White Paper:

Economic Impact of Corrosion and the Effect of Surface Decontamination on Coating and Asset Durability

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New Technology Advances Highly Effective Corrosion Control

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Economic Impact of Corrosion and the Effect of Surface Decontamination on Coating and Asset Durability

Abstract

Costs associated with corrosion-induced maintenance and the replacement of public sector and industrial infrastructure has become a staggering problem for domestic and global markets, causing a heavy burden to the profitability of businesses, and the budgetary limitations of governments. Standard approaches to corrosion remediation have proven ineffective and new long-term solutions are needed.

A key to effective corrosion prevention is molecular decontamination - the elemental cause in the process of corrosion and protective coatings deterioration. Traditional approaches do not address decontamination on the molecular scale needed to properly remediate corrosion. CleanWirx has developed a patented technology and process that provides an effective means of removing contaminant-driven corrosion on the molecular scale to more fully solve the problem of corrosion.

The Cost of Corrosion

Industrial assets comprised of metal and concrete are perpetually degraded by the negative impacts of corrosion, from the first day of service onward. The costs to maintain such assets can exceed the initial cost of the asset itself, sending total cost of ownership skyrocketing. In addition, corrosion reduces the effective service life of these assets, which further increases capital expenditures.

A comprehensive study on the cost of corrosion has determined that corrosion drains hundreds of billions of dollars from the US Economy alone, as the impact seriously threatens a wide range of affected sectors. In 2001, a 900-page+ study, titled Corrosion Costs and Preventive Strategies in the United States, was completed by corrosion control engineering firm CC Technologies with the support of the National Association of Corrosion Engineers (NACE), and funding from the Federal Highway Administration. This exhaustive study analyzed and identified the costs of corrosion in 26 industrial sectors in which corrosion is known to exist, and extrapolated the results to arrive at a nationwide estimate.

The study analyzed both direct and indirect costs of corrosion over service life cycles of relevant assets, such as the costs of corrosion as they relate to facilities, vehicles and infrastructure. Direct costs of corrosion include all activities throughout the service life of a structure that are performed to prevent corrosion, repair its damage and replace the structure. These activities include design, manufacturing, maintenance, inspection, repair, rehabilitation, and removal. Another large direct cost is the cost of downtime associated with maintenance activities due to the impacts of corrosion. Often the largest predictable direct cost comes from the decreased service life and corresponding increased depreciation of corroding assets.

Liability can also present an enormous burden. The costs associated with environmental catastrophes caused by corrosion-driven failures can be staggering, even to the point of bankrupting the owner of the failed asset. The total direct cost of corrosion was determined by the study to be $276 billion per year, or approximately 3.2 percent of the U.S. gross domestic product (GDP) as of 1998. Adjusted for 2005 U.S. GDP, annual direct costs increased to nearly $400 Billion. Indirect costs are equal to or greater than direct cost of corrosion. Examples of indirect costs include traffic delays from bridge maintenance caused by corrosion, pollution costs from corrosion induced leakage (underground gas and oil storage tanks), and higher prices for goods to compensate for accelerated costs of infrastructure replacement, to name a few. Indirect costs to society were conservatively estimated by the report to be equal to the direct costs. Expanding industrialization trends in metallic composition and other factors have further accelerating the problem. According to Dr. Jackson from the G2MT Labs, “In the 15 years that have passed since the study was released, inflation has driven both the direct and indirect costs of corrosion over $500 billion annually, totaling over $1 trillion in 2013”.

Internationally the problem is far worse due to inferior processes and substandard materials combined with challenging environmental factors. Reliable studies of the international problem are scarce, but estimates can be made based on the U.S. study. U.S. GDP is approximately 21% of the Worldwide Economy, which indicates a worldwide problem nearly five times greater than the U.S. However, the lower industrialization rate worldwide as compared to the U.S. suggests that cost of corrosion as a percent of GDP in lesser-developed countries is somewhat below that experienced in the U.S, although a more vulnerable international infrastructure would indicate higher rates of corrosion across similar assets. Taken together, it is safe to say that the worldwide cost of corrosion far exceeds that of the U.S. alone. Research clearly indicates that the problem is massive and will continue to worsen unless a new approach to corrosion prevention is adopted.

Standard Anti-Corrosion Measures

Standard responses to corrosion are little more than temporary stopgap measures. Typical corrosion prevention measures include the use of various surface blasting processes and anti-corrosion coating materials. Traditional NACE standards of surface preparation require that defined visual standard be attained prior to the application of corrosion resistant coatings.

However, these measures fail to address molecular causes of corrosion and only delay the inevitable impact on serviceability and destruction of industrial assets. For example, under normal circumstances metal in contact with corrosive materials must be remediated and recoated with a protective coating on average every five to ten years. This represents a significant ongoing cost that only delays the onset of corrosion.

The standard anti-corrosion process follows a series of industry-defined stages. The process typically begins with careful cleaning of surfaces to a visual standard, such as those specified by the National Association of Corrosion Engineers (NACE) or The Society for Protective Coatings (SSPC). These standards of cleanliness result in a surface that when viewed without magnification, appears to be “free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products and other foreign matter.”

The process consists of blasting with an abrasive to achieve a specified standard of visual cleanliness (i.e. NACE 1, NACE 2, etc.) according to the requirements of the project and the specifications of the coating to be applied. Typically, the blasting abrasive will consist of silica sand or equivalent material that is dry, neutral pH, and free of dust, clay or other foreign materials.

After the blasting stage, it is typically necessary to control the environment of the surface to allow for effective application of the coating. This costly, time-consuming process usually requires the use of industrial desiccant dryers as well s additional days of downtime. Alternatively, the environment may need to be cooled, which reduces humidity. Dehumidification (DH) is also costly and time consuming. In a typical maintenance scenario, DH can easily contribute 20% or more to required asset downtime, and increase process costs by up to 20%. The purpose of DH is to prevent surface rusting prior to coating. However, this does not prevent substrate corrosion, which can necessitate additional blasting. The need for additional blasting happens quite frequently, commonly requiring the process to be repeated up to three or four times before surfaces may be properly coated.

One technique used in an attempt to alleviate the problem is to apply a holding primer immediately after blasting to keep the surface visually clean and rust free prior to coating. Unfortunately, applying primer coats over Microbiological Influenced Corrosion (MIC) and other ionic contaminants. Still present after abrasive blasting (although the surface appears visually clean at the point of coating), simply masks the underlying cause of corrosion. At best, DH serves as a highly unpredictable and costly process in standard anti-corrosion maintenance that frequently fails to attain a desirable result.

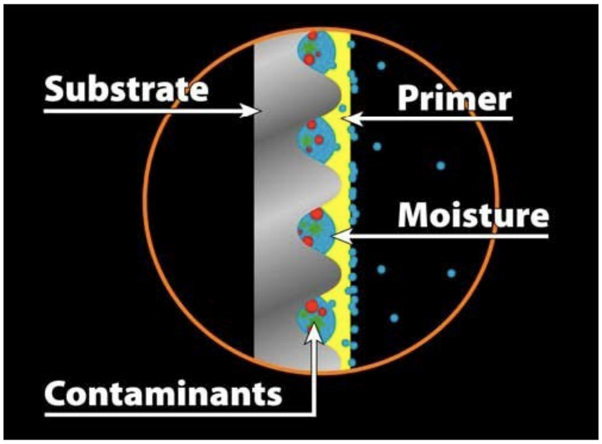


Diagram 1: Impact of coating over micro-contaminants: As moisture permeates the coating film it acts as a 'food source' or catalyst for microbial contaminants and accelerates the corrosion process. Source: CleanWirx, 2006.

Once surfaces are visually clean and existing environmental factors meet the specifications provided by the coatings manufacturer, an anti-corrosion coating may be applied. Coatings are typically sprayed onto surfaces. When the coating has cured, the asset is put back into service. The substrate, however, will continue to harbor and incubate molecular contaminants that were not removed during the blasting process. Thus the deterioration process begins as these contaminants trapped on the surface by the protective coating begin to 'bloom'.

The following scenario considers costs associated with preventing internal corrosion in industrial oil storage tanks that are maintained using standard corrosion maintenance measures.

Standard Lifecycle Cost Scenario

Oil Storage Tanks

Oil storage tanks experience significant deterioration from corrosion during their service life cycles. Industrial oil tanks are typically taken out of service and treated with a standard anti-corrosion process at least once every five to ten years.

The standard cleaning, drying, priming, painting, and inspection procedures for the internal lining of a 135-foot diameter tank will cost, on average, approximately $150,000. In addition, the cost of taking an industrial tank of this size out of service can easily run $5,000/day (and oftentimes much more), with total downtime

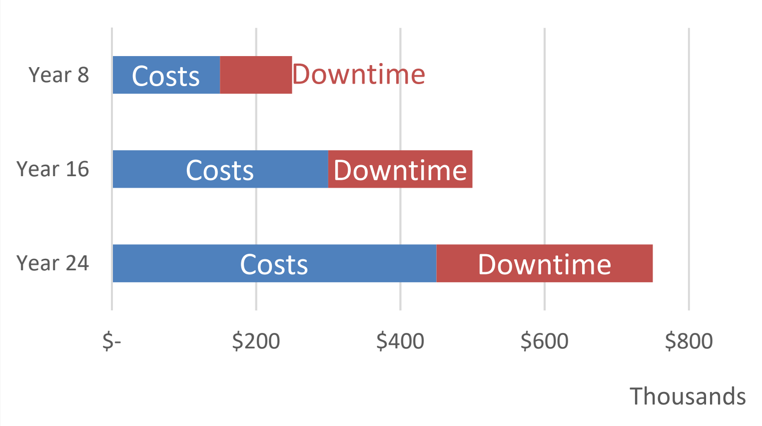


Chart 1 depicts a present-value cost scenario for a typical 135-foot diameter oil storage tank. Present Value Cost Scenario Using Standard Corrosion Control System, Cumulative Costs.

[1] The internal tank-bottom lining on 135-foot tank requires approximately 15,000 square feet of coating at $10/square foot.

[2] Figures are not adjusted for inflation.

[3] In years 8,16, and 24.

[4] Present Value amounts are rounded to the nearest $1000.

easily reaching 20 days. The resulting service will cost roughly $250,000 per event ($150,000 + [20 days x $5,000/day]). Over an average 30-year service life for large oil tanks, three additional tank lining maintenance events are a reasonable expectation.

Causes of Corrosion

The oil tank scenario illustrates a typical experience in the never-ending battle to contain the negative effects of corrosion. The discovery of highly effective solutions has been evasive because standard approaches have failed to address the core causes of corrosion. Unless the prime failure mechanism, Microbiological Influenced Corrosion (MIC), is recognized, standard preventative measures will continue to fail.

A key accelerant of aggressive corrosion is the presence of microbial surface contaminants, either because they directly attack substrates or cause premature coatings failure. MIC is caused by sulfate reducing bacteria, acid producing bacteria, and other contaminants that greatly increase osmotic blistering, which is the principal cause of coating failure. Bacteria settle next to the substrate and produce acids and other ionic compounds that corrode the steel and cannot be removed using abrasive blasting alone. Unless these contaminants are effectively removed, surface coatings trap contaminants within the film. As moisture begins to permeate the coating film these particles stimulate the activation of microbial contaminants and initiate the corrosion process. As the surface corrodes, moisture vapor begins building pressure on the coating, resulting in premature coating failure.

