. $11.

On our initial survey with 31 people answering- 8 had either Sleeve or CSN tests

Patch Test $7.00 per test 12-15 minutes per test YES
Initial Investment of $530 (25 tests)
On our initial survey with 31 people answering- 24 had Bresle patch tests

NST Salt Meter $12.00/test 10 min wait -then 1 min per test YES
Initial Investment of $895 (10 tests) Still under testing.
On our initial survey with 31 people answering- 1 had NST SaltSmart meter

130 Salt meter $2.75 per test 2 to 3 minutes per test YES
Initial investment of $5,900.00 (100 Tests)
On our initial survey with 31 people answering- 6 had Elcometer 130 absorbent paper meter

SSM meter Minimal 1 minute per test YES
Initial investment of $5,975.00; 5 minutes to set up initial calibration
Participants felt that initial cost of equipment was quickly repaid by not having to buy individual test media and by the savings in labor to take the measurements.
On our initial survey with 31 people answering- 12 had ARP Soluble Salt Meter.

Potassium Ferricyanide Paper $0.25 to $0.50 / test 30 seconds per test YES*
*Salts that react with Iron (II). It is a very sensitive test for areas that are experiencing oxidation.

Tables for Calculation of Measurements are based on 1000 tests.
Costs = cost of equipment + 1000 X [(cost of expendables) + $50/hr X Min/ test/60]
The next pages are from Spread Sheet Calculations.

Comparison of Equipment and Labor for Various Equipment

	Initial cost	Purchase/test	time	Datalogger	Conduct/ion	
Chlor*Test Sleeve (Cl-) (Elcometer 134)		$19.00	10		Ion	
Chlor*Test CSN	$999	$35.00	15-20		Ion	
		this is the Cost for 3 analytical results - chlorides, sulfates, and nitrates. Cost for each test is ca. $11.00				
Bresle Patch	$530	$6.50	12-15		Ion/Condu	for 25 tests includes a conductivity meter w/o data logger
Horiba Meter	$590			x	Conduct	for conductivity or need ion detection tube
NST Soluble Salt Meter	$795	$12.00	1	x	Conduct	Elcometer/KTA pricing initial has 10 tests
Elcometer 130 SaltMeter	$5,900	$2.75	2-3		Conduct	for 100tests absorbant paper
RPCT Smart Soluble Salt Meter	$5,975		1	x	Conduct	
DKK-TAO SSM-21	$3,335			x	Conduct	syringes $50/5 (need 10 ml)
software	$335					start-up kit- beaker etc $65
Chlor*Test Portable Chloride Meter		Under release		x	Ion	soon to be released

These test methods are available generally in the U.S.A. from several suppliers including, but not limited to KTA Tator, Elcometer, Delfesko, Paul N. Gardne
Mention of a specific tradename is NOT an endorsement
Chlor*Test test are self contained, they do not require gloves.
The cost of gloves as expendibles is NOT included. There are bulk suppliers - 100 count $4.40 to $6.00

The cost of DI water is NOT included. While DI water of highest quality is desirable; $16.00/gallon;
Distilled water from grocery store, ca $10/gallon, if a blank is run, can be used.

Syringe cost for 3 ml syringe is $0.14 in bulk, for a 10 ml syringe is $0.30 in bulk
If a syringe is needed for every test, include the cost of the syringe.
If a syringe is use for occasional calibration, or just to transfer DI water and can be use repeatedly- do not include cost of syringe

Bresle Patch - by itself $130 25 count $5.20

Conductance Meters

For kits that supply meters without data transfer, include the purchase of a meter with data storage and transfer capabilities.
For Example

Horiba b-173 Conductivity Meter	$269	it is digital, has no data logger, and included in the kit cost
Horiba Conductivity Meter	$590	data logger pH, temp, conductivity, ORP

Substitute the more expensive meter with transfer capability for the less expensive meter

Orbecco-Hellige 942- chloride	$338 to $415	no data logger
Orbecco-Hellige MC-500	$1,095	data logger

One minutes is allowed on all methods for Record, transfer, verify
This is the time for inspector to transfer number to data base and for second person (manager qa) to verify/release in Paint Record File

Labor rate is $50/hour
There is a range of time for some of the methods that came from various sources. Calculation is made for both high and low times.
Any one-time cost for equipment, software, set-up is included in the first 1000 Readings.
From our survey, it was estimated that a typical SY would take 1000 reading in a year (or shorter period).
The second calculation does NOT include the initial setup- just the expendables and time.
Calibration Time of 5 minutes
Calibration may take place only once a day. This time is noted but NOT included in the time for each test.
If calibration is needed for EACH test, then the time is included.

Figure 12 Comparison of Equipment and Labor

		Minutes	Time Minutes	
Use of Chlor*Test as conductivity measurement				
Chlor*Test Sleeve	Place on with liquid		3	Premeasure volume of DI, put in sleeve, swirl in sleeve and do conductivity measurement baseline.
chlor-rid.com	Water (for conductivity)			
Horiba Meter	Rub Sleeve (if vertical or ceilir	5	2.5	Initial time to calibrate Horiba- Do once each session- 5 min
	Take off		1	can run several during the same time period.
	Measure- Horiba		2	datalogger built in. 2 minutes came from NMC report Pang (Ref 127)
	Transfer-verify		1	verify, transfer data into file, second verification
	Remove Adhesive		0	Manufacturer says that there is no second step to remove adhesive
	total time		9.5	

Remove Adhesive- Author assumed a time of 5 minutes to remove adhesive or stuck sleeve. This time was changed to 0 on manufacturer comment

Cost for 1000 readings = initial cost of conductivty meter, sleeve for each test, and labor of 9.5 minutes.

"$590 +$19*1000 + $50(9.5/60)*1000 — Note from Chlor*Rid: *If the sleeves were sold alone, each would be much less than $19.*

Tests for several locations could be run simultaneously.

1000 readings at 9.5 n	$27,507	per test	$27.51	
	$23,757	per test	$23.76	Manufacturer says reading in field is 5-7 minutes
1000 readings (w/o equip purchase)				
1000 readings	$26,917		$26.92	
if time is 5 min	$23,167		$23.17	

With this alternative, there would be cost of one syringe/day as it is only used for the 10 ml DI water into the sleeve and doesn't contact the extract.

Distilled or DI water- see notes above.

As an option, The user could use the same water with a Kitagawa chloride detection tube from Chlor*Rid to measure chloride on the same extract.

		Minutes	Time Minutes	
Use of Chlor*Test as Chloride measurement				
Chlor*Test Sleeve	Place on		1	
Ion detection tube	Proprietary Liquid			in test kit
chlor-rid.com	Rub Sleeve (if vertical or ceiling)		2	can run several during the same time period.
	Take off		1	
	Measure-Tube		2	time for water to move up tube. you would run several tubes simultaneously
	Record- Transfer-verify		1	
	Remove Adhesive		0	Handled during "take off"
	total time		7	

Remove Adhesive- Author assumed a time of 5 minutes to remove adhesive or stuck sleeve. This time was changed to 0 on manufacturer comment

Cost for 1000 readings = sleeve for each test, and labor of 7 minutes.

"$19*1000 + $50(20/60)*1000

1000 readings at 7 mir	$24,833	per test	$24.83
if time is 10 min	$27,333	per test	$27.33
if time is 5 minutes	$23,167		$23.17

The kits are complete-there is no initial set-up

Figure 13 Cost of Chlor*Test Methods

			Minutes	Time Minutes	
Use of Bresle Patch for Conductivity					
elcometer.com, ktagage.com	Place on water			3	ISO -suitable period of soak time suggest 10 minutes
expendible- syringe	syringe in water		5	5	Initial time to calibrate Horiba- Do once each session
Horiba Meter- conductivity	Take off			1	can run several during the same time period.
	Measure- Horiba			2	datalogger built in. 2 minutes came from NMC report Pang (Ref 127)
	Record- Transfer-verify			1	verify
	Remove Adhesive			0	Handled during "take off"?
		total time		12	

Remove Adhesive- Author assumed a time of 5 minutes to remove adhesive or stuck sleeve. This time was changed to 0 on manufacturer comment
If the user is moving the water in-out during the soak period, then it is difficult to run several at the same time.

Cost for 1000 readings = initial cost of conductivty meter, syringe and sleeve for each test, and labor of 12 minutes.
$590+1000 ($5.20/sleeve $0.30/syringe + $50(12/60))

1000 tests	$16,090	per test	$16.09	
if time is 15 min	$18,590	per test	$18.59	according to NST Center 15 min/test
if time is 8 min	$12,757	per test	$12.76	according to RPCT web site 8 min/test
if time is 4 min	$9,423	per test	$9.42	
1000 tests no equip	$15,500		$15.50	
if time is 15 min	$18,000		$18.00	
if time is 8 min	$12,167		$12.17	
if time is 4 min	$8,833		$8.83	

			Minutes	Time Minutes	
Use of Bresle Patch for Chloride specific ion					
elcometer.com, ktagage.com	Place on water			3	10 min/patch ISO -suitable period of soak time suggest 10 minutes
expendible- syringe	syringe in water			5	
Orbeco-Hellige 942- chloride	Take off			1	Initial time to calibrate Horiba- Do once each session
cost $ 338	Measure- Orbecco		5	2	can get datalogger version
Orbeco-Hellige data transfer	Record- Transfer-verify			1	verify
cost $1000	Remove Adhesive			5	
		total time		17	

cost for 1000 readings =cost of chloride meter;syringe and sleeve for each test, chemistry for each test, and labor of 17 minutes

Tabsource for Chloride tabs		50 count chlori	$47.00	0.94

$1000 + 1000($5.2/sleeve+0.30/syringe +$0.94/test + $50 (17/60))

1000 tests	$21,607	per test	$21.61
if time is 8 min	$14,107	per test	$14.11
1000 tests- no equip	$20,607		$20.61
if time is 8 min	$13,107		$13.11

Note: Kitigawa chloride ion detection tubes could be used for specific chloride. This would not have a data logger

Figure 14 Cost of Bresle Methods

RPCT SolubleSalt Meter (SSM) for conductivity			Minutes	Time Minutes	
rpct.net	Place on			1	clean chamber, attach
	water auto				No calibration
	measure			1	auto pump agitation, activate reading
	take off				datalogger built in
	Record- Transfer-verify			1	verfy, log reading, upload
	total time			3	
cost for 1000 readings =meter and labor of 2 minutes					
=5900 + 1000*$50(3/60)					
1000 tests at 3 minutes	$8,400	per test	$8.40		
1000 tests at 4 minutes	$9,233		$9.23		
1000 test no meter	$2,500		$2.50		
1000 tests at 4 minutes	$3,333		$3.33		

DKK-TAO SSM-SP 21 for conductivity			Minutes	Time Minutes	
dkktoa.net;analyticon.com	Place on		5		Initial time to calibrate about 5 minutes- Do once each session
	Syringe in water				10 ml
	Measure			1	datalogger built in
	take off- rinse off			1	
	Record- Transfer-verify			1	verify
	total time			3	
cost for 1000 readings =meter+ software+ startup kit and labor of 3 minutes					
=3735 + 1000*$50(3/60)					
1000 tests	$6,235	per test	$6.24		
1000 tests at 4 minutes	$7,068		$7.07		
1000 tests no equip	$2,500		$2.50		
1000 tests at 4 minutes	$3,333		$3.33		

