

Manganese Reduction In Welding Project

ESIS[®]

**Reducing Welders' Exposure To
Manganese Welding Fume Using Low
Manganese Emissions Flux Core Wire**

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Objective

- The purpose of this study conducted by ESIS HS&E was to determine if welders' exposure to manganese welding fume is reduced by substituting low manganese (Mn) emissions flux core wire for the standard flux core wire.
- A secondary purpose of the study was to determine the effectiveness of the welder awareness training.
- This study also characterized welders' exposures to aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel, tin and zinc resulting from welding operations.

Locations

- **RAILCAR PRODUCTION**
- Texas
- October 29th, 30th & 31st, 2013
- **MARINE BARGE PRODUCTS**
- Louisiana
- July 8th, 9th and 10th, 2014

Background

- Welding joins materials together by melting a metal work piece along with a filler metal to form a strong joint. The welding process produces visible smoke that contains metallic fume and gas by-products.
- **Fume:** Airborne solid particulate, formed in air, by the vaporization and condensation of a metal. A fume is formed when a solid metal is melted and re-condenses in the air (i.e. welding fume, metal fumes, etc.). Because it is formed by condensation it is very small (<1 micron).

Background

- Welding in general has been linked with causing respiratory problems, lung cancers (due to hexavalent chromium) and metal (including lead) poisoning if controls are inadequate and exposures are significant.

Background

- Welding rods and many types of steel being welded contain manganese. During welding, metallic fumes are produced. These particles potentially can cause manganism, which is a severe form of chronic manganese poisoning and a malady that closely mimics Parkinson's disease.
- The welding industry acknowledges that high levels of manganese can be toxic and produce manganism as well as other associated central nervous system problems; but, still at issue is the dose that is needed to develop adverse health effects.

Background

Occupational Exposure Limits and Guidelines

- Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 5.0 milligrams per cubic meter (mg/m^3) as a Ceiling (C) value (please note this PEL threshold is over 40 years old and does not reflect the current scientific knowledge).

Background

Occupational Exposure Limits and Guidelines

- American Conference of Governmental Industrial Hygienist, which is a private, not-for-profit, non-governmental corporation whose members are industrial hygienist and safety professionals, publishes exposure guidelines know as Threshold Limit Values (TLVs).
- TLV for manganese is 0.02 milligrams per cubic meter [mg/m^3] or 20 micrograms per cubic meter [$20 \mu\text{g}/\text{m}^3$] as an 8-hour time-weighted average.

Background

- TLV is controversial and most industries would have practical difficulty reducing welders' exposures to those levels.
- Bailey et al,¹: “Our results suggest an occupational exposure level for welders that is 5- to 10-fold higher than the recently adopted ACGIH 8-hour TLV-TWA for respirable particulate Mn of 20 $\mu\text{g}/\text{m}^3$.”

¹ (Presented at 53rd Annual Meeting and ToxExpo Society of Toxicology (2014) Phoenix, AZ; March 23 - 27, 2014)

Texas Railcar Production

- ESIS HS&E collected ten (10) personal air samples on day one of the study while the welders used Hobart Formula XL-550 flux core welding wire. On day two of the study ESIS HS&E collected ten (10) personal air samples while the welders used Hobart Element 71T1C low manganese emissions flux core wire to determine the effectiveness of the low manganese flux core wire in reducing employee exposure to manganese fume.

Texas Railcar Production

- Based upon the ESIS sample results the mean (average) employee exposure using the 71T1C low manganese flux core wire was 0.359 mg/m³ which represent a **65%** reduction from the baseline XL-550 wire mean of 1.02 mg/m³.
- The results were statistically significant.