Another major factor in the reduction of coating life is the presence of soluble salts - chlorides - on steel substrates. The detrimental effect of chloride contaminants on coating performance has been discussed in coating-related literature for nearly 40 years. Soluble salts present on a substrate initiate coating failure and substrate corrosion through an osmotic blistering process. One typical mechanism of failure on dry-blasted chloride-contaminated steel substrate occurs as ferrous chloride is immediately formed whenever steel (iron) and chlorides come in contact. The reaction is highly corrosive to steel substrates. Upon exposure to air, ferrous chloride quickly oxidizes to form ferric chloride, a soluble salt with natural affinity for available moisture (hygroscopic salt). Residual ferric or ferrous chloride contaminants on the substrate accumulate moisture from the air, resulting in the formation of concentrated iron chloride solution on the surface of the steel. Iron ions, chloride ions, and water comprise an electrolytic solution that drives an electrochemical corrosion reaction. Coatings applied over the contaminated steel substrate will fail in a short period of time due to the concentration of iron chloride solution on the substrate.

Such concentration draws water through the porous coating membrane by osmosis, which in turn activates corrosion cells and promotes premature coating failure. Visual standards of cleanliness do nothing to assure the removal of the aforementioned microbial contaminants, a significant cause of coatings failures. The rate of coating failure due to this osmotic blistering is dependent on the service environment, coating thickness and coating porosity; but most importantly on the purity level of substrate cleanliness at the time of base coat application.

Due to the hygroscopic nature of ferric salts, controlled temperature and humidity conditions are not effective in preventing a monomolecular layer of water from collecting on salt-contaminated substrate surfaces. Such contaminants must be eliminated to avoid coating over microscopic moisture accumulations. While the mechanism of coating failure due to contamination of substrates by soluble salts has been understood and thoroughly documented, cost-effective solutions have not materialized. Blast cleaning specifications have primarily focused on visual standards, which failed to properly addressed removal of non-visible surface contaminants. The level of substrate cleanliness required for optimum coating adhesion varies significantly depending on the service environment and the characteristics of the selected coatings, although in practice the cleaner the substrate, the greater the resistance to coating disbondment.

CleanWirx

CleanWirx of Humble, Texas developed a revolutionary surface preparation process that eliminates the underlying causes of coatings failures described above, and thereby prevents corrosion even in the most demanding environments. CleanWirx prepares surfaces by eliminating microscopic levels of corrosive elements that cause coating failures at a molecular level. As a result of this decontamination process, subsequent surface coatings are significantly more able to withstand extremely hostile environments and remain durable and maintenance-free, thereby reducing future maintenance and refinishing cycles.

Decontamination Process

CleanWirx is a surface decontamination treatment that achieves a zero-detectable level of ionic contaminants on surfaces, well beyond the accepted visual standard. CleanWirx technology removes non-visible microscopic molecular bound contaminants that standard surface preparation processes leave behind. Achieving this level of decontamination effectively eliminates both visual and micro- contaminants that cause interference with coating adhesion. This thorough decontamination facilitates an intimate bond at the coating-to-substrate interface resulting enhanced coating performance. Coatings applied on CleanWirx treated substrates demonstrate far superior durability and resistance to corrosion.

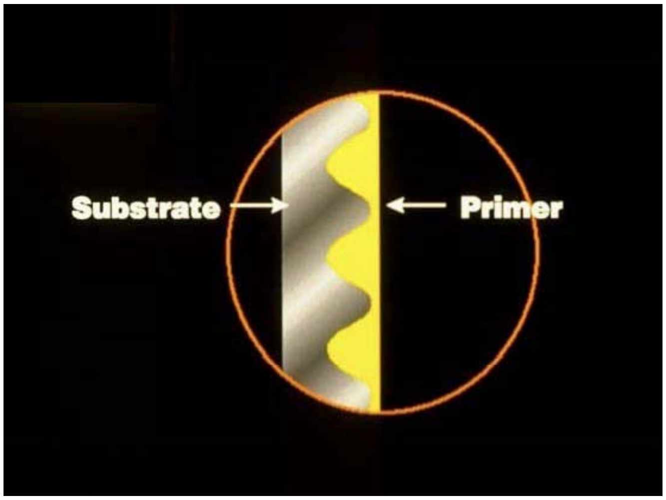


Diagram 2: By fully removing interference from contaminants, CleanWirx allows protective coatings to more truly, and effectively bond to the substrate. Impact of Coating over CleanWirx. Source: CleanWirx (2006).

CleanWirx technology employs a proprietary two-step process and a patented chemical neutralization agent to decontaminate surfaces. The result is a reaction of water and non-water soluble ionic contaminants that alters the molecular structure on the treated surface, which in turn removes MIC and other ionic contaminates. The decontamination step is followed by a clean water rinse to prepare surfaces for the application of a coating. Coated surfaces that have been decontaminated with CleanWirx have demonstrated greater resistance to corrosion and significantly extended the effective life of the coating.

CleanWirx integrates seamlessly with standard anti-corrosion processes and coatings. CleanWirx can easily be implemented during otherwise standard anti-corrosion maintenance events, and may often be applied by the regularly scheduled maintenance contractor. CleanWirx is applied following surface blasting but before application of a coating. CleanWirx is environmentally benign and has no Volatile Organic Compounds (VOC).

Following standard preparation requirements, substrates first undergo abrasive blasting or a high-pressure water wash to remove mill scale and other visible interference materials.

The minimum visual requirement is usually between a NACE 2 SSPC-SP10 to a NACE 3 SSPC-SP6 (and the accordingly appropriate blast profile). CleanWirx is implemented at this stage in a fairly straightforward process.

The two-step CleanWirx application process removes aggregated reaction sites on metal surfaces at the molecular level, eliminating visually undetectable levels of highly corrosive substances, providing a uniform receptive surface prior to coatings application. The result is that protective coatings are more durable, more corrosion resistant and, therefore, substantially less likely to require frequent maintenance cycles -- in other words; assets last longer and cost less to maintain. CleanWirx is simple, safe and straightforward. The next step in the process consists of applying the CleanWirx P2 Rinse to further decontaminate surfaces in preparation for coating.

Once the surface is dry, uncoated surfaces will resist corrosion for an extended period of time, allowing the DH step to be eliminated. By applying CleanWirx directly after blasting, the DH step and process repeats (i.e. re-blasting) become redundant and may be eliminated in corrosion control procedures. Thus, introducing CleanWirx into standard maintenance processes reduces both cost and downtime.

Aggressive Corrosion Applications

CleanWirx is ideal for aggressive corrosion applications such as tank farms, oil and gas pipelines, bulk rail and road tank cars and materials carriers, general industrial piping, chemical companies and refineries, and marine applications. CleanWirx significantly reduces costs associated with ongoing anti-corrosion maintenance and repair in terms of material and labor costs, including the considerable cost and subsequent downtime required for

Image 1, 2, & 3: 12" pipe and drums (located adjacent to four brine pits) were treated with CleanWirx, and coated with standard epoxy coating. Equipstar storage facility maintenance project conducted in October 1995 has enjoyed over ten years of maintenance-free durability. This photograph was taken in October 2005. Project demonstrated no corrosion and no coating deterioration. Source: CleanWirx (2006).

CHALLENGE: Aggressive corrosion on 12" pipe and drums adjacent to four brine pits going into water with a salt concentration of 300,000 parts per million.

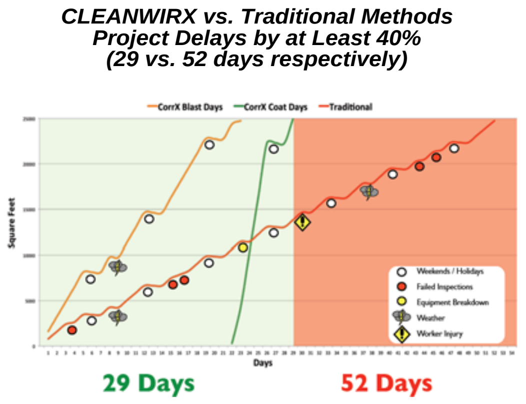
premature replacement of corrosion-damaged infrastructure. CleanWirx reduces the time it takes to return an asset to service, while extending its overall service life. CleanWirx is environmentally benign, making it a welcome ally in mitigating corporate liability, meeting environmental regulatory obligations, and advancing corporate environmental goals.

CleanWirx Cost Scenario

CleanWirx allows owners to avoid a range of expenditures typically incurred through standard corrosion prevention measures. These cost savings fall into three categories: 1) lower cost of treatment, 2) less downtime, and 3) longer service lifetimes resulting in lower depreciation.

CleanWirx lowers the cost of standard corrosion maintenance by eliminating dehumidification and the need to re-blast, simultaneously trimming associated labor spend. CleanWirx typically reduces the direct costs of corrosion service events by approximately 10%-15%. Add to this the fact that CleanWirx also speeds up maintenance events (allowing assets to remain in service more continuously), and the long-term benefits are considerable. By implementing CleanWirx into standard corrosion maintenance procedures, companies can reduce downtime associated with an internal tank lining service event by 20%-40%, while spending 10-15% less.

Moreover, CleanWirx limits the number of maintenance events necessary during the service life of the asset. The CleanWirx effect on maintenance in the field can be drawn from data from the earliest date of CleanWirx application to present, over 18 years (see Table 1). No corrosion-related maintenance events have occurred since initial treatment, in spite of a high-chloride environment surrounding the asset. Although no longer-term results are available, assets decontaminated with CleanWirx and properly coated are predicted to require re-treatment in 20 year intervals. In the oil tank scenario, maintenance events would thus be reduced from three additional events to one over a 30-year expected service life (one at the beginning and only one additional in 20 years).


CLEANWIRX vs. Traditional Methods
Project Delays by at Least 40%
(29 vs. 52 days respectively)

This table compares the oil storage tank scenario CleanWirx maintenance procedure vs. traditional maintenance procedure.

Tank Size: 135 feet	
Area: 15000 sq. ft.	
Standard Maintenance: per event	$93,333
Avg. number of maintenance ever	3
Cost/sq. ft: $18.67	$280,000

Tank Size: 135 feet	
Area: 15000 sq. ft.	
+CleanWirx Maintenance: per eve	$75,000
Avg. number of maintenance ever	1
Cost/sq. ft: $5.00	$75,000

Savings/sq. ft:	$13.67
Savings over 30-year Life Cycle	$205,000

Table 1 compares the oil storage tank scenario Standard maintenance procedure vs. CleanWirx maintenance procedure.

While it will require decades to fully gauge the impact of CleanWirx in terms of service life demonstrated by CleanWirx treated assets, experiences thus far indicate that CleanWirx will extend usable service life. It is entirely viable to experience an increase in asset lifecycle of 30% to 50%, although this only applies to an asset's corrosion-impacted service life (versus accidents, forces of nature, land use, etc.). Actual field results confirm that

CleanWirx provides considerable benefits in asset management costs.