Figure 15 RPCT SSM and DKK Costs

NST Soluble Salt Meter for conductivity						
saltsmartonline.com		Place on			1	attach
	30 min hold time	measure			8	simultaneous 5 strips in 5 minutes
		Record- Transfer-verify			1	
		total time			10	10 min/test
field tests indicate they can process 20 samples in 30 minutes						
NST saltsmart		10 count	$120	$12.00		
	=$795 + 1000 ($12/strip + $50(10/60)					
	1000 tests	$21,128 per test		$21.10		
	if time is 2.5 min/test	$14,878 per test		$14.90		
	1000 tests- no meter	$20,333		$20.33		
	if time is 2.5 min/test	$14,083		$14.10		
Elcometer 130 SaltMeter for conductivity by paper absorbance						
elcometer.com		wet paper			1	
		place on			2	need to stay with paper
		measure			2	time for meter to come to measurement
		Record- Transfer			2	no data logger, write on form, enter into database
		total time			7	
Unknown factor- The average is over a large total surface area compared to the other methods.						
Advantage- simple, easy		Disadvantage- might dry out, need to make close contact with surface				
elcometer paper		100 sheets	$225.00	$2.25		
cost for 1000 readings =meter+ paper and labor of 7 minutes						
	=$5900 + 1000 ($2.25/strip + $50(7/60)					
	1000 tests	$13,983 per test		$14.00		
	if time is 4 minutes	$11,483 per test		$11.50		
	1000 tests- no meter	$8,083		$8.08		
	if time is 4 minutes	$5,583		$5.58		

Figure 16 NST SmartMeter Elcometer 130 Costs

Comparison of Tests with Initial set-up

	Type	Datalogger	Time/test	Cost/test
Chlor*Test sleeve	conductivity	X	5-10 min	$23.7 - $27.5
Chlor*Test sleeve	Chloride		5-10 min	$23-$27
Bresle	Conductivity	X	4 to 17 min	$9.4 to $18.6
Bresle	Chloride	X	8 to 17 min	$14 to $21.6
RPCT SSM	Conductivity	X	3-4 min	$8.4 to $9.2
DKK-TAO SSM	Conductivity	X	3-4 min	$6.2 to $7
NST SaltSmart	Conductivity	X	2.5 to 10 min	$15 to $21
Elcometer 130 Paper absorbance	Conductivity		4-7 min	$11 to $14
Chlor*Test portable chloride meter	Chloride	x	In Development	

Comparison Cost after initial equipment purchase is amortized			
	Type	Time/test	Cost/test
Chlor*Test sleeve	conductivity	5-10 min	$23 to $27
Chlor*Test sleeve	Chloride	5-10 min	$23-$25
Bresle	Conductivity	4 to 17 min	$8.9 to $18
Bresle	Chloride	8 to 17 min	$13 to $20.6
RPCT SSM	Conductivity	3-4 min	$2.5 -$3.3
DKK-TAO SSM	Conductivity	3-4 min	$2.5 to $3.33
NST SaltSmart	Conductivity	2.5 to 10 min	$14 to $20
Elcometer 130 Paper absorbance	Conductivity	4-7 min	$5.6 to $8
Chlor*Test portable chloride meter	Chloride	In Development	

Figure 17 Cost of Test with and without Initial Setup Charges

Frequency of Measurements				
5 in first 1000 ft2; then one per 500 ft2				
Formula = 5 + (Total area-1000)/500				
Large Surfaces as underwater hull				
			Low cost	high cost
Underwater Hull Sq Footag	Sq Feet	No. of Measurements	$2.50	$27.00
Misc Hull Repair	2,000	7	$17.50	$189.00
Typical Smaller Craft	30,000	63	$157.50	$1,701.00
Aircraft Carrier	150,000	303	$757.50	$8,181.00
Tanks				
assume that tank is 2000 sq feet with 4 sides and top and bottom- 6 sides.				
Each wall, top, bottom is 350 sq feet. 2 readings/surface or 6 readings per tank				
Each tank has 12 reading minimum.				
When the module has smaller surface areas, there are more readings.				
It is possilbe to interpret 009-032 as requiring 5 readings per side, or 30 per tank				
		No. of Measurements		
1 tank	2,000	12	$30.00	$324.00
15 tanks	30,000	180	$450.00	$4,860.00
75 tanks	150,000	900	$2,250.00	$24,300.00
Number of measurement reported by Baek on tank				
400 m2 tank	4000	20		
		No. of Measurements by US Navy requirement		
ft2 area = ca. 10 x m2	4000	11		
VLCC (Very Large Crude Carrier)				
WBT Total Coating Area 240,000m2				
		No. of Measurements by US Navy requirement		
ft2 area = 9 x m2	2160000	4323		
Lee and Baek report 1 to 3 readings for each block or steel plate.				
ABS indicates minimum of 1 reading for block, unit, plate.				

Figure 18 Comparison of Flat & Tanks Wt Costs

Cost of Salt Measurements with Direct Labor to measure

Include initial equipment setup

	Ave Test/week	Low of $6.24	High $27.00	Annual costs 52 weeks	52 weeks
Mixed Commercial-Navy NB	18	$112	$486	$5,841	$25,272
Commercial New Build Avg	51	$318	$1,377	$16,548	$71,604
Commercial Repair offshore	20	$125	$540	$6,490	$28,080
Navy New Build	20	$125	$540	$6,490	$28,080
Navy Repair	20	$125	$540	$6,490	$28,080

Cost of Salt Measurements with Call-out Time for SY and Navy

Include initial equipment setup

	Ave Test/week	Low of $6.24	High $27.00	Annual costs 52 weeks	52 weeks
Mixed Commercial-Navy NB	18	$162	$546	$8,403	$28,392
Commercial New Build Avg	51	$416	$1,422	$21,642	$73,944
Commercial Repair offshore	20	$174	$590	$9,048	$30,680
Navy New Build	20	$174	$590	$9,048	$30,680
Navy Repair	20	$174	$590	$9,048	$30,680

Low Labor time is 3 minutes = 1 hour; high labor is 10 min = 3 hours
Low Labor time is 2 man hour; high labor is 6 man hours (SY and Witness/Inspector/ Qualifed person)
Presumably the 1-3 hours for the SY is already in the test data; so add $50 to $150 for 2nd Qualified person)

Cost of Salt Measurements with Direct Labor to measure

No set-up costs

	Ave Test/week	Low of $2.50	High $27.00	Annual costs 52 weeks	52 weeks
Mixed Commercial-Navy NB	18	$45	$486	$2,340	$25,272
Commercial New Build Avg	51	$128	$1,377	$6,630	$71,604
Commercial Repair offshore	20	$50	$540	$2,600	$28,080
Navy New Build	20	$50	$540	$2,600	$28,080
Navy Repair	20	$50	$540	$2,600	$28,080

Cost of Salt Measurements with Call-out Time for SY and Navy

No set-up costs

	Ave Test/week	Low of $2.50	High $27.00	Annual costs 52 weeks	52 weeks
Mixed Commercial-Navy NB	18	$95	$546	$4,940	$28,392
Commercial New Build Avg	51	$228	$1,422	$11,830	$73,944
Commercial Repair offshore	20	$100	$590	$5,200	$30,680
Navy New Build	20	$100	$590	$5,200	$30,680
Navy Repair	20	$100	$590	$5,200	$30,680

Assume that there are 20 readings per week. There will be ONE Inspection Pont call-out. The duration is minimum of 2 hours; maximum of 4 hours. Average of 3 hours This is average of 6 man hours = $300.

Figure 19 Cost Weekly & Annually with All Labor

Appendix 5 Survey of public and private shipyards July, 2010

The invitation for the initial survey went to 44 persons, some were duplicate in shipyards.

- US Shipyards 15
- US Gov Entities(SY + QC)- 7
- Contractors 5
- Consultant, Interested Party- 5
- Foreign SY 3
- Inspection Firm- 1
- Owner 1

Some of our original invitees emailed that they had no one working in the SY taking the data. They are very interested in this result. Individuals with ancillary organization who said that they would assist include: American Bureau of Shipping (ABS), DNV, NACE, NST Center, Applied Research Lab- Penn State University, Safinah, and SSPC.

While these contacts do not actively engage in taking measurement, they have been very supportive by providing documents and technical in-house reports, and observations on the extent of ionic measurements.

We received 34 responses, 2 are unknown, 4 d most of questions

- US Shipyard- 9
- Contractors- 5
- US Gov Entities- SY-3, QC- 2
- Consultants- 2
- Foreign SY- 2
- Foreign-4 (2 Shipbuilders, 1 consultant, 1 contractor)
- Unknown- 2

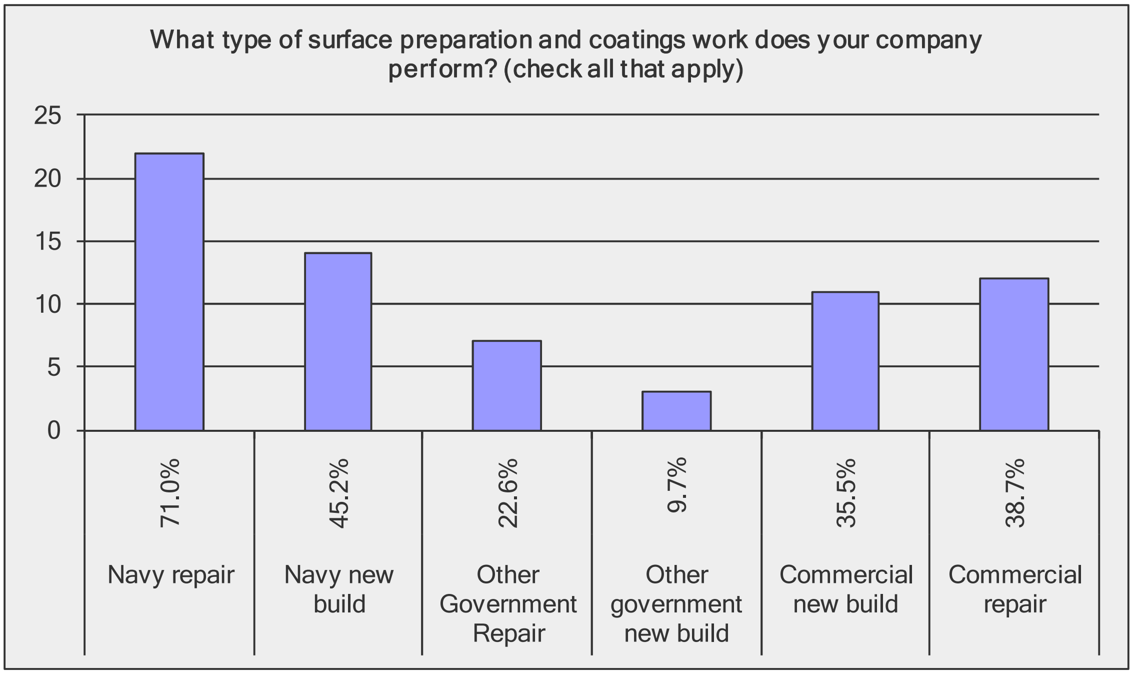
There are some shipyards who say they never have had to take salt readings. They are predominately Commercial.

Results of Initial Survey

What type of surface preparation and coatings work does your company perform?