Texas Railcar Production

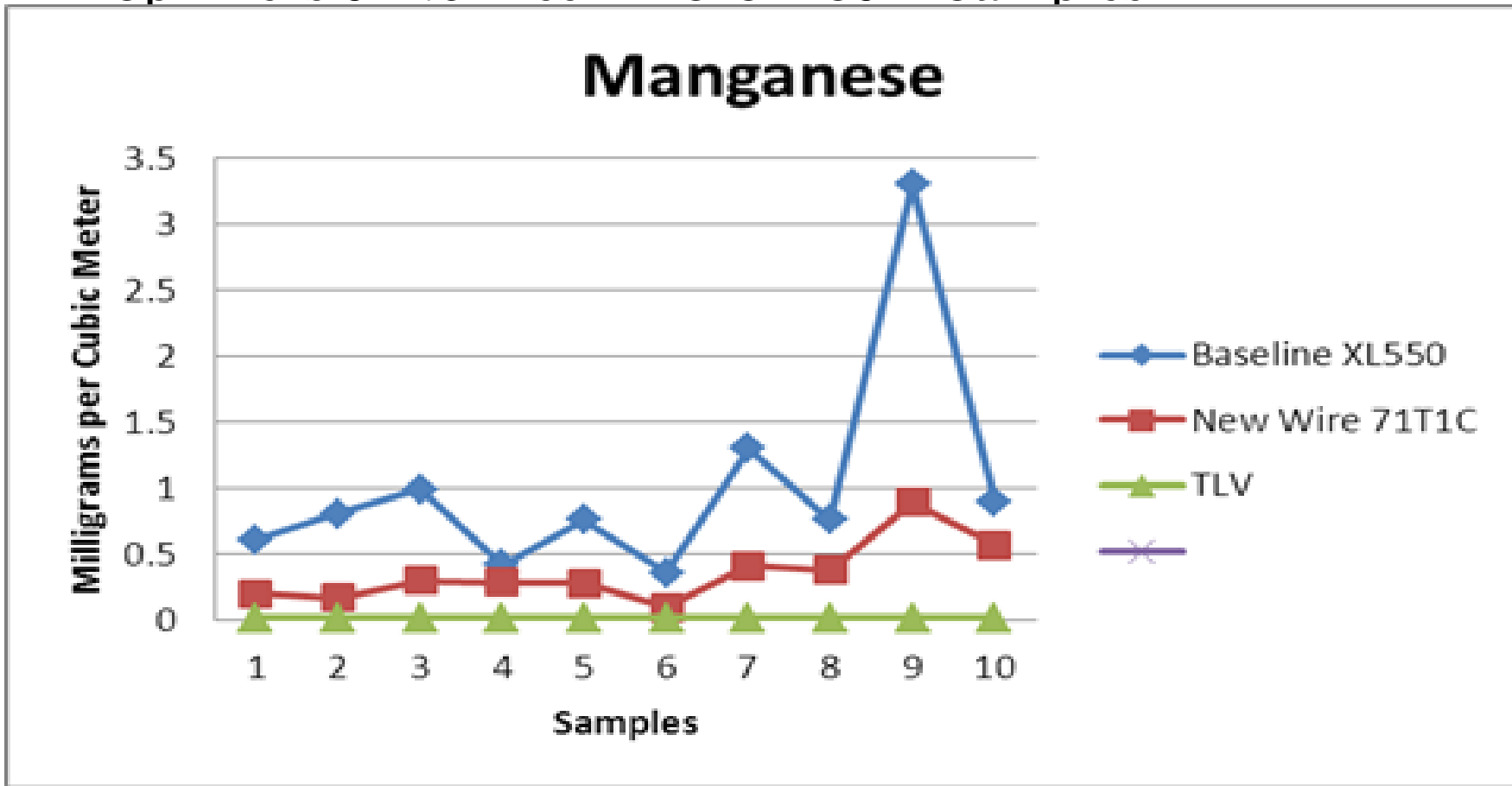
Standard vs. Low Manganese Flux Core Wire

– Spinners & Nozzles Mn Results – ESIS HS&E Samples

Descriptive Statistics	October 29, 2013 Formula XL-550 Flux Core Wire (Standard Wire Used)	October 30, 2013 Element 71T1C Flux Core Wire (Low Manganese Wire Tested)	Comment
Number of Samples (n)	10	10	All samples were obtained from under welding helmet.
Maximum	3.3	0.89	
Minimum	0.36	0.1	
Range	2.94	0.79	---
Mean	1.02	0.359	65% reduction from XL-550
Median	0.785	0.295	62% reduction from XL-550
Standard Deviation	0.846	0.229	---
Geometric Mean	0.835	0.303	64% reduction from XL-550
Geometric Standard Deviation	1.85	1.86	---

Texas Railcar Production

Standard vs. Low Manganese Flux Core Wire
 – Spinners & Nozzles – ESIS HS&E Samples



Texas Railcar Production

- Ten (10) personal air samples were collected by ESIS HS&E on day one of the study while the welders used Hobart Formula XL-550 flux core welding wire. After their shift on day two, welders attended welder awareness training conducted by Lincoln Electric. On day three of the study 10 personal air samples were collected by ESIS HS&E while the welders used Formula XL-550 flux core wire to determine the effectiveness of the welder awareness training.