Summary

Corrosion is an ongoing problem that is projected to only get worse. As economies expand so does the amount infrastructure susceptible to corrosion-driven depreciation. The nations develop and infrastructure begins to age, depreciation will occur at the higher rate.

A second contributing factor that significantly aggravates the problem is the fact that more and more metals are being recycled. The recycling of metals results in unintentional mixtures of dissimilar metals that radically accelerate the corrosive process. As older assets are replaced with recycled materials, an ever-expanding portion of the infrastructure consists of highly corrosion-susceptible metals.

The third factor to take into account: nearly thirty years ago the use of lead-based coatings was banned for environmental reasons, prohibiting the use of one of the best protections against corrosion. Taken together these three factors further exacerbate the long-standing problem of corrosion. Standard methods of blasting and coating are unable to effectively mitigate the problem, and only serve to delay the inevitable. The need for an entirely new approach has never been greater. The most viable solution involves stopping corrosion at its source. Because the greatest cause of corrosion on properly coated surfaces is the existence of molecular contaminants, coatings failures can largely be prevented by simply and effectively removing these contaminants from surfaces. By doing so, we can significantly reduce costs and enhance asset service life cycles. CleanWirx provides an effective approach to molecular decontamination that stops corrosion at the source.

CUT LIFE CYCLE CORROSION COSTS
When the coating application process takes place following CleanWirx decontamination, the protective coating system has a higher life expectancy potential.

CLEANWIRX™

For CleanWirx case studies and more information, visit www.ruggedcoatings.com.
Contact information: info@ruggedcoatings.com / 360-216-0136.

References
1. G.H. Koch, M.P.H. Brongers, N.G. thompson, Y.P. Virmani, J.H. Payer, "Corrosion Costs and Preventive Strategies in the United States," FHWA-RD-01-156 (McLean, VA: FHWA, 2002).
2. G.H. Koch, N.G. Thompson, O. Moghissi, J.H. Payer, J. Varney, "IMPACT (International Measures of Prevention, Application, and Economics of Corrosion Technologies Study," Report No. OAPUS310GKOCH (AP110272) (Houston, TX: NACE International, 2016).

(IMPACT study available at: http://impact.nace.org/)

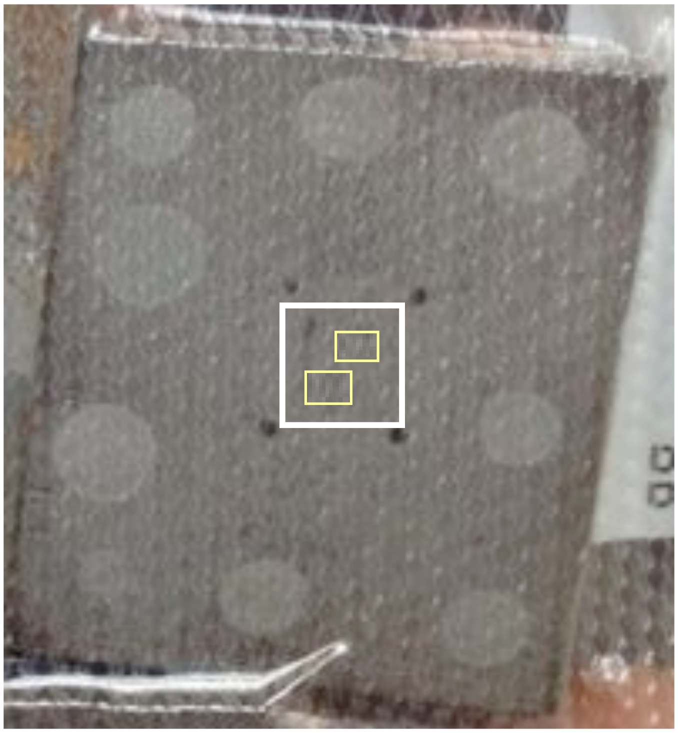
Appendix
Scanning Electron Microscope & Energy Dispersive X-Ray Spectrometer Analysis of Samples Cleaned with CleanWirx
Loren L. Hatle, NACE Level 3, CIP Cert. #207, CTO
Spectroscopy Services Provided by Anastas Technical Services

Sample #1
Images
Contaminated Area

(Sulfur Field Over Ferric Chloride Field)

Sample #1

#1



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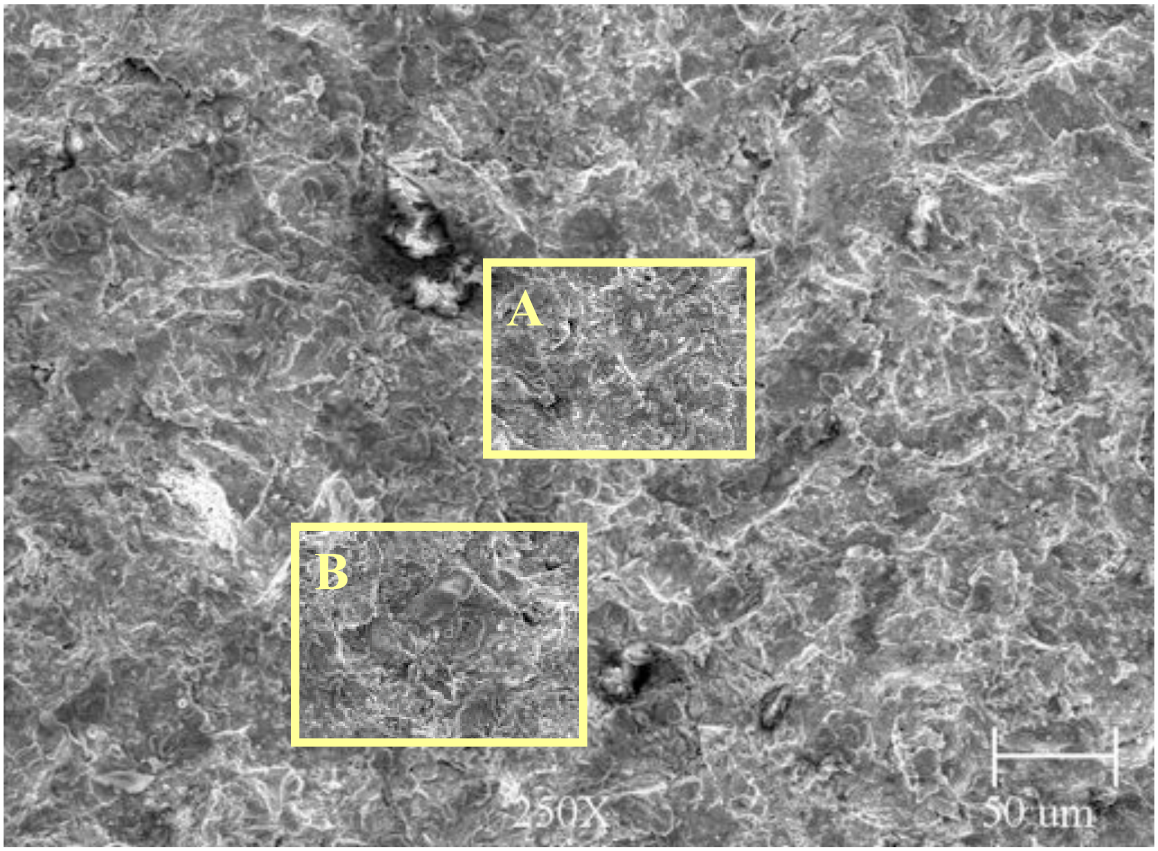
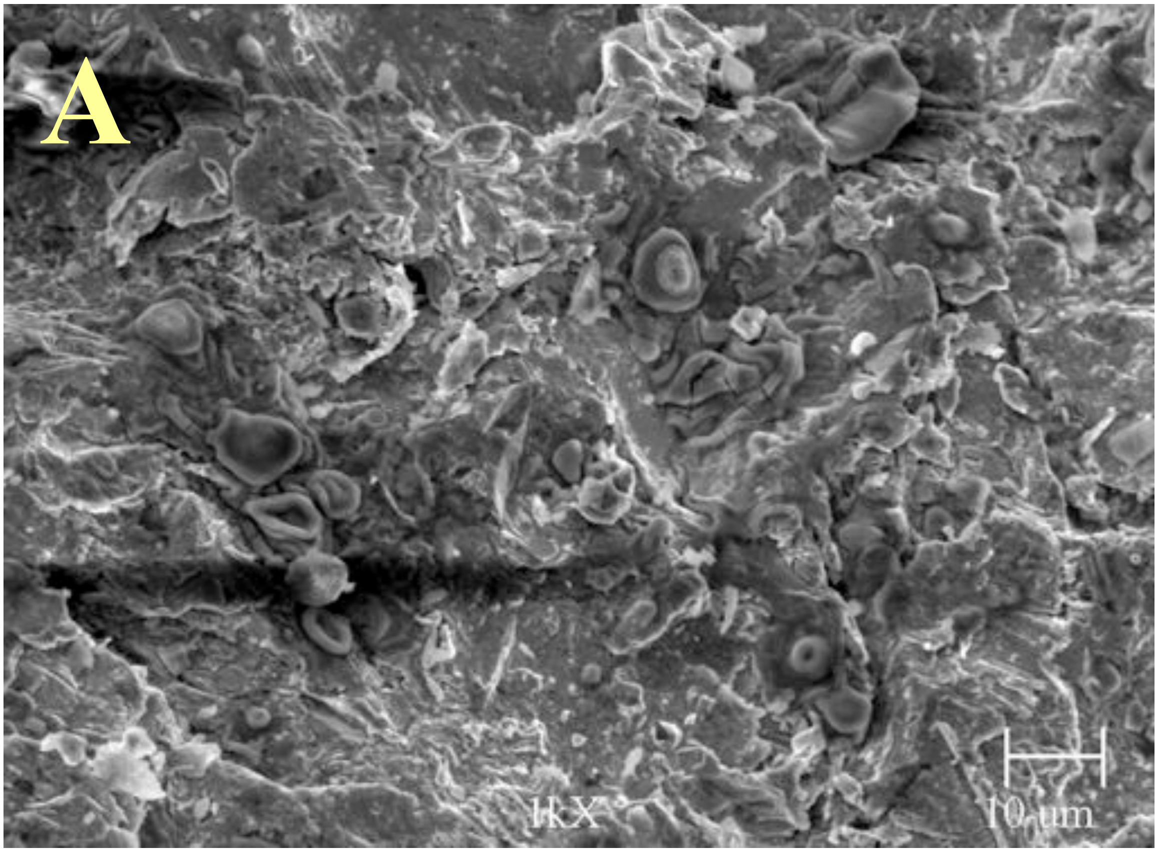