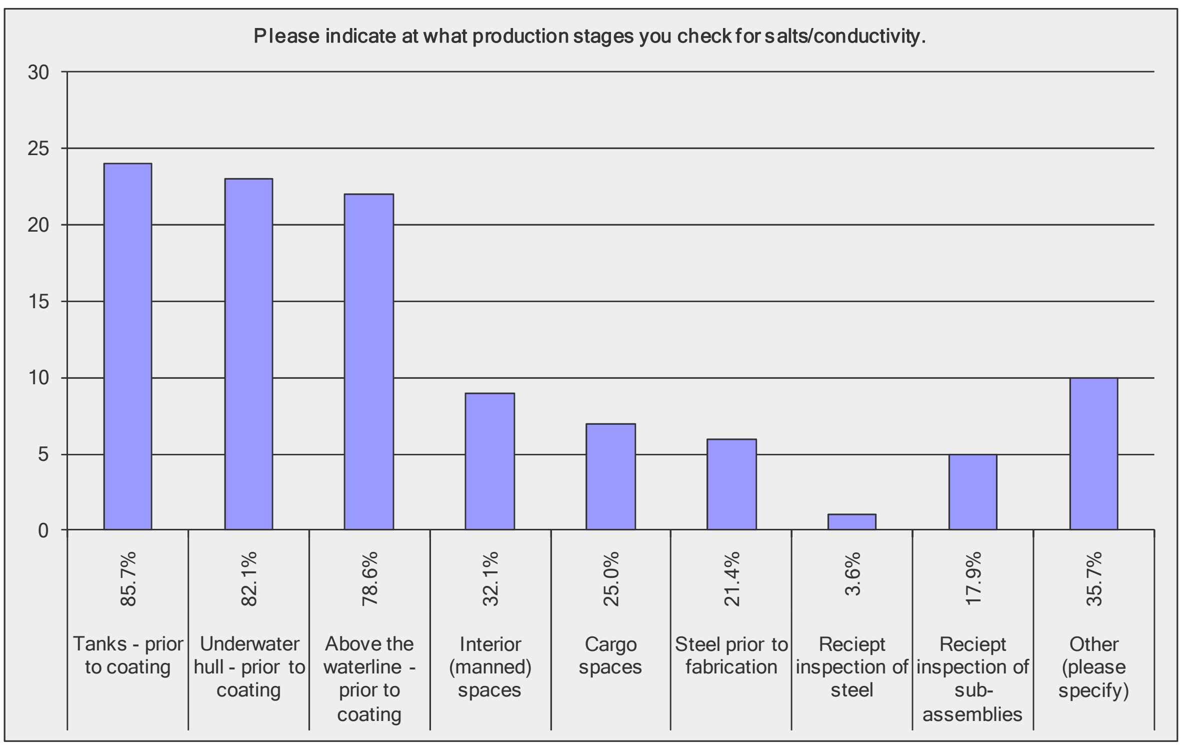
Answer Options	Response Percent	Response Count
Navy repair	71.0%	22
Navy new build	45.2%	14
Other Government Repair	22.6%	7
Other government new build	9.7%	3
commercial new build	35.5%	11
commercial repair	38.7%	12

answered question	**31**
skipped question	**3**

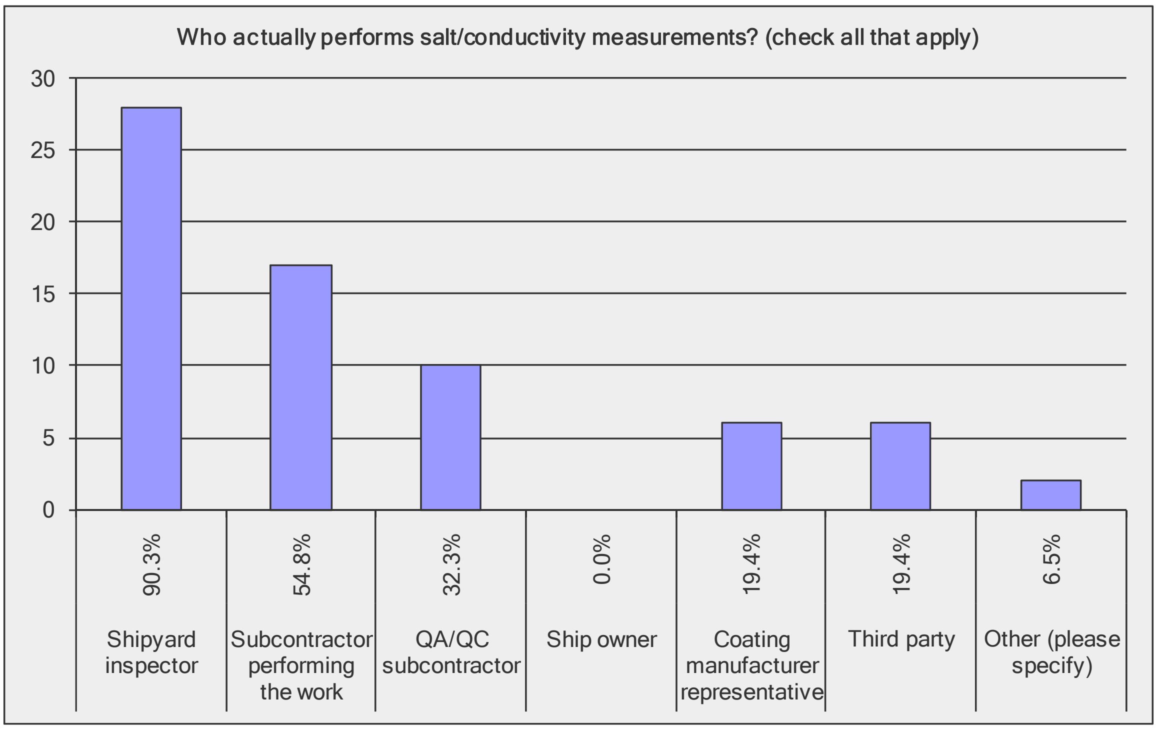


Do you measure salts or conductivity as part of the surface preparation process/QA? Yes 100.0% 29 4 skipped the question.
We had requested the SY who did not take the measurements to participate in this initial survey. We will follow up on their commercial practices.

Please indicate at what production stages you check for salts/conductivity.		
Answer Options	**Response Percent**	**Response Count**
Tanks - prior to coating	85.7%	24
Underwater hull - prior to coating	82.1%	23
Above the waterline - prior to coating	78.6%	22
Interior (manned) spaces	32.1%	9
Cargo spaces	25.0%	7
Steel prior to fabrication	21.4%	6
Receipt inspection of steel	3.6%	1
Receipt inspection of sub-assemblies	17.9%	5
Other (please specify)	35.7%	10
answered question		**28**
skipped question		**6**

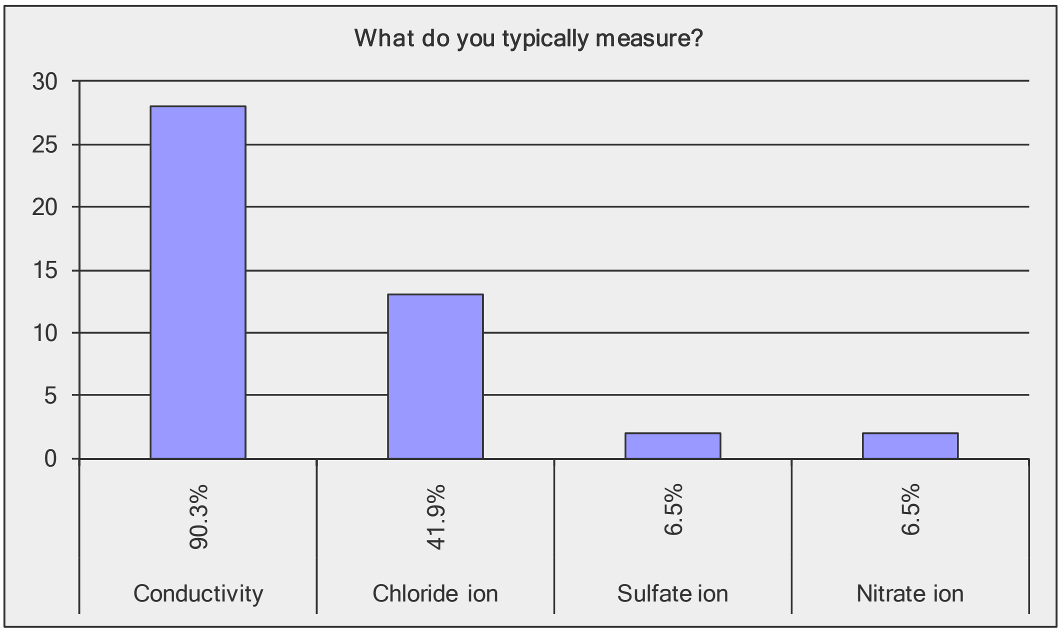


Who actually performs salt/conductivity measurements? (check all that apply)			
Answer Options		**Response Percent**	**Response Count**
	Shipyard inspector	90.3%	28
	Subcontractor performing the work	54.8%	17
	QA/QC subcontractor	32.3%	10
	Ship owner	0.0%	0
	Coating manufacturer representative	19.4%	6
	Third party	19.4%	6
	Other (please specify)	6.5%	2
answered question			**31**
skipped question			**3**



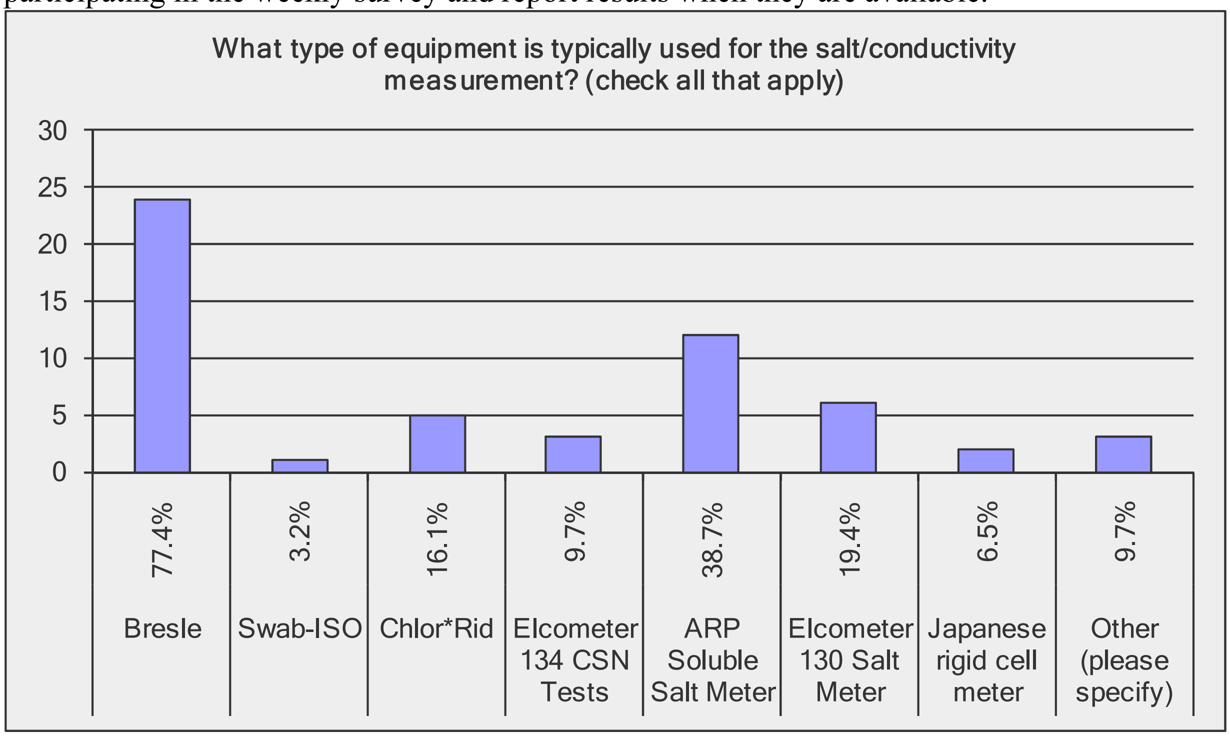
Other Comments:
Lab Technician,
Our Paint Shop has QC personnel that conduct most all paint inspections
Paint Department Inspector
Readings are taken in house by the coatings dept

What do you typically measure?		
Answer Options	Response Percent	Response Count
Conductivity	90.3%	28
Chloride ion	41.9%	13
Sulfate ion	6.5%	2
Nitrate ion	6.5%	2
	answered question	31
	skipped question	3