Texas Railcar Production

- The mean employee exposure based upon ESIS HS&E manganese sample results following the welding awareness training was 0.773 mg/m³ or a **24%** reduction from the baseline mean of 01.02 mg/m³.
- The results were not statistically significant.

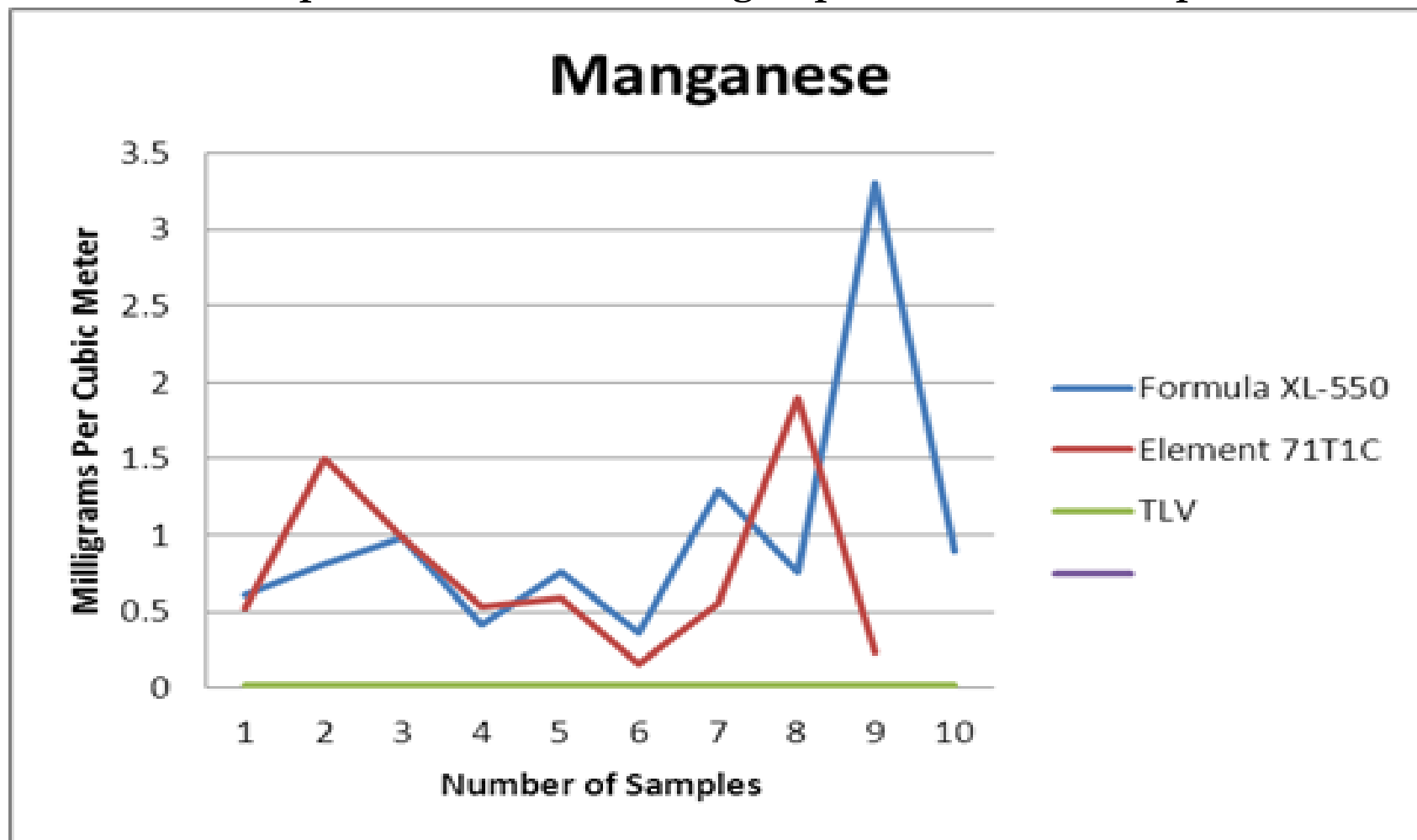
Texas Railcar Production

Baseline Exposure vs. Post Training Exposure – ESIS Sample Results

Descriptive Statistics	October 29, 2013 Formula XL-550 Flux Core Wire (Standard Wire Used) Baseline	October 31, 2013 Formula XL-550 Flux Core Wire (Standard Wire Used) Post Training	Comment
Number of Samples (n)	10	9	All samples were obtained from under welding helmet
Maximum	3.3	1.9	
Minimum	0.36	0.16	
Range	2.94	1.74	---
Mean	1.02	0.773	24% reduction from XL-550