Sample #1

#3



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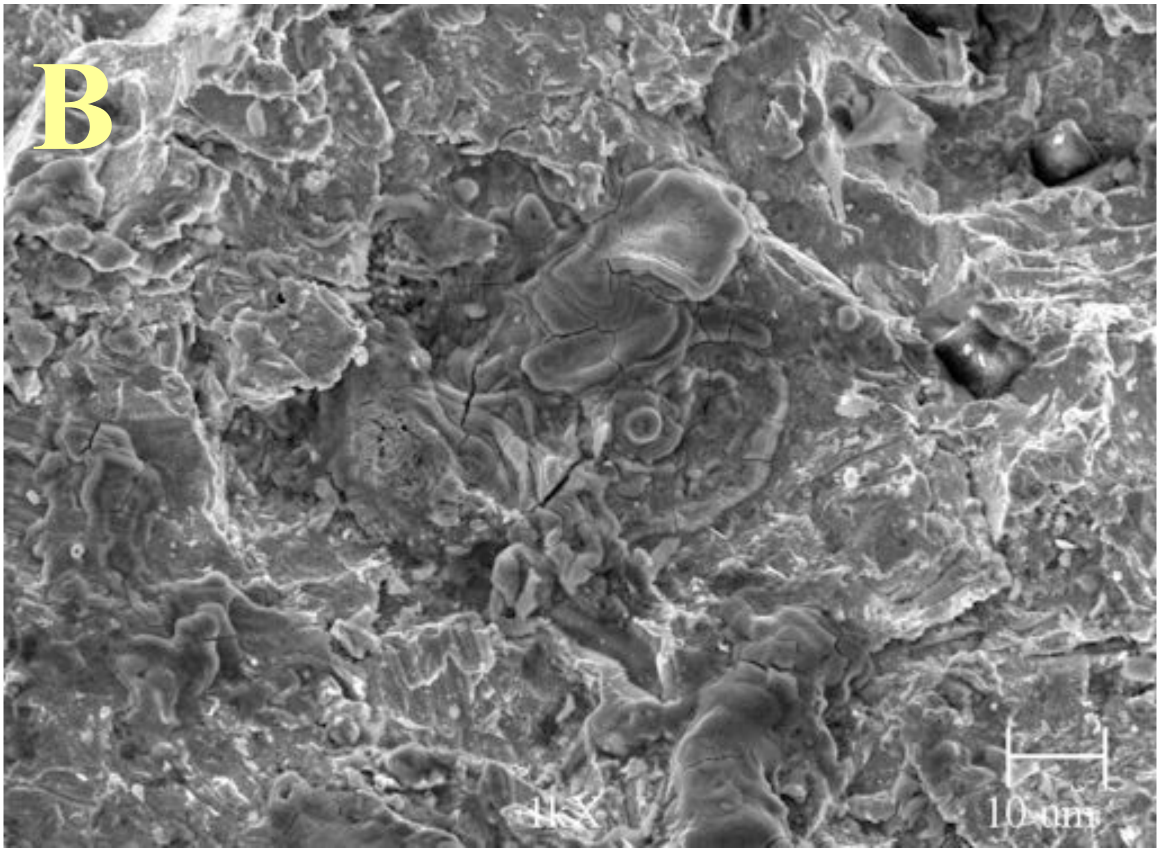
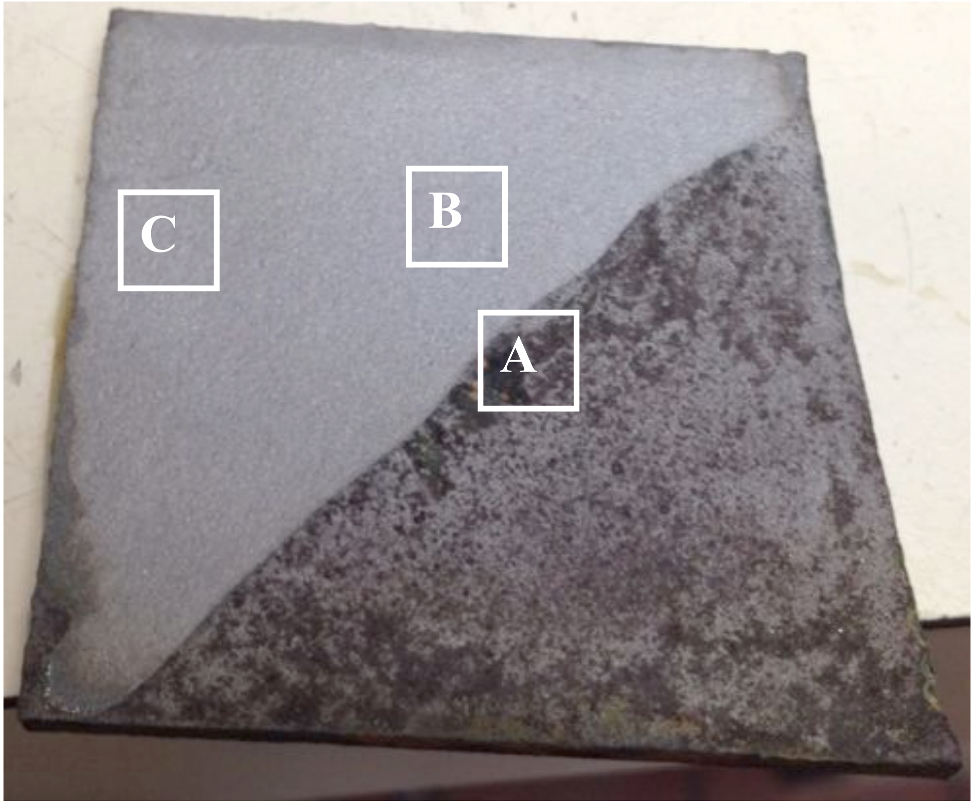


Sample #2

EDS Reports &
Images - Contaminated Side

Sample #2 – Contaminated Side, Field A:

#5



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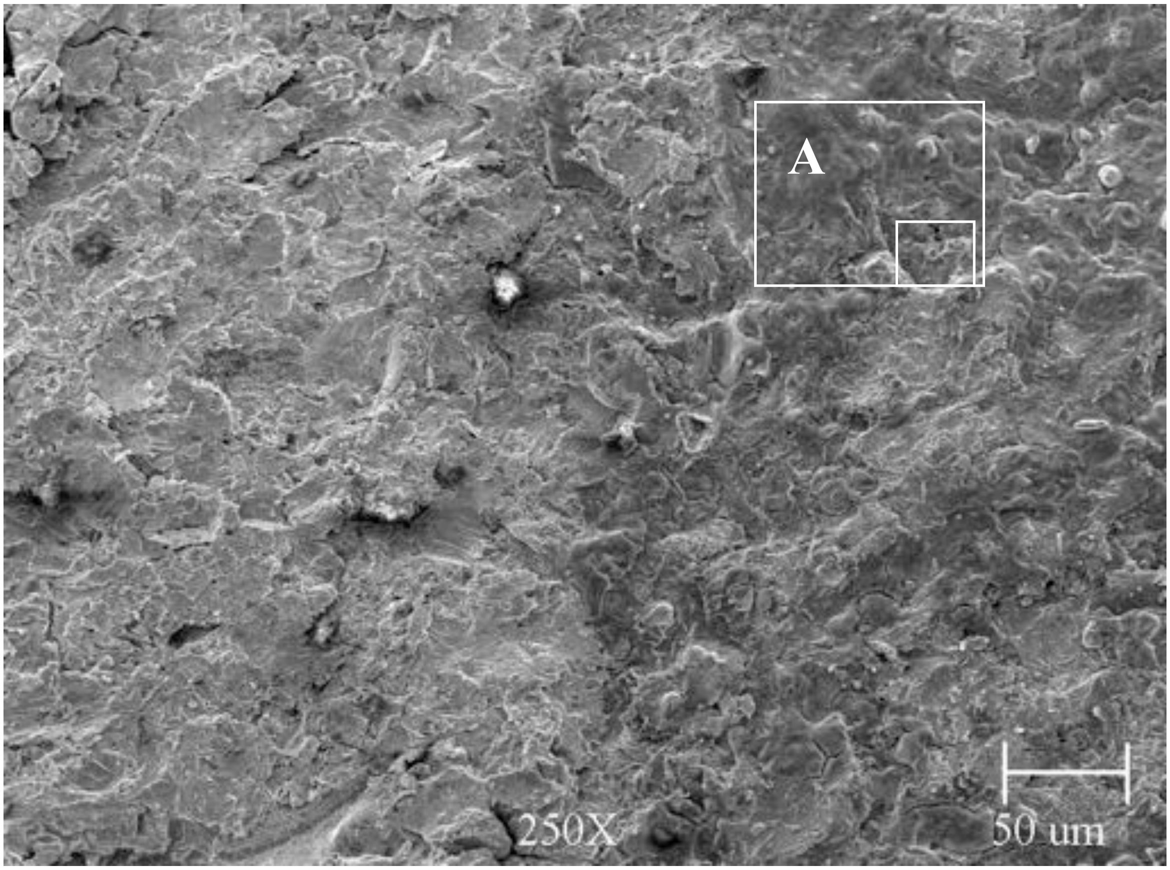
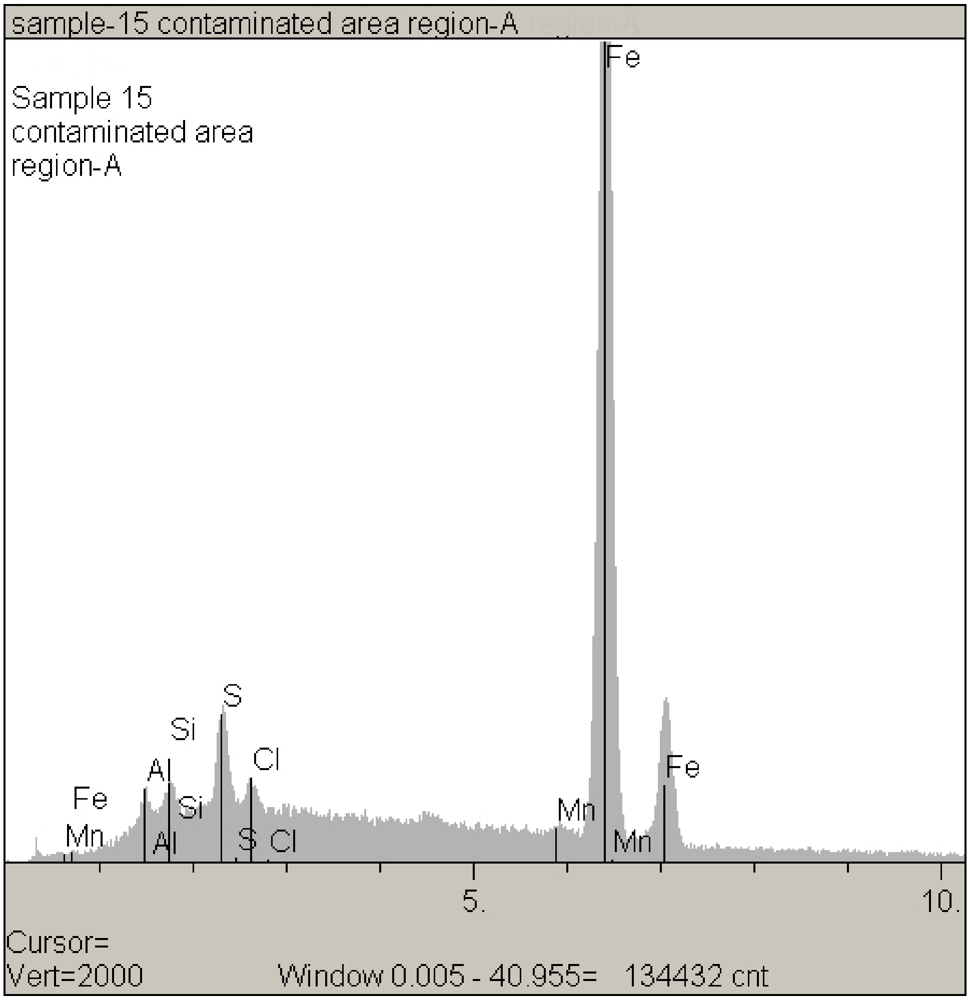