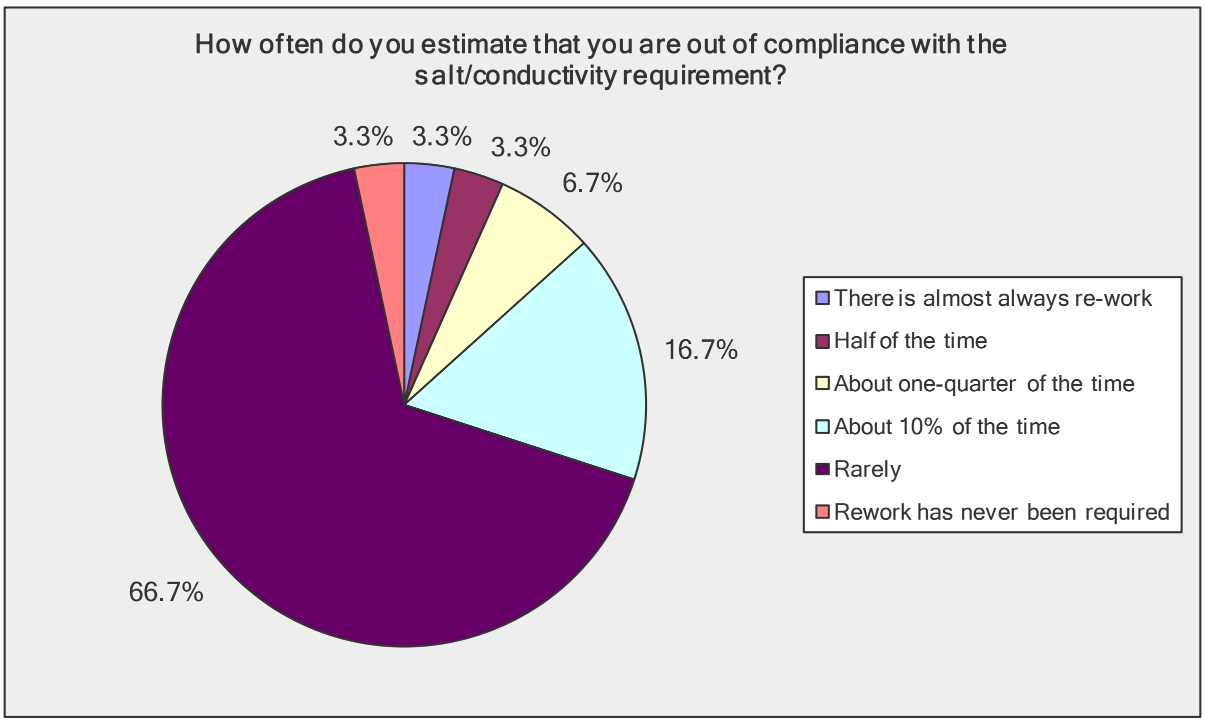
What type of equipment is typically used for the salt/conductivity measurement? (check all that apply)		
Answer Options	Response Percent	Response Count
Bresle	77.4%	24
Swab-ISO	3.2%	1
Chlor*Test	16.1%	5
Elcometer 134 CSN Tests	9.7%	3
ARP Soluble Salt Meter	38.7%	12
Elcometer 130 Salt Meter	19.4%	6
Japanese rigid cell meter	6.5%	2
Other (please specify)	9.7%	3
	answered question	31
	skipped question	3

Other is Horiba, SCAT chloride titration ion strips, and Salt Smart. The NST Center is participating in the weekly survey and report results when they are available.



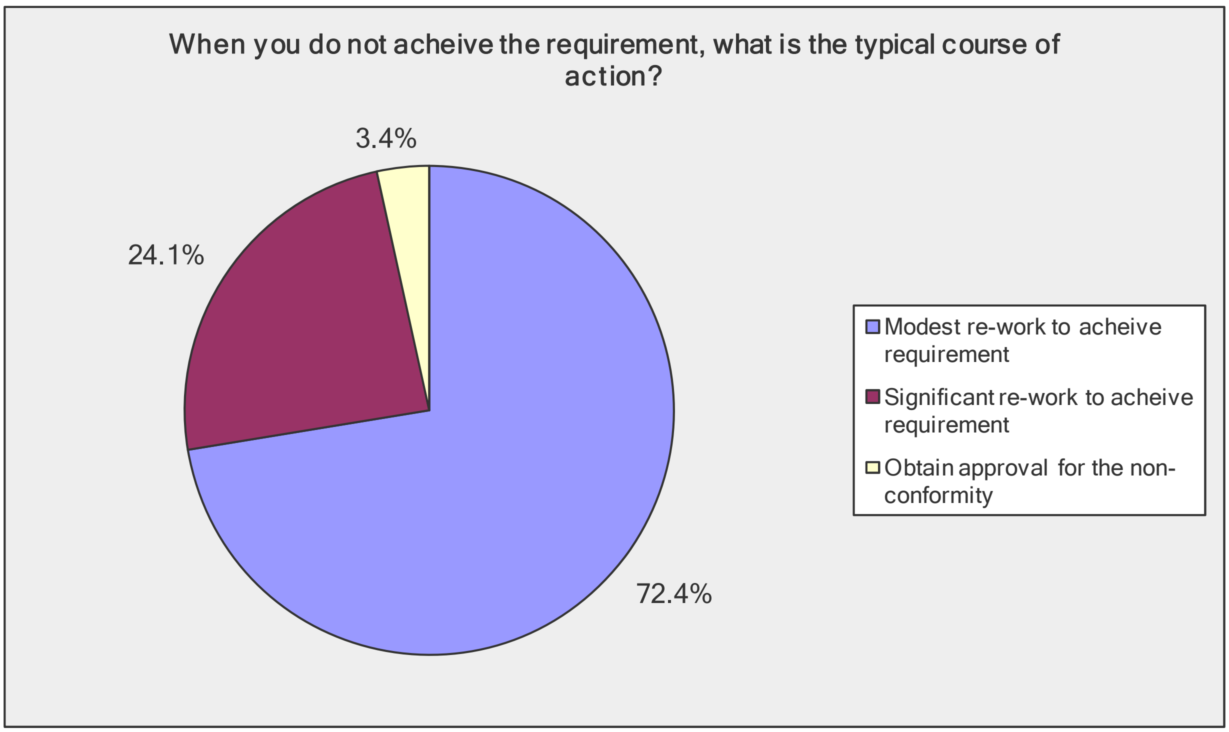
How often do you estimate that you are out of compliance with the salt/conductivity requirement?		
Answer Options	Response Percent	Response Count
There is almost always re-work	3.3%	1
Half of the time	3.3%	1
About one-quarter of the time	6.7%	2
About 10% of the time	16.7%	5
Rarely	66.7%	20
Rework has never been required	3.3%	1
	answered question	30
	skipped question	4

The average re-work is 9%. This question would predict that there is no major disagreements and that the limits are reasonable.



When you do not achieve the requirement, what is the typical course of action?		
Answer Options	Response Percent	Response Count
Modest re-work to achieve requirement	72.4%	21
Significant re-work to achieve requirement	24.1%	7
Obtain approval for the non-conformity	3.4%	1
	answered question	29
	skipped question	5

Achieve was mis-spelled. Some of our foreign correspondents asked what did we mean.



If non-compliant, what methods do you use to remove chlorides? (check all that apply)		
Answer Options	Response Percent	Response Count
Abrasive blasting	25.8%	8
Pressure wash (water only)	87.1%	27
Solvent wipe	51.6%	16
Wash with salt remover	6.5%	2
Other (please specify)	9.7%	3
	answered question	31
	skipped question	3

Other answers

"Other" Responses:

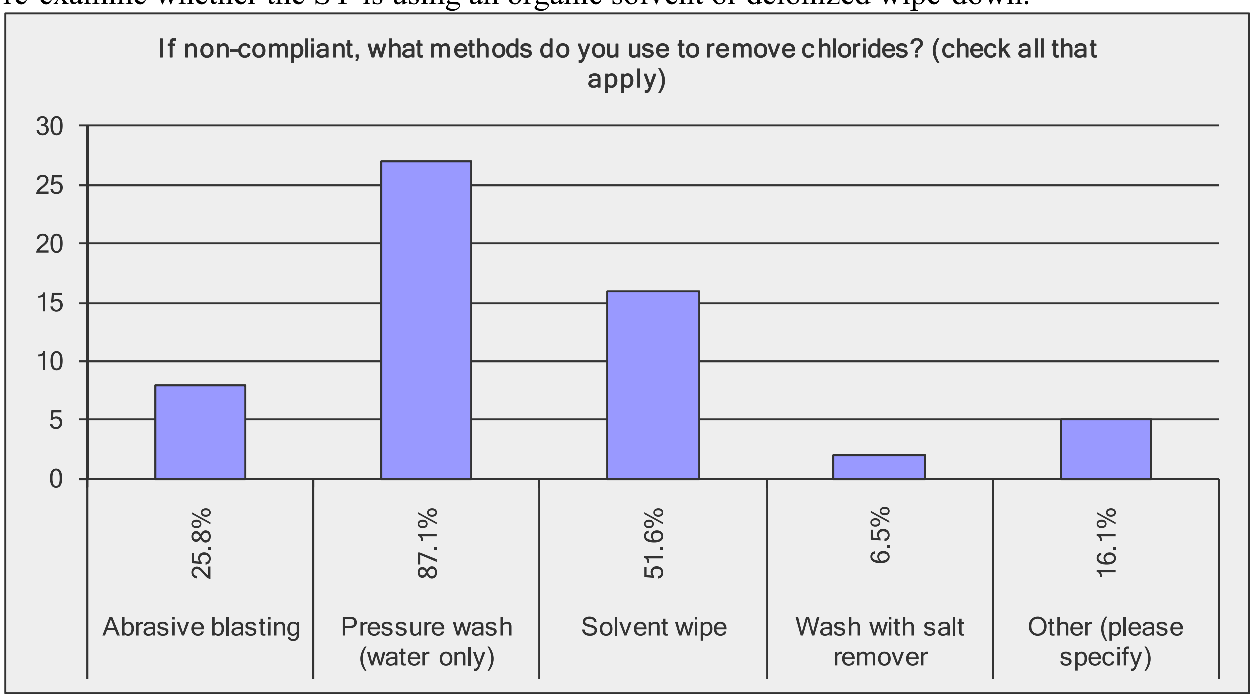
My company doesn't do the remediation

(steam) removal method depends on out of spec values and extent there of, if sporadic and isolated with slightly high readings than spot clean with di water suffices. If high readings throughout then pressure wash with steam genie and no dh and repeat as needed until lower levels are attained.

wipe w/de-ionized water & wire brush

WIRE BRUSH WITH DE-IONIZED WATER

The responders appeared to think that there is a difference between Solvent Wipe (SP-1) and water wipe. We placed wipe down with de-ionized water into solvent wipe. We will re-examine whether the SY is using an organic solvent or deionized wipe-down.



Appendix 6 Interview Notes

List included:
Classification Society- 1

Shipyards- 10 (Some of whom did not participate in survey)

Coating Manufacturers- 5

Contractor- 2

Test Kit Manufacturer-1

Classification Society

Classification Society- multiple sources Comments:

Coating inspections are left to the builders and the Certified Coating Inspector, mutually appointed by the 3 parties involved, i.e. the builders, the owner and the coating producer.

There is no specific number on salt contamination in any specific application, as that would imply that there is an agreed performance and risk scenario. Each situation is different, and each situation can absorb a different level of risk. If there is a limit to funds available, a higher risk might be justified. . So, it's a matter of defining a set, well defined group of reasonable numbers that the market can price, and that a proper risk/cost analysis can be made in each situation.

The current extraction methods are important. Accuracy goes to defining what we talk about - when we know what we measure, and understand the values, we can assign risk, and then evaluate that against cost.