Median	0.785	0.55	30% reduction from XL-550
Standard Deviation	0.846	0.583	---
Geometric Mean	0.835	0.594	29% reduction from XL-550
Geometric Standard Deviation	1.85	2.23	---

Texas Railcar Production

- Baseline Exposure vs. Post Training Exposure – ESIS Sample Results



Texas Railcar Production

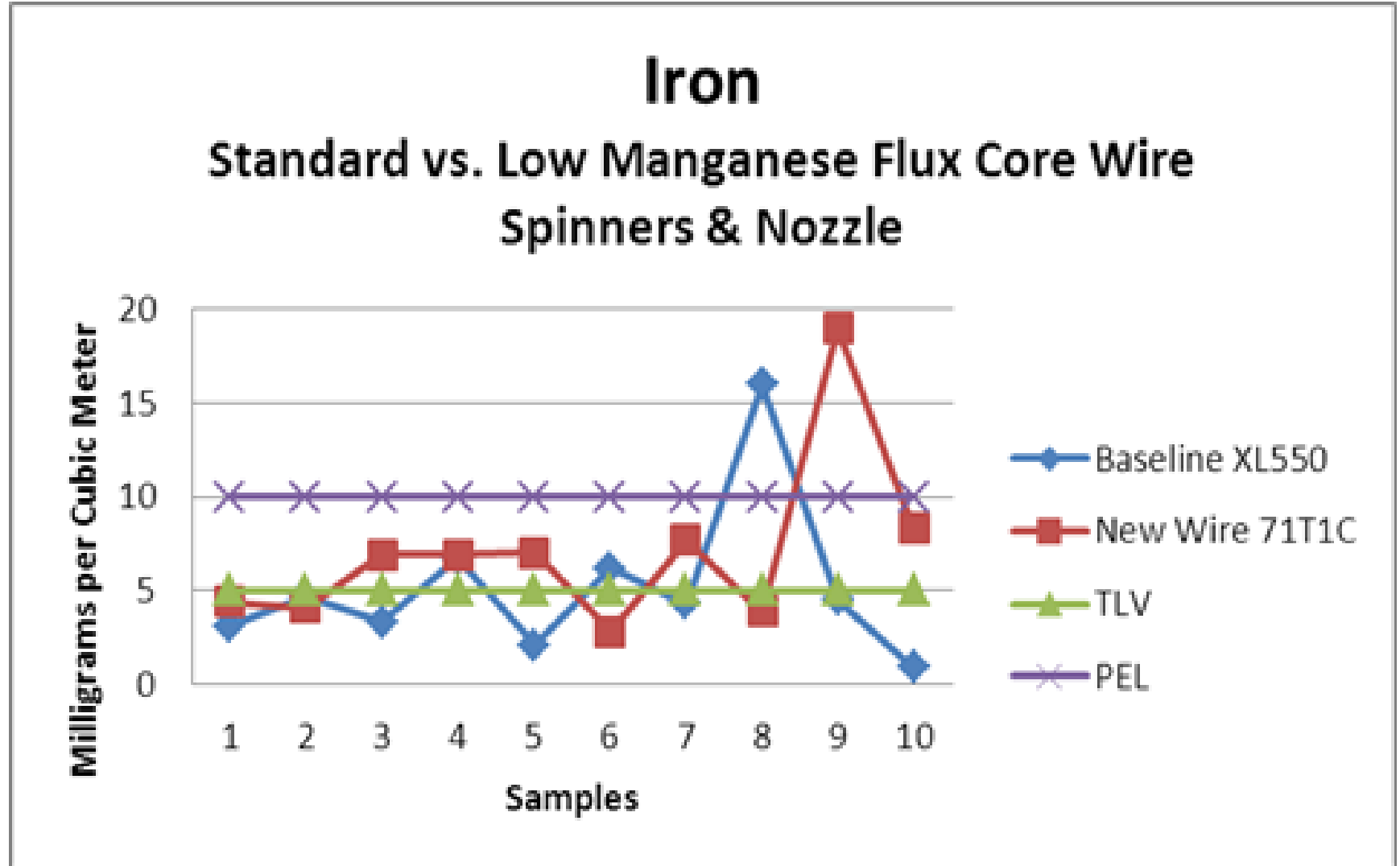
- Additional Findings from ESIS HS&E Sample Results
 - The mean iron oxide concentrations increased **28%** from the baseline with the standard wire having a mean of 5.56 mg/m³ for iron oxide versus a mean of 7.1 mg/m³ for the low manganese flux core wire.
 - Aluminum, cadmium, chromium, copper, lead, nickel, tin and zinc oxide were not detected at concentrations at or above the applicable occupational exposure limits.