Sample #2 – EDS Report, Field A, Region A:

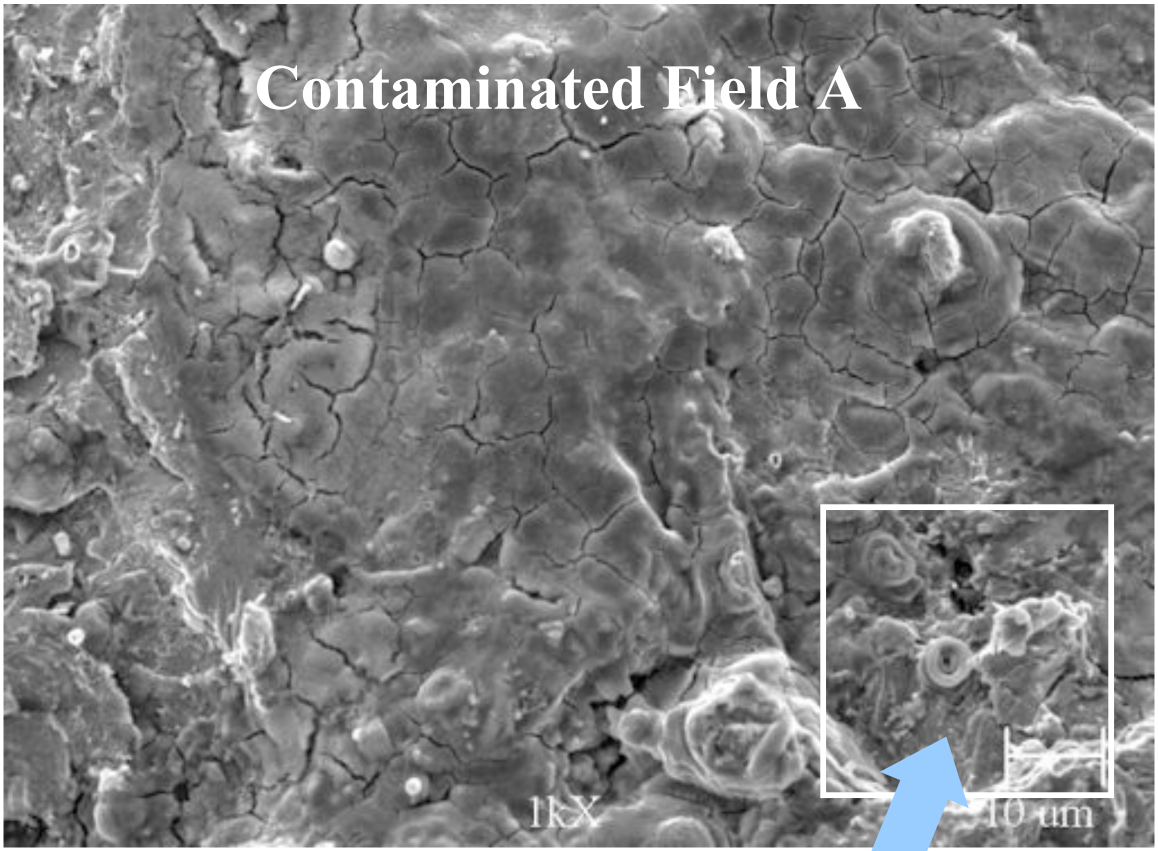


Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Al	Ka	14.57	0.986	1.620	wt.%	
Si	Ka	17.55	1.082	1.492	wt.%	
S	Ka	57.13	1.952	3.251	wt.%	
Cl	Ka	14.26	0.975	0.784	wt.%	
Mn	Ka	4.22	0.531	0.315	wt.%	
Fe	Ka	755.60	7.097	92.538	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

Sample #2 – Contaminated Side, Field A, Cont'd:

#7



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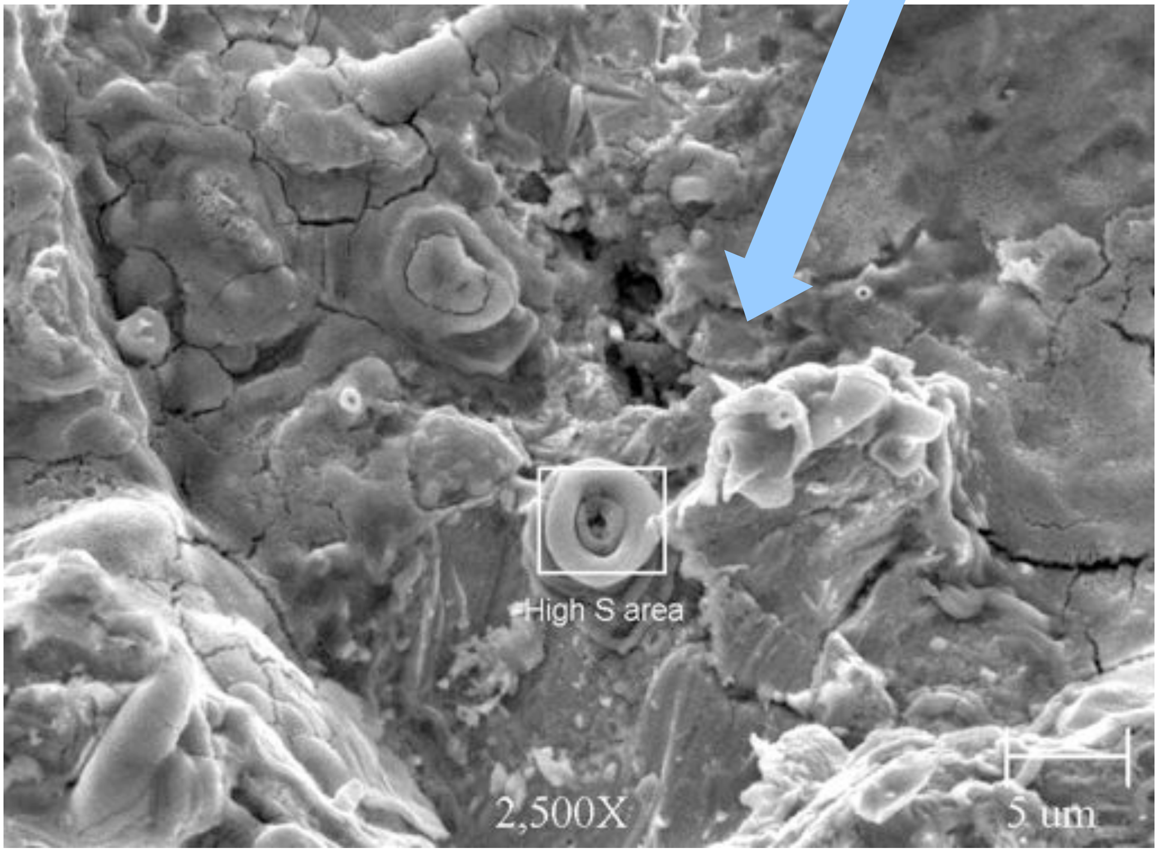
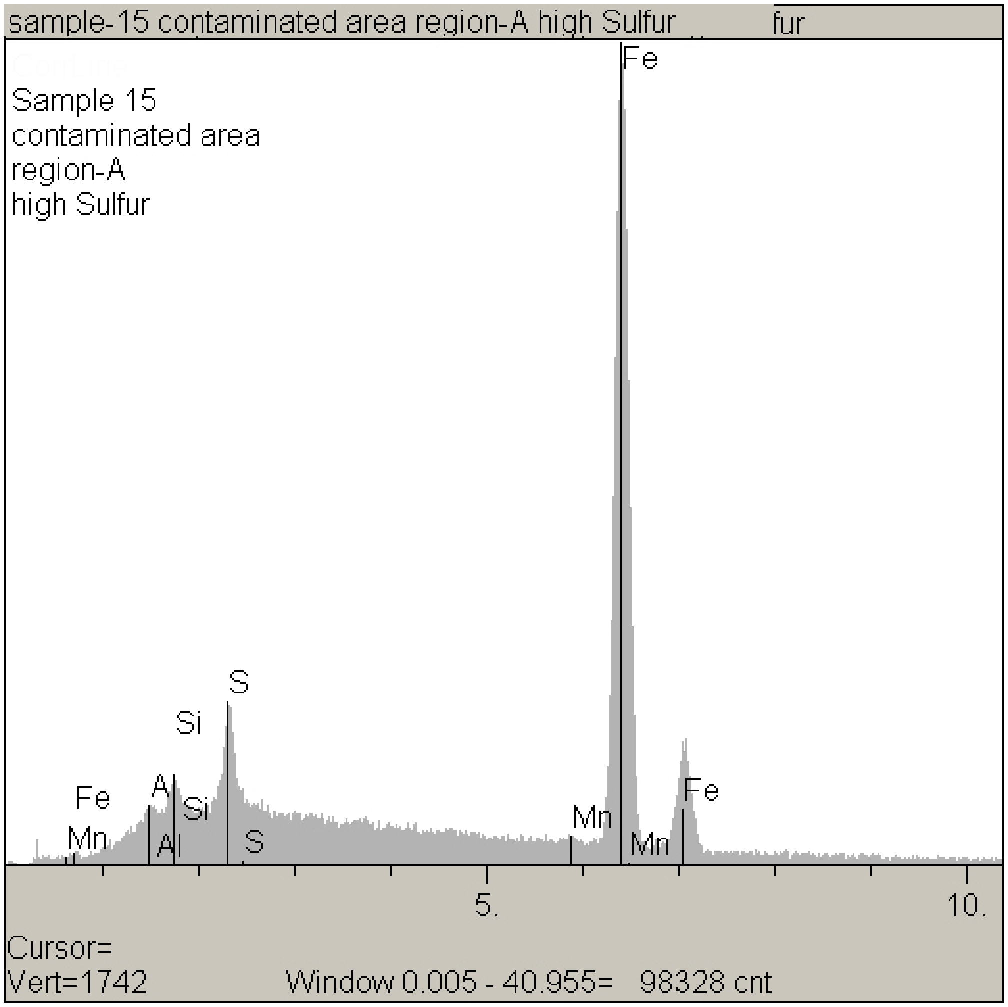


Sample #2 – EDS Report, Field A, Region A:



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Al	Ka	5.09	0.583	0.871	wt.%	
Si	Ka	14.24	0.974	1.846	wt.%	
S	Ka	50.59	1.836	4.423	wt.%	
Mn	Ka	2.79	0.431	0.320	wt.%	
Fe	Ka	490.90	5.720	92.540	wt.%	
				100.000	wt.%	Total