Except for the IMO PSPC regulated application of coatings in ballast water tanks, Class Surveyors such as from ABS are not involved in coating inspections. Even in case of IMO PSPC, as dictated by IMO PSPC Section 7.5, Class Surveyors are limited to monitor the implementation of the IMO PSPC regulations only. As defined by IACS (PR34 Section 4.1.1) monitoring means checking, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods. That's all.

Speaking as ABS representative within the IACS Expert Group (IACS EG/C) on Coatings, it is good for you to know that 'Salt Levels' applied to the test panels for IMO PSPC coating approval are actually under discussion within this Group. It came to our attention that for testing the IMO PSPC requires a maximum level of 50 mg/m2 NaCl while the same maximum is dictated to be applied during shipbuilding in practice. As a consequence most test panels used for coating testing are freshwater washed to almost zero salt levels, while in practice the salt levels are often found close to the 50 mg/m^2

max. On top of that, IACS PR34 requires a minimum salt reading of 1 (one) per block which is often translated in building contracts with deletion of the word 'minimum'.

With regard your question about our 'monitoring'; it is my experience that in general salt measurements are taken as required by IACS PR34 2.3 copied below:

Common Interpretation

===

The conductivity of soluble salts is measured in accordance with ISO 8502-6 and ISO 8502-9, and compared with the conductivity of 50 mg/m2 NaCl. If the measured conductivity is less than or equal to, then it is acceptable.

Minimum readings to be taken are one (1) reading per block/section/unit prior to applying coating or one (1) per plate in the case of manually applied shop primer. In cases where an automatic process for application of ship primer is used, there should be means to demonstrate compliance with PSPC through a Quality Control System, which should include a monthly test.

As far as I am aware, the technique used is limited to (ISO 8502-9:1998) the manual Bresle Test by adhesive patch, syringe, distilled water and conductivity gauge. It should be noted that our surveyors are trained to monitor if the Standard is applied correctly. Particularly related to the minimum time and flushing of the medium by sucking and pumping in as well as where exactly to expect the highest concentrations. Although 50 mg/m2 is the Rule, in some cases and under some circumstances we nevertheless recommend/suggest to lower this limit to 20-30 mg/m2 same as we recommend/suggest in some cases to raise the minimum limit for roughness profile from 30 Microns to 60 Microns.

DSME, SHI and HHI have a vast number of salt readings in their files - The Korean, Japanese and Chinese yards took many readings in a lot of yards to check how much problem the PSPC 50 mg/m2 as NaCl weight by ISO 8502-9 requirement would be for them. I heard they found that 95% of the readings were OK, and they decided not to fight the proposed set limit. Note also that blocks that are barged over sea is rinsed with fresh water upon arrival as a matter of normal standard practice in most modern yards in the Far East.

The coatings manufacturers, International Paint, Jotun, Hempel, PPG maintain all the readings that are electronically reported in access data base.

Shipyards

1. Shipyard- non-nsrp

Repair and overhaul yard. Located on East Coast. Can handle in drydock-draft 33 feet (10 m); length 750 feet (229 m), beam- 110 feet (33.5 m) Pierside, the SY can handle in excess of 900 feet. Their method of surface preparation is predominately pressure washing and UHP WJ.

Type of Work:
The SY does very little work for US Navy. They did a Navy floating dry dock about two years ago. There was a sub-contractor doing the critically coated areas- this contractor used a conductivity meter for salt readings.

The SY does MSC/MARAD, Coast Guard, Army, Corps of Engineers vessels; these vessels require salt tests.

Their major market is commercial ship repair; they repair and convert vessels such as cruise ships, dredges, barge, and containers, and foreign military vessels for several countries.

Many of their commercial customers do not require salt testing; they just want the ship repaired and returned as soon as possible. Typically the paint companies do not require salt testing. The SY is set up to do salt testing routinely as requested or required by project documents.

Q: On frequency, what is your experience?

On Coast Guard, there are way too many. It is like, 5 reading per 1000 sq feet which gets redundant. A designated CG ship representative observes the readings taken by the SY personnel.

Insert: US Coast Guard Requirement: "Soluble salt conductivity measurements. Measure and document conductivity due to soluble salts, randomly over the prepared surfaces (take 5 measurements every 1,000 square feet or five total measurements for surfaces less than 1,000 square feet), using a suitable surface contamination analysis equipment, in accordance with ISO 8502-9."

The Army wants chloride tests, but do not give frequency. When Army inspector shows up, the SY is at their mercy on frequency; this can be excessive.

MARAD wants salt reading before you even start to pressure wash the vessel. They check for salts before wash, before blast, after blast. Note: This SY uses UHP WJ for cleaning.

Specific Chloride Tests:
Typically all the work has pre-checks in the general production. Then the SY sets up parameters, calls the customer, and is ready for their qa inspectors. When the owner reps get there, they should have no discrepancy. The SY personnel do the testing.

The SY used the Bresle patch for extraction in the past. They have gone to "Chlor*Test" flexible membrane for specific chloride. They do not typically test for conductivity.

Other than new steel that is profiled in a blast house, the SY uses pressure washing and hydroblasting. They very rarely have any readings above specification. He would estimate less than 1 percent. If out of compliance, the SY re-washes.

Commercial Work Warranty- Cooperation with Paint Suppliers
The respondent is not acquainted about “warranty” requirements. The contracts office handles this. His major work is the hull. Often there is a sub-contractor for critically coated areas or tank and void work. He cannot comment on any IMO changes.

The SY works with the paint suppliers, such as International Paint, Hempel, or Jotun, particularly on foreign vessels. All the MSC hulls have a paint representative on site around the clock.

Incoming Steel Handling
New incoming steel goes directly from truck to inside of blast house. Anything that is old or transported by ship is pressure washed before blast cleaning.

2. Northern West Coast NSRP shipyard
They worked July, Aug, and Sept. We got results from July and Aug.

Perform both commercial and Navy repair. Remarks are limited to Naval Repair. Most is critically coated tank work. They follow 009-032 and preservation process procedures.

Navy repair.
As a rule, they are in compliance with salts when they test for inspection points.
For example, on a cht (collection, holding, transfer) tank in aircraft carrier in June. Out of 20-30 readings, they were out of compliance in only one area- about 4 square feet. When they are out of compliance, it is high; the specific ion reading is in 60-70 $\mu g/cm^2$ Cl. The SY did an SP-1 and got the 4 square feet back into compliance with minimal rework.

The US Coast Guard requires a test for a specific ion or chemical, i.e. chlorides, sulfates, etc.

On Commercial Work-
Typically, we do not take salt readings on commercial jobs. We typically UHP WJ with a wand or a mechanized head the surfaces to be coated. That preparation almost always remediates any salts. Most customers do not contractually require measuring salt. The State Ferry System puts it in as an option at their request but not as “have to do.”

Repair in the Great Lakes region on US Flag ships, including ferries.
The respondent had experience on the Great Lakes with the fresh water version of any large vessels working in the US. These vessels range from 190 feet long to 1000-1300 feet long with 125 ft beam. They never take salt readings.

There are approximately 65 US flag carriers that ply the Great Lakes from Duluth MN, Toledo, Cleveland, Buffalo NY and on up to Hamilton Ontario. These routes are all on fresh water. The Great Lakes vessel operators feel that the effect of salts is over stated and the use of a salt removing liquid is marketing.

There is a tremendous number of coal-fired plants in the Great Lakes area. A lot of the American vessels carry coal for these plants. Thus far, the American vessels are not going to spend the money to use the salt mitigation liquids.

In another example, the issue was tremendous corrosion on the deck of a car ferry. The operator understood that the car would carry road salt to the deck. You need to power wash thoroughly- get within 2-3 inches. When the yard gave the price of a power wash within 2-3 inches, rather than a shower wash at 3-4 feet, it was more that what the ferry operator wanted to spend. The operator chose to deal with touch-up and repair.

The respondent went on to say that to have an effective pressure wash to remove salts, the jetter has to be 2-3 inches from the steel and physically be right on the steel. When people use pw where the wand is 3-4 feet away, this does not remove the salts. The commercial operators do not want to pay for a thorough wash-down.

Lastly, the Great Lake repair shops (for example Toledo, Superior WI, Sturgeon Bay, Erie PA, or Chicago) will operate through the first part of December, where it is 32 º in the daytime and 15º at night. The yards are not equipped to handle water at those temperatures.

As an aside note, there are about 85 Canadian flag vessels. They do take some salt readings even though most work is on fresh water. Their vessels get up to Nova Scotia, and out the St. Lawrence Seaway. They see salt water and use anti-foulant on which is not normal for fresh water. See Canada Steamship Line. They have a NACE CIP 3 in charge of all painting and they do take salt readings.

Comment by Frenzel- There is an ideal standoff distance from the nozzle tip to the surface where water is effective for cleaning and removal. This range is determined by the orifice nozzle diameter. Most people stand-back too far with pressure washers. Canadians do operate water cleaning operations in sub-freezing weather. The water is heated and quickly removed from the project, for example, by vacuum.

3. Non NSRP SY - East Coast; founded 1924. Focus on NO DELAY. Almost all work is commercial – some new build but mostly repair. Governmental work is state-local level- for example fireboats and small buoy tenders but not US military.

Full fabrication and machine shop, Dry Dock, Wet Berth, tug and barge, fire, pilot boats, riding crews to continue repair as needed
Interior/Exterior- to meet SSPC/NACE standards- uhp water blast, abrasive blast, self-contained floating blast and coating operations.

Do state and local governmental work, new build barges; Fresh and salt water vessels

Dry dock will accommodate flat keel of 192 feet, 60 ft between wing walls; 1200 ton displacement.

SY has affiliates in New York, India, Hong Kong, London, Greece, Norway

Interview made with company representative who spent 30 years with major marine coatings manufacturers working with commercial accounts, Coast Guard and the US Navy.

The SY is still not taking any chloride readings for commercial vessels. Customers are concerned with quick turn-around and keeping expenses down.

The SY does some in-process control to meet SSPC/NACE requirements, but formal inspection where a client walks the ship checking that SSPC requirements are met is infrequent.

The only chloride readings that they have ever taken were recently for one particular Coast Guard vessel. It was a small vessel in for repair and was 49' long. The deck was about 800 sq feet; underwater hull about 1100 sq feet. Took about 5 on each side of hull and about 6 on the deck.

It cost a couple of thousand dollars of new equipment to do the CG vessel. SY upgraded to a digital read-out DFT gauge, purchased new Testex equipment, and surface temperature gauges. The rep already had a Horiba (conductivity) gauge so the SY used his gauge. SY did not specifically train people for the inspection. The Representative, who has years of experience but is not NACE, SSPC, etc. certified, did the readings. These reading were taken as the SY progressed in the work. SY took them and gave CG paperwork. He did find some out-of-spec readings in regards to surface profile. Inspection parameters are filled out by hand in a form, made copies, and SY retained a copy.

In all the years, he had been in the commercial Marine (ca 30 years) surveying commercial and navy vessels- he has never seen blistering or coating failure proven to be caused by salts. Rep was government liaison with Navy for Marine coatings manufacturer

4. NSRP Shipyard- Northern US

We just started taking salt reading in late 2009, early 2010. This is all new build.
In my 30 years with the building Naval vessels, chloride testing was not required.

We are still not required to do chloride testing as we are not governed by 009-32, but through new build ship specifications, we are starting to do them on the critical areas for the current program.

We test in a variety of places. The list was included in an interim report.

We have some experience with salts as we sometimes fall into IMO.
A couple of years ago, we did chloride testing on the underwater hull work. We were doing the sleeve test, specifically for chloride.

Currently, we did some preliminary work to see if we did have a chloride problem. We were concerned about remediation. If you have a chloride problem, then you need to pressure wash.

We wanted to see if we needed to pre wash prior to blasting. We found that we were in very good shape. We had a couple of spikes this past year when we were doing some of this testing. We traced back to the wintertime with the road salt.