Texas Railcar Production

Standard vs. Low Manganese Flux Core Wire
 –Iron Oxide Results – ESIS HS&E Sample Results

Descriptive Statistics	October 29, 2013 Formula XL-550 Flux Core Wire (Standard Wire Used)	October 30, 2013 Element 71T1C Flux Core Wire (Low Manganese Wire Tested)	Comment
Number of Samples (n)	10	10	All samples were obtained from under welding helmet.
Maximum	16	19	
Minimum	2.1	2.8	
Range	13.9	16.2	---
Mean	5.56	7.1	28% increase from XL-550
Median	4.6	6.9	50% increase from XL-550
Standard Deviation	3.92	4.58	---
Geometric Mean	4.77	6.17	29% increase from XL-550
Geometric Standard Deviation	1.72	1.70	---

Texas Railcar Production



Marine Barge Products

- Nine (9) personal air samples were collected by ESIS HS&E on day one of the study while the welders used ESAB Dual Shield 7100LC flux core welding wire. On day two of the study, nine (9) personal air samples were collected by ESIS HS&E while the welders used Hobart Element 71T1C low manganese emissions flux core wire to determine the effectiveness of the low manganese flux core wire in reducing employee exposure to manganese fume.

Marine Barge Products

- Based upon the ESIS HS&E sample results the mean employee exposure to manganese using the 71T1C low manganese flux core wire was 0.188 mg/m³ which represent a **64%** reduction from the baseline 7100LC wire mean of 0.521 mg/m³.
- The results were statistically significant.