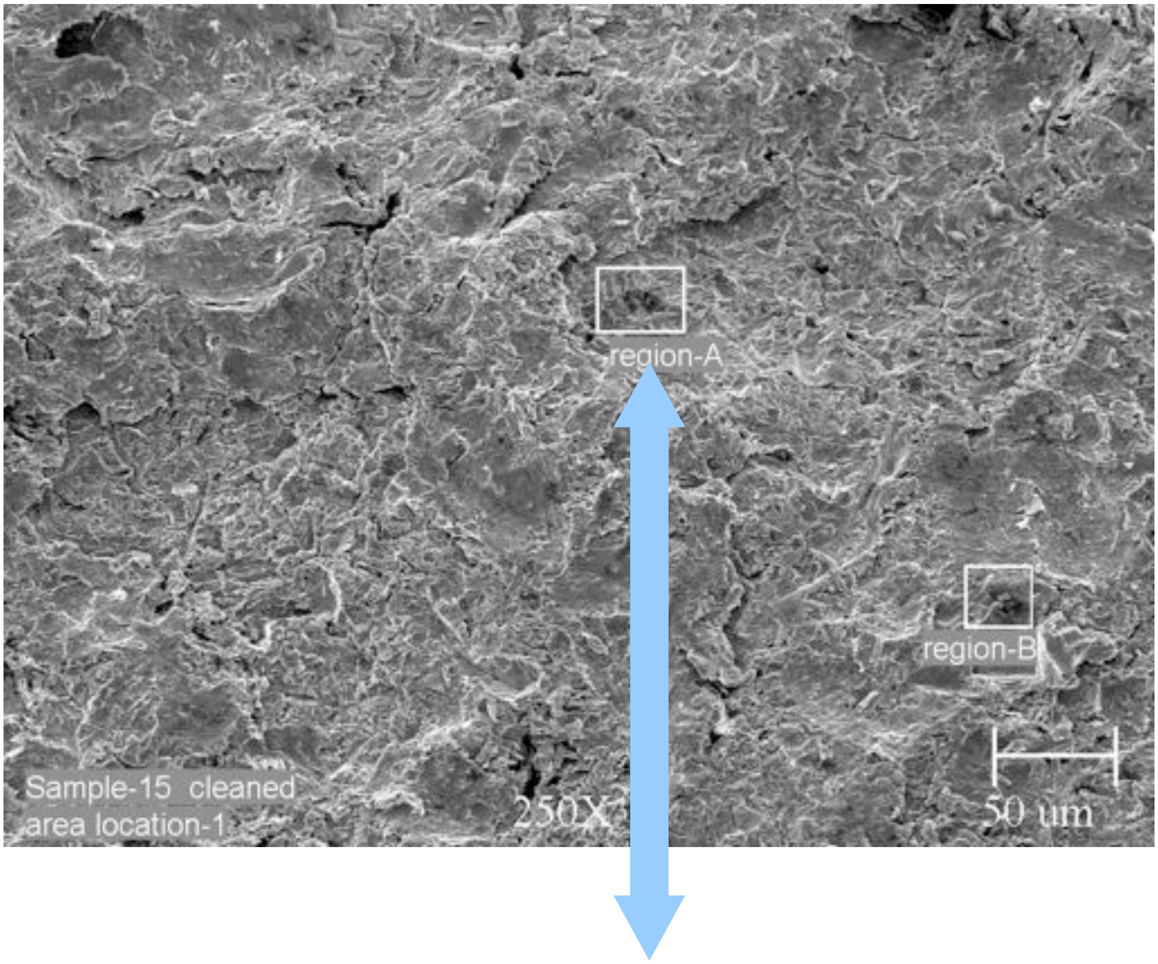
kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

Sample #2
Field B,
Regions A & B

EDS Reports &
Images - Decontaminated (Clean) Side

Sample #2 - Clean Side, Field B, Region A:

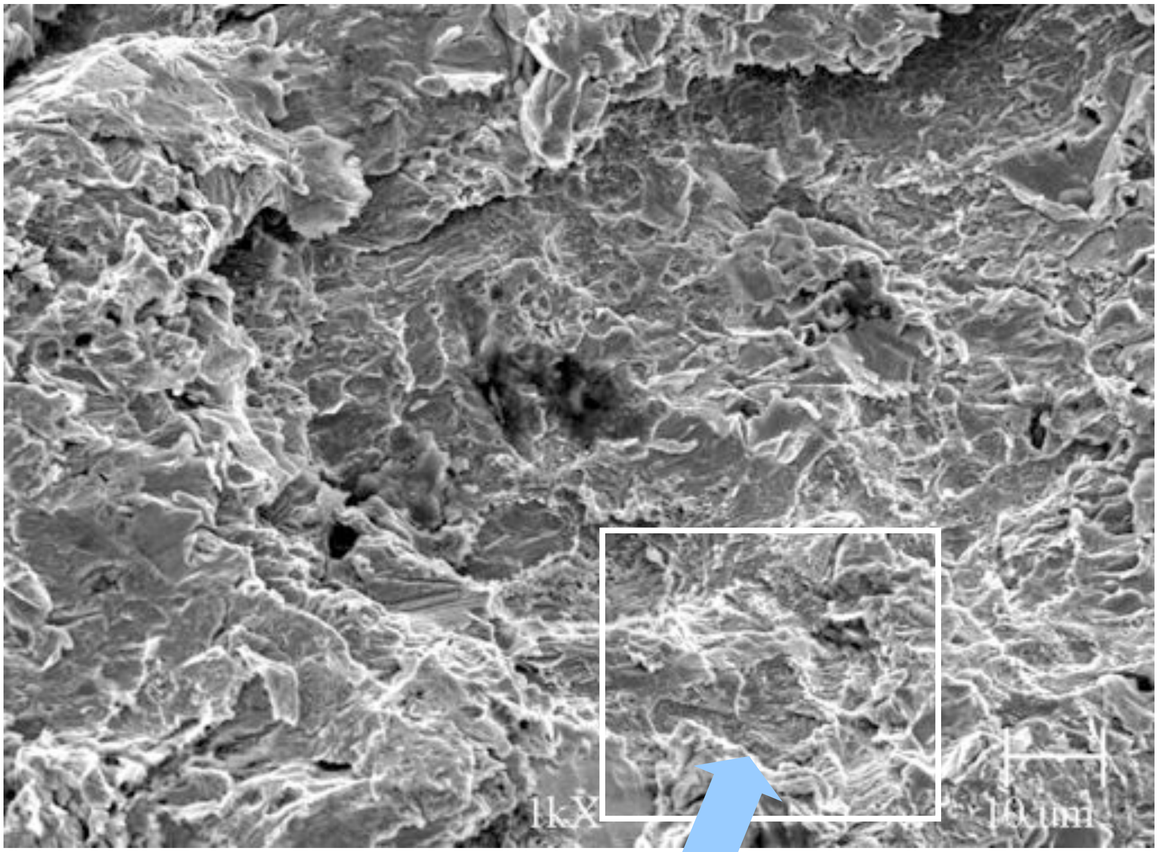
#9



See Images #10 & #11

Sample #2, Clean Side, Field B, Region A

#10



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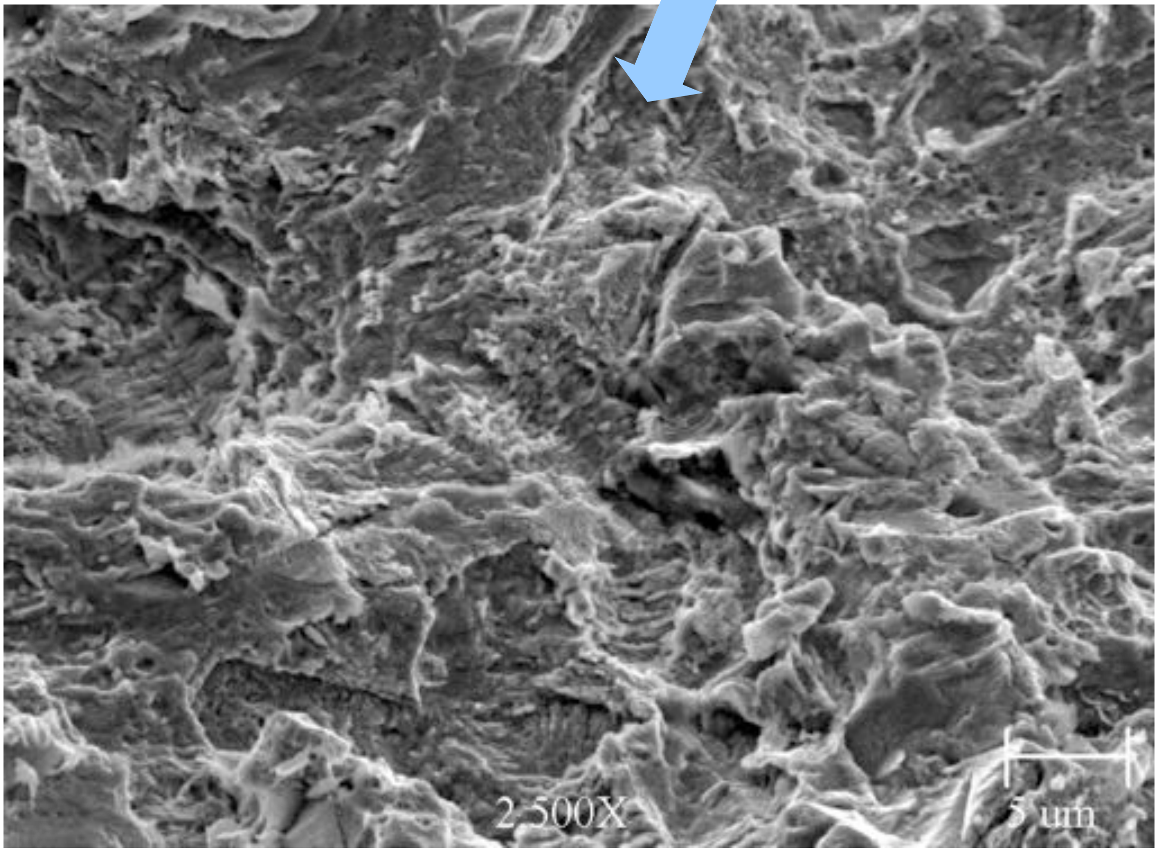
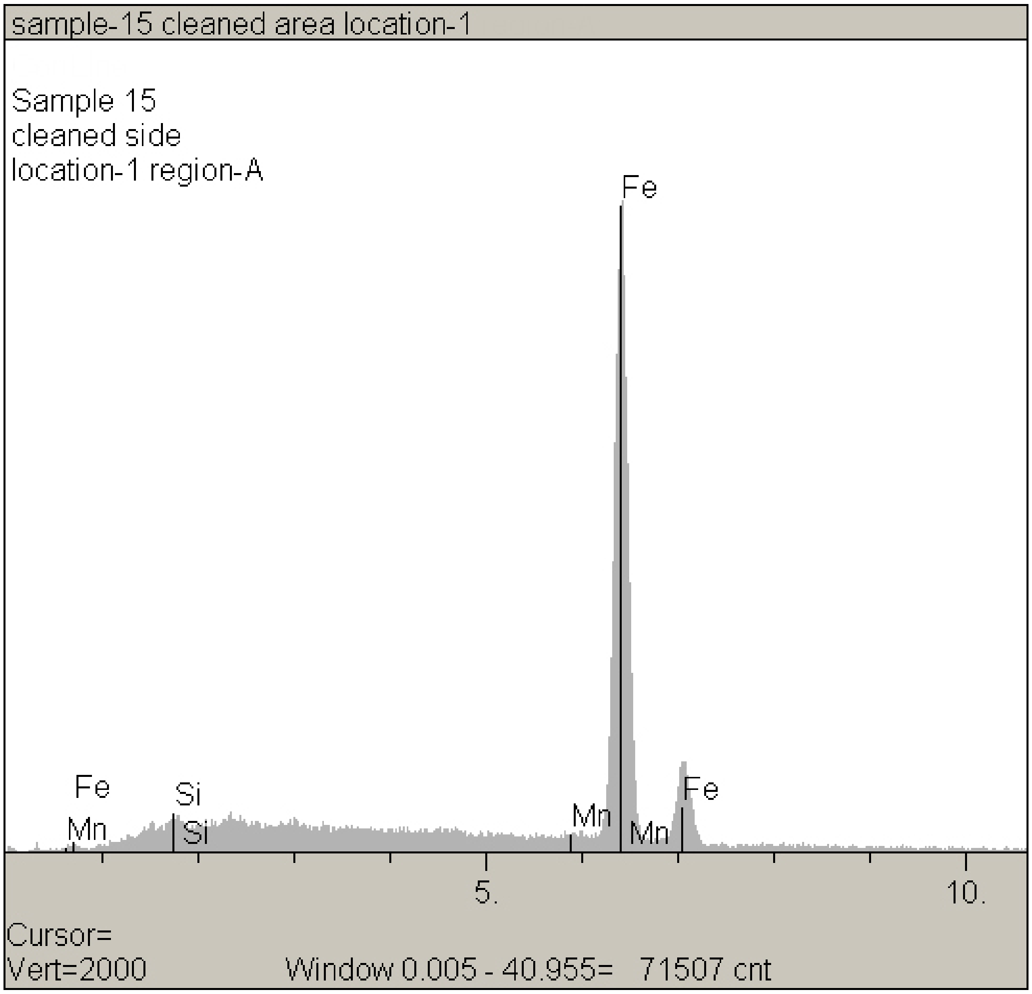