We were concerned about springtime because we fabricate units in the winter, and in March April, they go through the blast and paint facility. We were concerned about spikes, but so far we have had satisfactory readings.

Initially we were doing the Bresle test. However, we did go out and buy salt meters. We have two salt meters in house now because the Bresle Test was so time consuming.

It takes at least 10 minutes minimum to run Bresle. For the number of tests, it would take the tech unit guys a good part of the day to get all of those accomplished and to get everything recorded.

We would look at a 3-4 hour period for the numbers of readings, because when you build a structural unit that resembles a 3-story house, you have the underwater hull, interior tanks, a variety of compartments. You would be doing testing in all the different areas.

The square footage drives the readings. If you are under a certain amount you have to take a number of readings, as the area gets much large, then that rate drops down unless you run into a problem. Then you do some reading to determine how big the area is.
I might have readings one week and periods of time without readings

It take time to pressure wash if you are out of specification; even if you spot wipe with wetted clothes or wire brush and de-ionized water.

We had ONE situation of that small area- where we had a prominent foot print on the steel. It stuck right out. We took the readings there to see what was going on. Obviously something was picked up in the winter months.

We started doing testing getting ready for the program. We did a series of tests, tried to baseline where we were on units whether they were critically coated or not-just knowing where they were in the build process. Respondent sent those baseline readings.

We have not had any significant issues so the testing does not seem to be costing a whole lot.

We have not written any mitigation procedures to date, due to the lack of any need to clean any areas.

Correspondent sent data tables for critical coated area versus all surface of his painting projects. Approximately 16% of the total square footage we have prepped and painted to date is critical coated.

At one point, I have a funny, serious story about one incident several years ago. Several years ago, we had a structural unit that had freckles on it. They were just freckles- no rhyme or reason. In wintertime, the doors on the blast building slide open on a rail system and they would freeze up. They would put calcium chloride down. The calcium chloride bags got broken, got into the grit reclaim system. Calcium chloride absorbs moisture; the blast media had calcium chloride, They burst and we ended up with freckles on the hull. That was quite a clean-up job... We ended up pulling 100 tons of steel abrasive, trashing it, and resupplying the building, drying all the systems to get rid of the calcium chloride. This was unique to the blast chamber. Everything goes to the top. Everything floats down from the top so the moisture in the air and calcium chloride went everywhere. For that unit, we cleaned it, reblasted the unit, but of course, now I had a higher salt content in those spots we never really did make all those spots go away.
I worked to reduce it. We reblasted it, worked to get it down to a reasonable level. That was 10-12 years ago.

Frenzel Comment: My first experience getting salt off was plates for rail cars, shipped on deck from Romania. They blasted and blasted in control building. They never got rid of it. It's called over blast- you just move metal around

Response- Yes- you move metal around.
Frenzel- It looked bright, then the next thing you know it turned
Response Yes- it kept turning.

Frenzel- I saw the salt in a blast on a rail car manufacturer plant. Because there was salt on the steel, it got into the blast abrasives. The spent abrasive would rain down on the other side or the tank car and cause a rust bloom.
Response- Yes- I have seen this.
Frenzel- We were actually blaming the volcanoes in Mexico bringing things up in the air currents when it was steel picking up salt from the top of the car and carrying it down the sides.

5. NSRP SY Navy New Build- Gulf.

SY was not having any paint production during the time of the survey.
SY is not doing any commercial work.
Working on a Navy contract for new build. The paint dept. does not get the paperwork, so they can't respond to NSRP.

Salts readings are sporadic, depending on critical and non-critical areas.

SY has two levels of salt readings; some are in-house to get ready for the QA inspectors to come on site. They keep those separately. When they do salts with QA, then the readings are done jointly between SY QA, and Navy.

Use subcontractors for salt readings. Readings get reported directly to their qa dept. Thus this data is lost to the survey and cost of tests are not broken out.

In the next few months down the road, SY will be doing readings on overheads on well decks and flight decks.

6. NSRP Shipyard- Northern US. Located directly on sea channel.

Paint Super- They are doing salts on State Ferry boats. QA dept is doing specific salt tests. Winter time is their time to repair and paint ships.

Their Navy New Build is very limited.

QA Department
SY builds and maintains marine ferries under commercial contracts. The ferry vessels are 300-400 ft long and see seawater. Ships will come in for annual maintenance. SY has the contract for all general maintenance.

SY also does Coast Guard vessels.

SY has quality assurance and control. All vessels get a 4000 to 65000 psi pressure wash as they come into the yard. Everything has to be cleaned before they start any job. Decks are not included, unless the decks are scheduled as part of the contract to be maintained.

SY will spot blast, or SP-3 power tool prep, then blow down. QA dept. head does the chloride test routinely. Typically there is 12,000 sq feet on hull and they will be repairing part of it. He will take four tests using the Bresle Patch with Expertus titration.

His Expertus test has a lower limit of 10 µg/cm2. He has never had anything go over 10 µg/cm2, in other words, all the readings are null. He has never had a test fail. The Navy new-build vessel was built under Navy and State project specifications and limits.

He has a test kit to look for lower limits if he needs them. This SY has actually never had a separate Navy inspector to come in for “G point” verification.

SY gets same results on new build and on repairs. All vessels are treated alike. For their Navy new build project, the plates came with Nippon pre-prime. They washed the plates that had been in storage before continuing with coatings work.

They could have a salt problem because storms spread salt spray everywhere, but they wash everything. They have a procedure in hand for mitigation of salts, and haven't need it because of extensive washing procedure.

The Coast Guard is stricter than any other client is. The SY takes readings every day and a Coast Guard rep is there on site for all the readings. There is a designated tech person on each Coast Guard vessel who watches over the vessel. The SY takes at least 1 per 1000 sq feet.

If they have an area that is turning, it is usually the whole boat. They have a lot of rain and this washes the boats. They watch for areas where water can collect.

7. Public Shipyard

We do not have a problem with salts at the current limits. Occasionally we find a small area which has to mitigated. What I am finding with additional study that the instruments we are using probably do not provide us with the accuracy needed. Well I guess this is speaking out of line but are the upper and lower limits currently correct? Are we getting a false positive or a false negative?

If the limits are changed will we get the same service life from coating?

This is one of the drivers behind our cumbersome work practice (CWP) (QA) quality assurance tool initiative for chloride measurement. This also includes accuracy, cost, ability to down load (minimize transcription errors), process time and adjudication.

8. NSRP Shipyard Northern US

SY does new build Navy, MARAD, Coast Guard and commercial. They do not handle much repair.

Their ships are in the fresh water, not normally ships from salt water environment.

Marad has most stringent- they are washing the MARAD plates multiple times.

They use Bresle to collect with test kit for titration determination of chloride. Conductivity testing doesn't take into consideration the other contaminants that maybe measured, which may make readings suspect. The SY focuses on chloride ion.

Doesn't see any conflict, nor opportunity for large cost savings- other than need to take readings at receipt, before blast chamber, NOT wait for just before paint is applied.

They wash their incoming plate before it goes into blast room.
They are very seldom out of specification by the time they measure it. Then they just pressure wash it without salt remover additive.

Very seldom do they have another inspector on yard- sometimes Supships, and coatings manufacturer will have someone on.

Warranty- SY has a year. Coatings manufacturer is just responsible for the materials- the SY has all the expense of drydock, blast, etc.

He is the onsite ABS qualified inspector with NACE CIP 2. They follow ABS Naval Vessel Rules (NVR) 631-1; Part 8 ch 4 sect 1- materials and welding

They will wash steel upon receipt of plate. They will wash inside- outside of modules prior to painting. He is adamant that the committee should stress taking salt readings on receipt of steel. They store steel outside- flat, they wrap the navy steel- but wind catches the tarps. He wants oil, salts, etc off the steel before it enters the blast room.

They check for salts- tanks-prior to coating, underwater hull, above waterline, not manned spaces. Some sub-assemblies, and receipt of steel, and before blast chamber.

He feels that they are taking the reading too many times. But in 5 years, he has found maybe 3 readings over the specification limit.

The number of chloride readings the IMO/NACE/SSPC/ASTM/NVR asks for per 1000sq. ft. is high and doesn't address all of the building environments. In his opinion, if building (new construction) is near an ocean environment more of the specified number of chloride readings should be taken. If new construction takes place near a fresh water environment, the amount of readings should be less. Repair work is a completely different ball game.

Use Bresle with titration (3 bottles) it turns purple- no chloride.
He feels like he can take the readings in 5 minutes. Puts on patch, puts water in it, then leaves and comes back.

9. NSRP Shipyard
Navy and Commercial- new build and repair
On Commercial

No one asks for conductivity. All depends on coatings supplier. Only one ship in last 4 years asked for conductivity. It was one reading requested by coatings supplier.

10. NSRP Shipyard- West Coast

Both commercial (IMO) and Naval new build.

On Commercial
We work with coating supplier rep and owner.

There is no frequency requirement for the surface conductivity test specifically called out in the IMO reg. The only real requirement is the water ballast tank. We will follow the Paint Suppliers guideline…normally spot check at least five areas on the blocks…if all negative, then move forward…if any are positive, continue in the positive area every 500 to 1000 square feet until the test results are negative so we can isolate where the problem is. The biggest cost drivers in the IMO requirement are the 2mm edge prep, dft readings and the Coating Technical File….

On Navy ship, the critical coated area is 50-60% of total square footage, the commercial area is much less.

There are two sets of checks- pre-inspection check points, and government inspections. Pre-inspections checks points might not be recorded.
The cost would be the prior-to, and the G inspections. We do in-process inspection- so that we know that we have done what we are supposed to do. It is only counted when you do your official call-out.

On cost of measuring and accounting
If it takes 100 man hours to blast a block, how many man hours of qa did the SY use to insure we met the specification?, no matter what it is- profile, chloride. What was the labor hours so we could say- "go ahead and paint."

It is a "level of effort" account.. Let's say I spent 30,000 man hours blasting and painting tanks and I had 3 inspectors full time during that window, then I would count all of that towards the inspection costs of those 30,000 man hours. It would not necessarily be broken into quality assurance.

The in-process is expensive. If I am going to have a call out for chloride checks-I have to do it- it is mandated by spec, etc. I will have an on-going effort to insure that when I have the official call-out we would meet the G inspection and be able to proceed. We have the cost for the time we do it officially, and the cost for the preparation for the inspection.

Coatings Manufacturer

1 Major Coating Manufacturer
Respondent has been cooperating with Navy entities since the 1970's.

Level of salts:
Cargo Tanks (chemical immersion) 5ug/cm2
Fresh water tanks 5ug/cm2
Ballast tanks and outer hull (sea Water immersion) 10ug/cm2
Atmospheric exposure 25ug/cm2

These values were for sodium chloride as measured by Bresle Patch method.

The Coating manufacturer (CM) normally only includes soluble salt levels in tank coating specifications for commercial customers. These areas are where salt levels are routinely measured.

The CM is not currently looking at level of salts and evaluating risks. Their work in this area was accomplished some time ago (circa1985) when they became involved in hydroblasting (HB) in the European community. HB brought salts to mind and they were seeing very good results with removal of salts. Their paint inspectors were seeing some infrequent failures because of immersion in tanks and condensation.

They looked at salt levels with tests involving: Condensation and immersion test, Cyclic Weathering- wet-dry; Different films and formulations, Different temperatures, and permeability of water through the coatings. They use for example, ASTM 1653- Standard Test Method for Water Vapor Transmission of Organic Coatings Films.

Most people do not understand the process of permeability. This CM measures permeability of coatings. Permeability is a thermodynamic problem based on water vapor pressure, temperature, and concentration. The water that is being absorbed into the coating can't see what is on the other side (substrate interface.) When you change the number of defects on the substrate, the water vapor migrates to the substrate and ends up at those spots. This is not a change in rate!

This CM said that they gave, to the Navy, a commercial specification for tanks of a level of 3 micrograms/cm^2 as the CM had prior experience with tanks that lasted up to 15 years in pristine condition. The CM also advised and educated Navy personnel on use of stripe coatings; the hazards of sharp edges, allowing time for cure and not closing the tank before cure was complete, and the breakdown of thin coatings.

Frequency of Tests:
When compared to successful commercial vessels, the CM representative feels that the Navy does far too many salts tests. If the Coast Guard does more frequent tests than the Navy, they must be mad. MARAD, in his personal opinion, must be driven by a third party interest who is making money for the number of salt tests that they require. His experience, on commercial and military vessels, is if the certified abrasive blasting media doesn't have salts, and there is reasonable control during the blasting conditions, then there need be only a few, if any tests, for salts.

In his opinion, the Navy assumes everything with respect to quality control and surface preparation is out of control by the SY personnel when the Navy sets up their quality assurance requirements in 009-032. He feels that the Navy could save funds and maintain a quality product by adopting commercial surface preparation of owners who build and hold their vessels.

It is always true that owners who build vessels and will operate for life time of 20-30 years will be more strict than owner who build to sell in a short time The CM typically aims for a middle position so it is possible that the long-term owners might have more stringent specification than the average CM requirements.

The current personnel at Navy Sea Systems Commands are very receptive to technical discussions about moving to joint warranties or graded quality assurance. The CM representative views the greatest obstacle to adopting commercial practices is the legal considerations of contracts/document/specifications. He is not optimistic that this legal objection will ever be overcome.

2. Coating Manufacturer
180 F is too hot for testing coatings in an effort to determine the effects of soluble salts on blistering. I've seen coatings that perform extremely well in long term cold water service that will blister quickly in hot water. Many factors involved. I think 140 F is reasonable to accelerate the test- as is the use of de-mineralized water. Provided Company data on salts.

This Manufacturer has purchased several of the original marine coatings divisions. Their salt sheet is a combination of guidance from the prior companies. They have extensive testing labs.

3. Coatings Manufacturer
This coatings manufacturer supplies coatings primarily to the OEM equipment (tanks, heavy equipment) manufacturers, military (US Army and Marines and the US Navy. The coatings are water reducible/Water based and Solvent Based paint coatings in Low VOC, Low HAPS solutions and electrostatic coatings.

They do not supply globally to the marine market. They do not make non-skid or hull coatings. They produce QPL Mil formula coatings for Army, Navy, and Marine.

Wash primers
Epoxy primers for equipment
Epoxy equipment coatings
Chemical resistant coatings
MIL-PRF-24635E Type II & III Silicone Alkyds-(Standard, LRC, LSA, and LSA/Non-Stain Versions)
Navy formula 111 alkyd, Formula 30, Formula 84- zinc molybdate primer ; high temperature aluminum, non-flame alkyds, acrylic emulsion (standard and LSA), urethane camouflage,

They test their coatings according to the standard tests that the Navy, ARL, or TACOM requires for acceptance.
They start with standard clean and blasted panels from commercial source.
They do not test their materials over salt contaminated surfaces.
They look for comparison to prior coatings to meet the Navy specifications, and then get them accepted.

“Salt” just isn’t an issue for this company. The individual has not considered “salt” to be a problem, nor has she discussed levels of “salt” amongst other coating manufacturers with respect to other commercial/project sites.

Their policy is “Get all the salts off,” but they accept the levels that the clients, including the US Navy, have in procurement or performance specifications.

4. Coatings Manufacturer- generally will accept number that client sets as a specification. They provided statement and technical bulletin. Their ISO representative put it together over several years.

This bulletin has atmospheric, immersion, and different chemistries. Their in-house expert (ISO rep) is retiring in December, 2010.

Their limits were higher than Navy, but the client is always correct. He does not have any feel for risks versus the higher limits. The Navy warships are expensive assets.

Chlorides are a concern in railcars, more so sulfates. Petrochem has a concern to varying degrees. He feels the general coating industry knows and is concerned.

Coating manufacturer does participate with SY and Project with everyday involvement. Some SY they have active participation; some SY it is more oversight. Tech Rep drops by a few times a week. Their primary marine business is in the US, Central and South America, and are branching off to global SY.

In Navy new build yards, they have limited interaction- there at project start-up, support if asked, but not 24/7. On the Navy work, the SY does the inspection check points, and then calls the Navy for the “inspection” points. Two sets of check points.

On commercial project, frequently the sy, coatings rep, and inspectors get together simultaneously. Interaction and discussion happen all the time.

Used SCAT, Bresle, Chlor*Test, has not used Elcometer paper absorbance. Bresle patch is most widely used. Chlor*Test and Bresle are very similar- he is not aware of cost which could be an issue.

5. **Coatings Manufacturer** European; Global

These observations are properly more valid for commercial vessels rather than US Navy vessels.

In general if nothing else is specified or no standards are referred to we would allow 80 mg/m2 NaCl on under water areas, including WBT.

The WBT will change now though with the implementation of the new PSPC rules for coating WBT. This standard clearly sets a limit at 50 mg/m2 NaCl.

For new buildings, Company Technical Rep. will do spot checks on blocks, the first 3-4 blocks will be carefully checked and if the trend is good, we would go to spot check.

I do understand that some people have asked for 0 salt level. From a practical perspective I must admit that I have **always** been able to get some level of salt with the field equipment available today and the last 15 years for that matter. I have personally seen contractors having to buy de-ionized water to try to bring salt levels down.

I might add that for protective linings, such as flue gas ducts or fresh water storage facilities we set the limit of 20 mg NaCl.

I have, to date, not seen failures on any structures where we have managed to maintain such a level.

For external hull and legs of offshore structures, I have seen more failures due to poor cathodic systems, rather than blisters related to salt.

I have however also seen 3-4 failures in my time due to inadequate control of NaCl, the result was indeed blisters, but where the steel was still white, not rusty in the blister, simply due to the anodes protecting the steel.

I would however state that in my experience if we have a salt level between 40-80 milli-grams NaCl/m2 on the steel surface, then I would be more concerned of repair of joints (grinding and polishing of steel), extensive use of high tensile steel (resulting in too flexible structures, meaning leading to risk of cracking), combined with excessive DFT's.

Submitted technical bulletin from company

Contractor

1. Interview: Contractor who works globally and predominately uses UHP WJ for overhaul, maintenance, and repair work on various shipyards, refineries, offshore platforms.
All the salt readings sent to NSRP project were Navy repair and maintenance; they removed and replaced paints as ships came back from deployment.

The contractors works in many locations. On some facilities, such as in Virginia, MHI Ship Repair and Services requires salt reading. MHI serves US Navy, Military Sealift Command (MSC), Maritime Administration (MARAD), and commercial ship owner-operators world wide for overhaul and maintenance.

On individual commercial contracts, whether on not the owners require salt readings is very dependent on the owner. Smaller tugs and vessels do not require salts. Tanks on ships for pipeline companies don't require salt readings. Offshore rigs overseas require salt readings.

For surface preparation, the contractor always performs profile, wet film and dry film readings. The salt readings might, or might not, be required.

For salts, they use RPCT Saltmeter. Buying the RPCT meter has saved them time on large projects. 70 mS is upper limit for conductivity.

The respondent has many years of experience and has not ever had any readings go high. It would be very unusual for any readings to be high as they use UHP WJ for cleaning. As a consequence, they do not have a standard procedure for remediation.

2. Contractor
Working on offshore rigs- Australia

All of our work are offshore oil and gas installations, and is coating maintenance repair work. All surface preparation is via UHP water jetting (30 to 35 000 psi).

Generally contamination may occur when completing decks on a rolling vessel , when adjacent to unblasted decks and the water transfers from the unblasted substrate to the freshly blasted areas. It is usually limited to an area at the interface.

The client painting specification relating to salt testing is
AS 3894.6 Method A or equivalent (e.g. ISO 8502-9). Spot checks- this is not specified any further.

Maximum corresponding to < 50 mg/m^2 (atmospheric service) and 25 mg/m^2 NaCl (immersion service).

Recleaning and retesting until acceptable.

The readings are generally close to the upper limit, never exceeding by great margins. We re-clean the surface.

This contractor sent in their in progress salt checks. The rework is more frequently than the SY that submitted the government inspection points. This work reflects what would be expected as the contractor is 'getting ready" for the inspector.

Test Kit Supplier

1. Manufacturer Salt Remover and Chloride Measurement Kit
Initial Correspondence as the Study was starting.

I am responding to a general communication you made recently which I understood you to be indicating that NAVSEA is considering relaxing the chloride (salt) specification limits on surfaces prior to coating.

I have had an opportunity to speak with several people who are intimately involved in this issue on an ongoing basis. Although some contractors would like to have the specified limit relaxed, especially when it cannot be met using the methods detailed in the present 009-32, there is no one in the Navy's technical community considering the relaxation of the limits.

Considering NAVFAC has changed its specifications (used by the US Air Force and selectively by the US Army) to non-detectable chloride, sulfate, and nitrate limits using the sleeve and tube titration method for testing of surfaces intended for immersion service, relaxing the standard would seem counterproductive due the risk associated with premature coating failures.

Furthermore, it is documented that the Bresle patch with DI water extracts around 50% (at best) of the actual surface salts on weathered panels or naturally corroded surfaces. Used in conjunction with the conductivity method outlined in 8502-9, the 30 microSiemens/cm limit in 009-32 would seem to be relaxed already.

Addressing the issue to be studied, the facts would indicate that the specified testing method for surface chlorides in the 009-32 are already relaxed. Why? Although the attached report is from Boocock1994 (ref 33, JPCL), it is still very relevant since the methodology for surface testing outlined in the report is the same.
1. Note the summary outlined in Table 7 on page 34 which reflects the accuracy of each commercial test method. The blister patch is the Bresle extraction method specified in 009-32.
2. The blister patch extraction on weathered steel (which is more realistic since that is what is experienced in the field as compared to laboratory doped samples) ranges from 26% to 53% in Table 5, page 32.
3. This report predates the introduction of the ion specific CHLOR*TEST, with an acidic extraction solution, which is addressed in this report (p 43).

In summary, hypothetically the use of the Bresle extraction patch with conductivity measurement is only about 50% accurate so the 30 microSiemens (3 micrograms/cm2) specified in 009-32 is actually 60 microSiemens (or 6 micrograms/cm2). Keep in mind that the origin of this test method is the ISO 8502-6 (Bresle patch extraction) and ISO 8502-9 (conductivity of chlorides or equivalents) and that the ARP Salt Meter accepted in the 009-32 for FY-10 (3.10.7.3) is set to be equivalent to the ISO method. I am not sure what positive service or protection the ARP Salt Meter is giving NAVSEA with respect to actual testing of surface chlorides present when it is set to be equivalent to something that is demonstrated to be about 50% accurate.

Appendix 7 Dual Field Measurements

June 2008 report by J. Eliasson to NACE Task Group

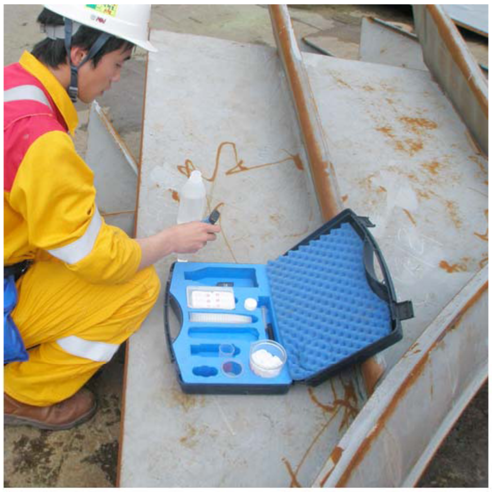
.