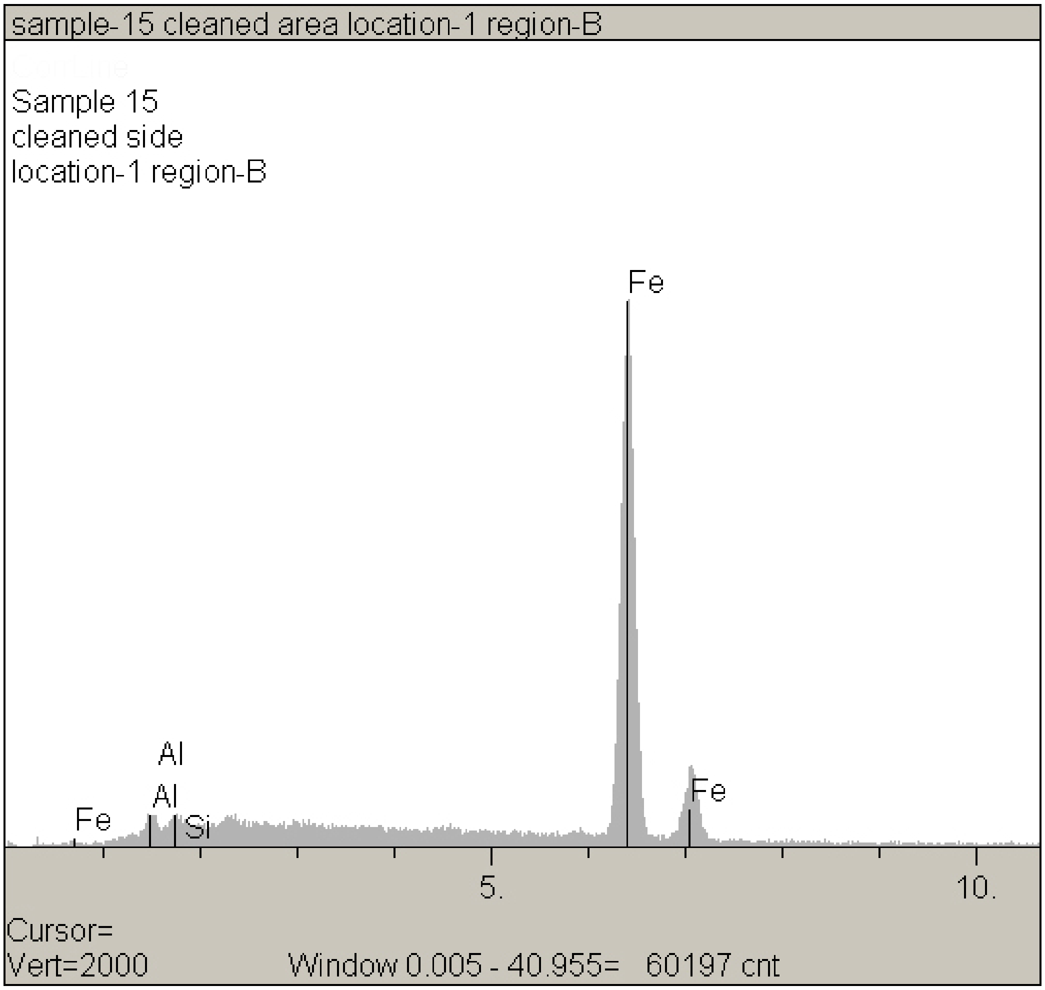
Sample #2, EDS Report, Field B, Region A



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Si	Ka	5.46	0.603	0.869	wt.%	
Mn	Ka	1.92	0.357	0.221	wt.%	
Fe	Ka	444.66	5.445	98.910	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

Sample #2, EDS Report, Field B, Region B



sample-15 cleaned area location-1 region-B

Sample 15
cleaned side
location-1 region-B

Cursor=
Vert=2000 Window 0.005 - 40.955= 60197 cnt

Elt.	**Line**	**Intensity (c/s)**	**Error 2-sig**	**Conc**	**Units**	
Al	Ka	7.87	0.724	1.917	wt.%	
Si	Ka	6.18	0.642	1.152	wt.%	
Fe	Ka	374.48	4.996	96.931	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