Report

Testing of Salt Levels about 100 mm appart

J. Eliasson

June 20, 2008



Background
It was assumed that the naturally doped steel present at marine locations would be generally consistently contaminated – at least within a short distance. For that reason the distance chosen for the in-situ test in the ISO8502-9 equivalence validation standard procedure was 100 mm. Tests were conducted in Japan that gave values that varied much more than expected – the distance though also being greater than 100 mm. Tests were therefore conducted in a shipyard in Korea under normal in-situ conditions to establish the variance in pairs of measurements about 100 mm apart.

Executive Summary

It was found that in fact the amounts of salts measured vary a lot between spots, also very close together. One panel had very good values in close proximity, but another panel and a block showed great variance.

It must be concluded that the In-Situ test would be unsuited as a validation tool unless the surfaces on which the validation is to be conducted is to be quality controlled and found evenly contaminated.

Salt Readings in Pairs **Readings in mg/m2**

Reading #	Panel I	Panel II	Block	Deviance
1	30			Very large
2	18			
3	6			Very large
4	24			
5	30			
6	18			
7		24		0
8		24		
9		6		0
10		6		
11			54	Very large
12			12	
13			42	Large
14			30	
15			12	Very large
16			30	
17			54	Large
18			60	
19			36	Very large
20			60	

Panel I was not suitable as a panel for validation tests in-situ, nor was the block found to be.

Panel II could have been used.

How to run a quality control to ensure that the surface on which the in-situ validation takes is now a new challenge. Is it solvable in a practical way?

Inspection

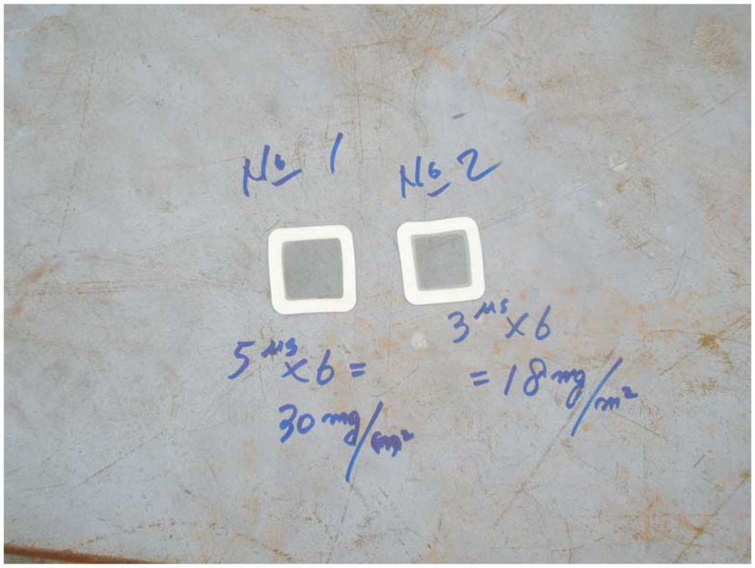
The salt reading was done using a ISO8502-9 method adopted in Korea, It involved using a larger volume of water, part of which was used to extract salt with a Bresle patch. The test solution then added back to the container with the remaining water, and the conductivity measured on the larger volume using a HANNA conductivity meter.
The gauge gave only whole numbers, and not decimals, hence there was an added deviance in the system only for that fact – but the deviation was much larger than for this to be the main issue.
The dwell time (wetness when measuring was about 1 ½ min, with 4 times in-and-out, and constant finger rubbing in between.
This method is not in harmony with the method in the equivalence validation standard practice, but it was consistently applied. I was not interested in the values in them selves, but the variance within 100 mm.
The distance between the patches were not measured to be exactly 100 mm, but were close enough for this evaluation.

The patches were applied in pairs; 1+2, 3+4, 4+5, etc.

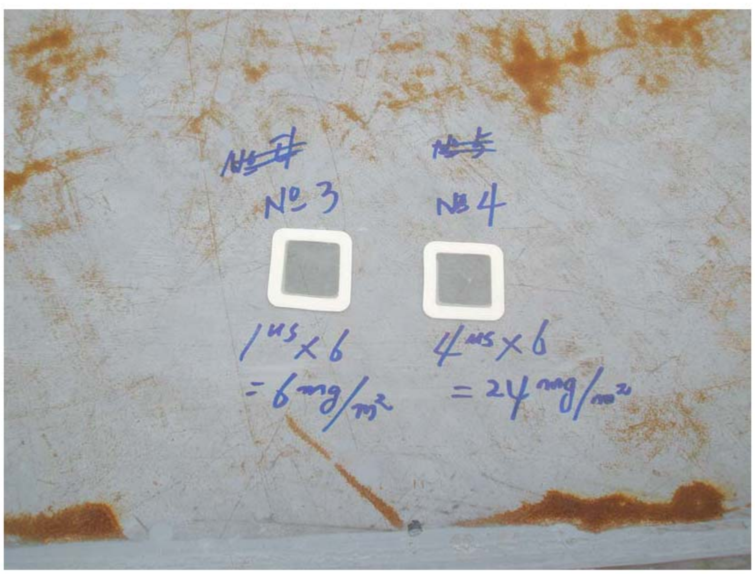
Measurements

Salt Readings in Pairs			**Readings in mg/m2**	
Reading #	**Panel I**	**Panel II**	**Block**	**Deviance**
1	30			Very large
2	18			
3	6			Very large
4	24			
5	30			
6	18			
7		24		0
8		24		
9		6		0
10		6		
11			54	Very large
12			12	
13			42	Large
14			30	
15			12	Very large
16			30	
17			54	Large
18			60	
19			36	Very large
20			60	

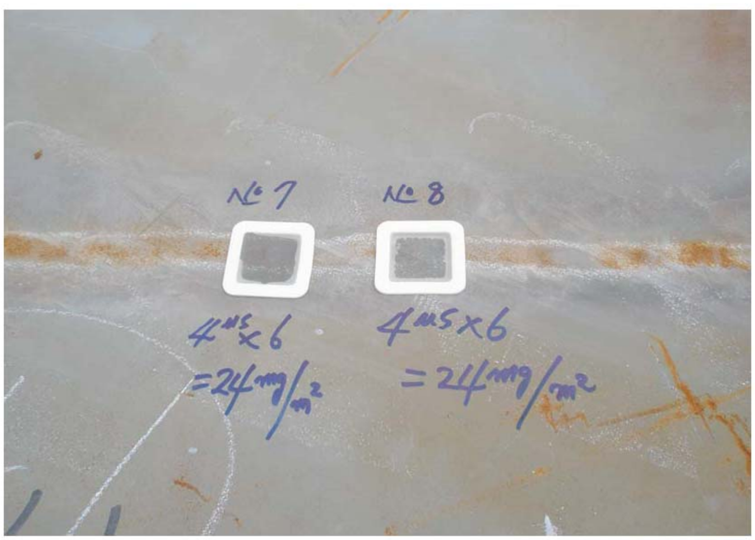
Shown is also the conductivity gauge.



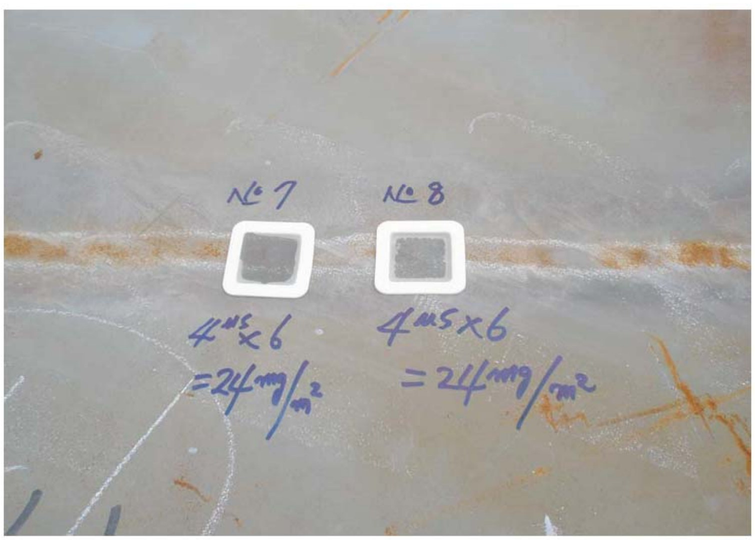
Panel I – Area that had been washed quite well by recent rain. Horizontal surfaces!



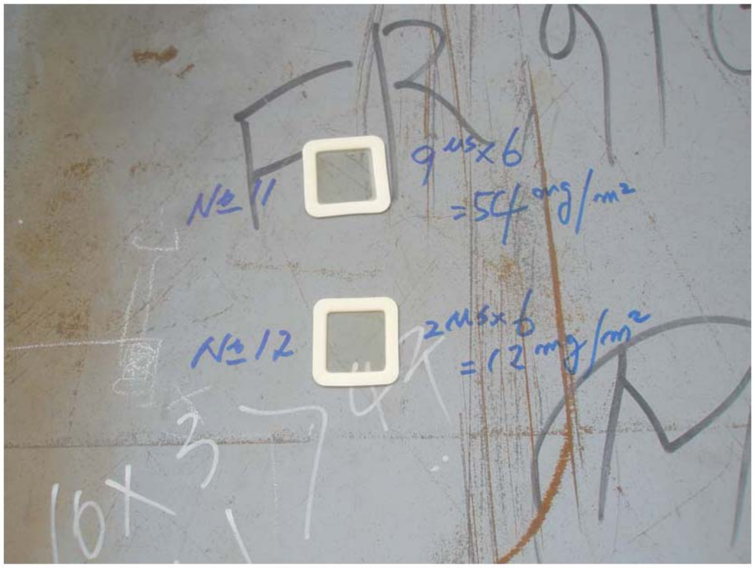
Above Panel I – Below Panel II 1st pair – also horizontal washed in recent rains, on a heat weld damaged spot.



Above Panel I – Below Panel II 1st pair – also horizontal washed in recent rains, on a heat weld damaged spot.

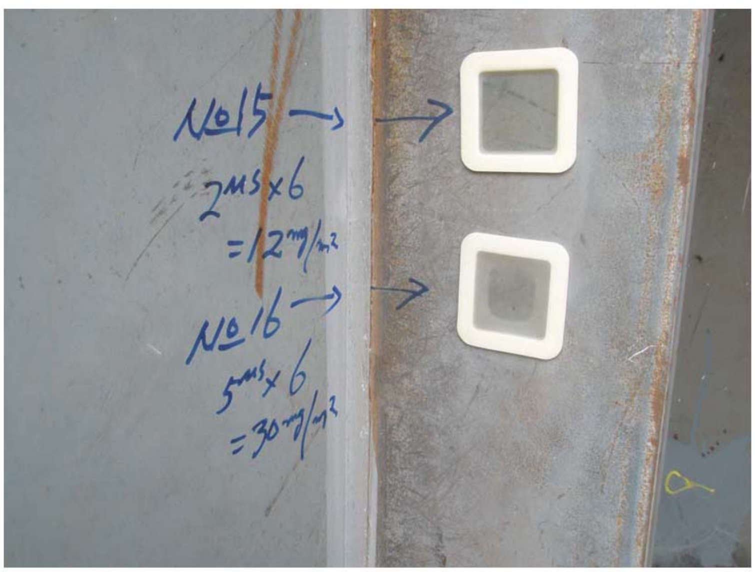


Panel II above on a rain protected spot – Below the block.



Block – Area where people touch with hands – access part.

On bracket – typically not an area touched much by hand.



Block on an area with rust stain contamination over-head -Not expected to be contaminated by human traffic! Below, outer bilge area on the bottom plate.

Attempts were made to measure on several types of surfaces. Intact shop primer, degraded shop primer, rusty parts, vertical, horizontal, overhead and bottom parts. The variance found was well in excess of what had been expected!
J. Eliasson
June 20, 2008