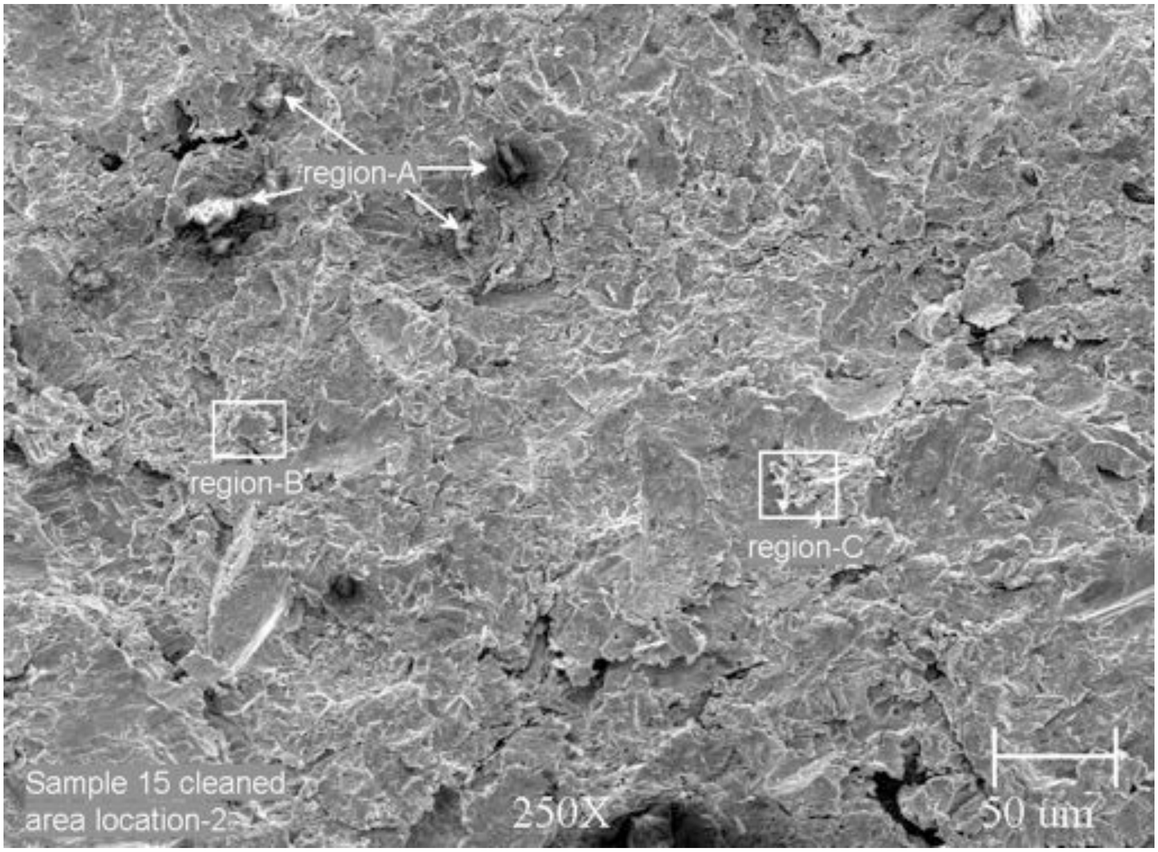
Sample #2

Field C
Regions A, B, C

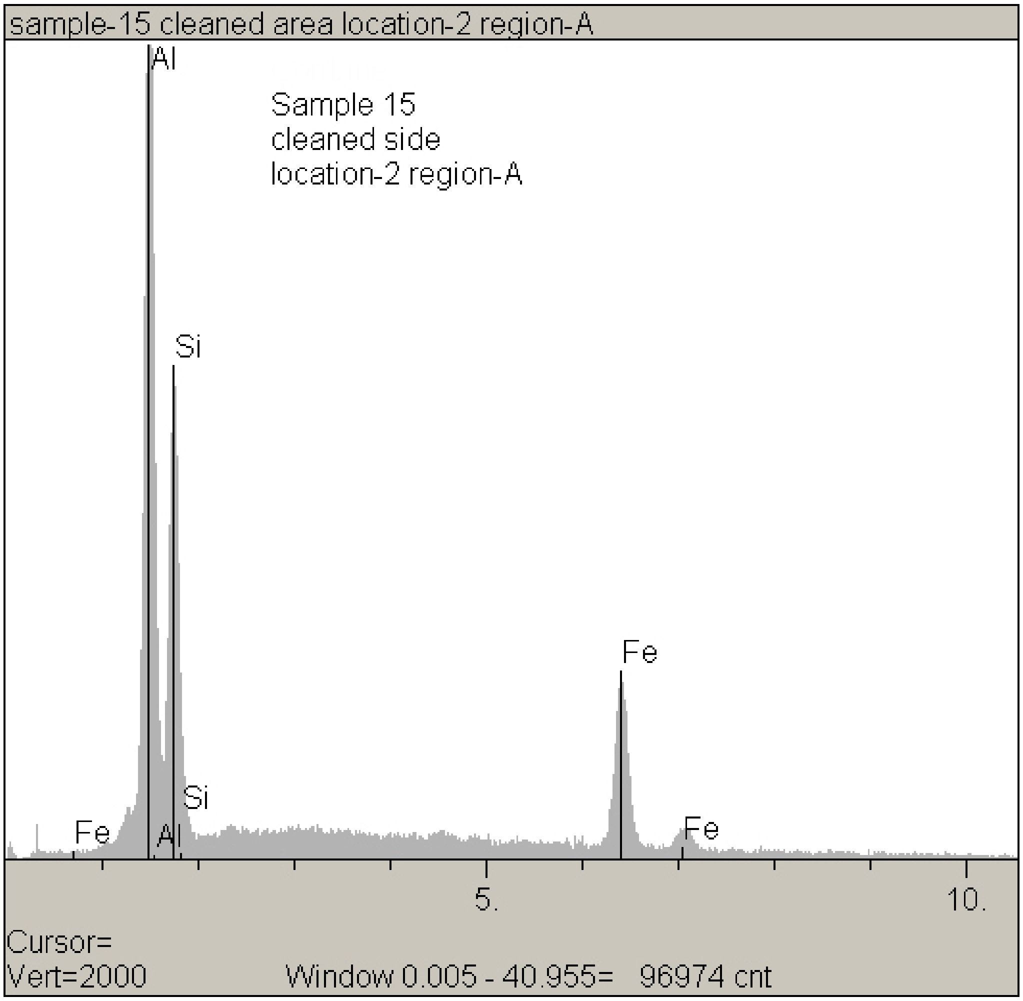
EDS Reports &
Images - Decontaminated (Clean) Side

Sample #2, Clean. Side, Field C, Regions A,B,C:

#12



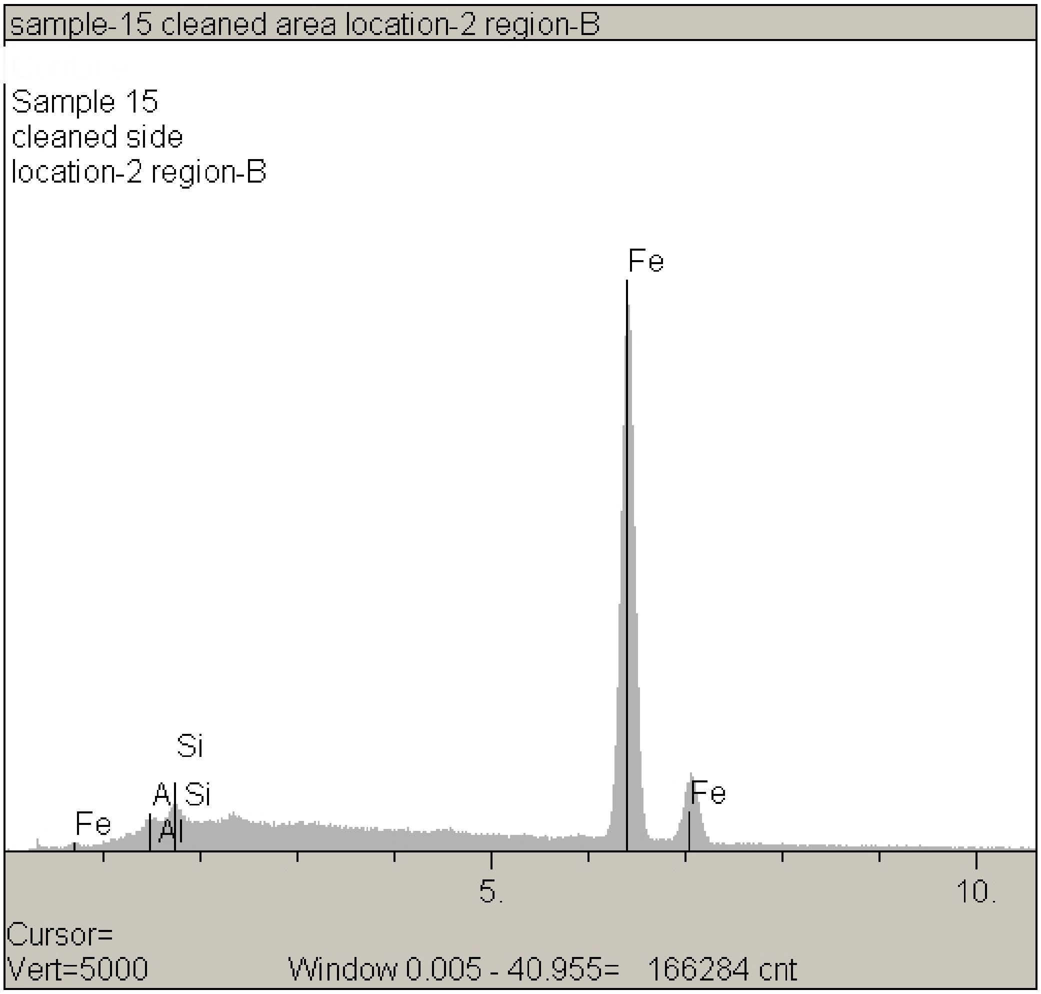
Sample #2, EDS Report, Field C, Region A



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Al	Ka	461.70	5.548	39.720	wt.%	
Si	Ka	236.35	3.969	34.473	wt.%	
Fe	Ka	115.43	2.774	25.807	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

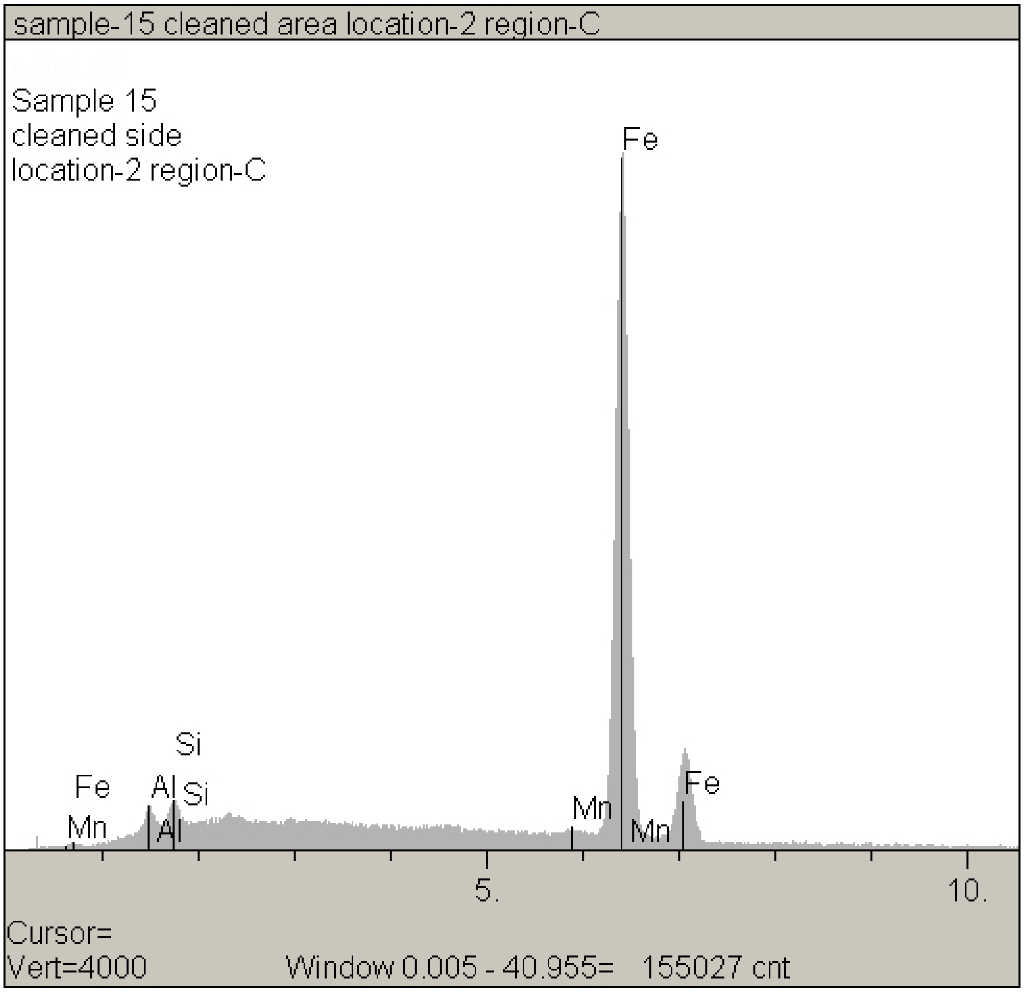
Sample #2, EDS Report, Field C, Region B



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Al	Ka	14.59	0.986	1.359	wt.%	
Si	Ka	28.54	1.379	2.022	wt.%	
Fe	Ka	973.30	8.055	96.619	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

Sample #2, EDS Report, Field C, Region C



sample-15 cleaned area location-2 region-C

ComLine

Sample 15
cleaned side
location-2 region-C

Cursor=
Vert=4000 Window 0.005 - 40.955= 155027 cnt

Elt.	Line	Intensity (c/s)	Error 2-sig	Conc	Units	
Al	Ka	19.80	1.149	1.842	wt.%	
Si	Ka	23.96	1.264	1.705	wt.%	
Mn	Ka	5.86	0.625	0.327	wt.%	
Fe	Ka	967.93	8.033	96.126	wt.%	
				100.000	wt.%	Total

kV 15.0
Takeoff Angle 10.0°
Elapsed Livetime 60.0

Anastas Technical Services
17300 Mercury
Houston, TX 77058
(281) 488-9736

January 18, 2012

[redacted]
P.O. Box 6553
Kingwood, TX 77325

Dear Mr. Hatle,

As requested I have examined and analyzed the corrosion coupon sample#15 that you submitted. The coupon sample was analyzed using a Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectrometer (EDS). It was desired to examine locations on the treated and untreated (corroded) sides of the coupon for the presence of corrosion products.

The sample was placed in the SEM and 15-20 locations were examined on the treated and untreated sides of the coupon. Each location was visually examined and the several regions of the surface deposits were checked using the EDS. Every location on the untreated side showed varying amounts of detectable Sulfur and Chlorine, in addition to Aluminum and Silicon along with Manganese and Iron that were components of the coupon base material. The deposits on the surface were typical for corrosion products and oxides. The examination of 15-20 locations on the treated side of the coupon showed no detectable Sulfur or Chlorine in any of the locations examined. There was evidence of embedded Aluminum and Silicon material that appears to be some type of abrasive blasting media. Several representative locations were documented and the SEM images and EDS spectra were submitted with the sample. If you have any questions or need any additional testing please let me know.

Thank you,

Tedd Anastas
Anastas Technical Services

Exhibits List:

**NOTE: Green areas indicate related images and EDS reports