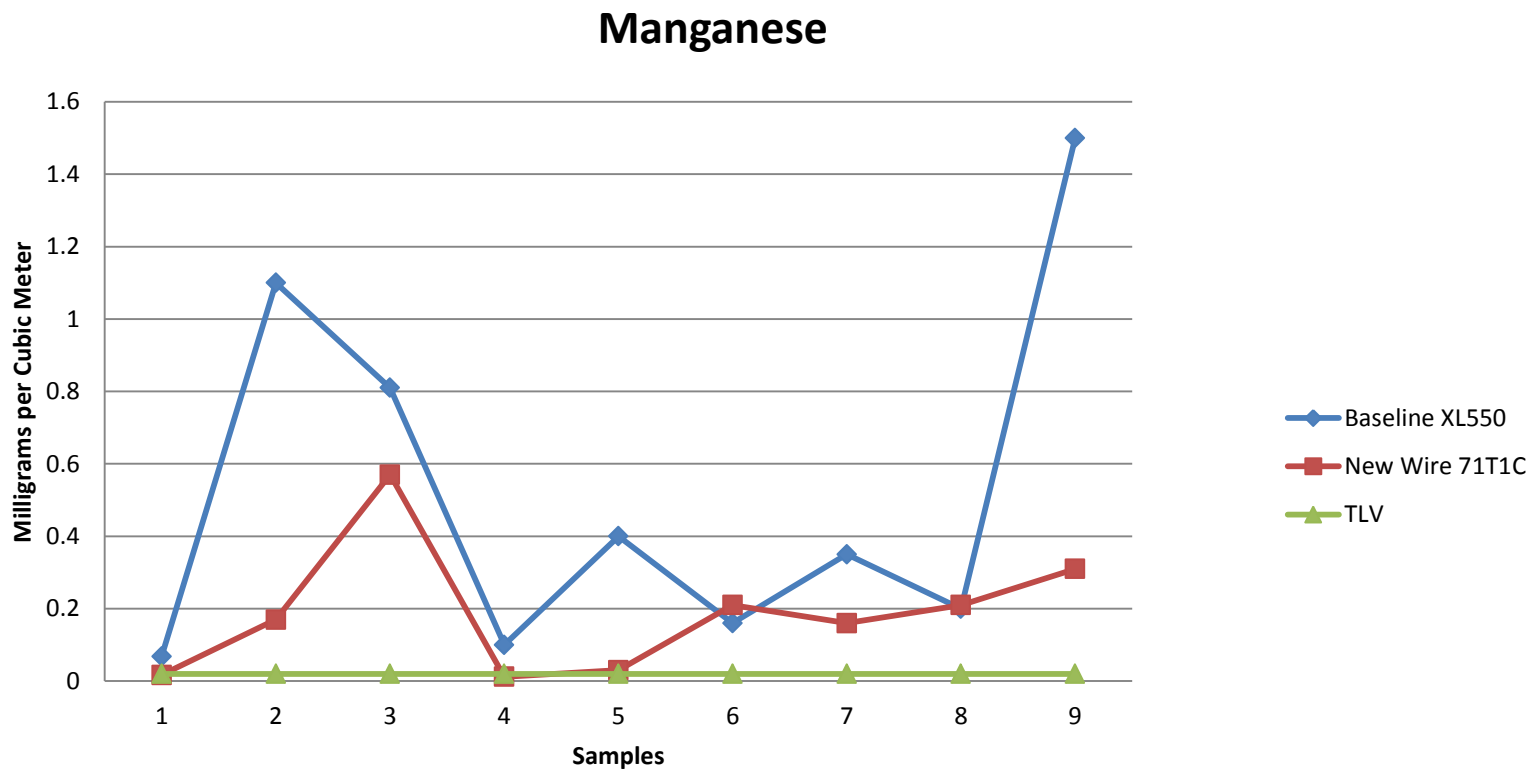
Marine Barge Products

Standard vs. Low Manganese Flux Core Wire
 – Mn Results for All Sampled Locations (trunks, bottoms, rakes, sterns, erection and sides) – ESIS HS&E Samples.

Descriptive Statistics	July 8, 2014 ESAB Dual Shield 7100LC Flux Core Wire (Standard Wire Used)	July 9, 2014 Element 71T1C Flux Core Wire (Low Manganese Wire Tested)	Comment
Number of Samples (n)	9	9	All samples were obtained from under welding helmet.
Maximum	1.5	0.57	
Minimum	0.068	0.012	
Range	1.432	0.588	---
Mean	0.521	0.188	64% reduction from 7100LC
Median	0.35	0.17	51% reduction from 7100LC
Standard Deviation	0.505	0.176	---
Geometric Mean	0.325	0.103	68% reduction from 7100LC
Geometric Standard Deviation	2.94	3.93	---

Marine Barge Products

- Standard vs. Low Manganese Flux Core Wire
- Mn Results for All ESIS HS&E Sampled Locations



Marine Barge Products

- Nine (9) personal air samples were collected by ESIS HS&E on day one of the study while the welders used ESAB Dual Shield 7100LC flux core welding wire. Prior to their shift on day three, welders attended welder awareness training using a DVD and supplemental information was provided by the welding instructor. On day three of the study nine (9) personal air samples were collected by ESIS HS&E while the welders used ESAB Dual Shield 7100LC flux core welding wire to determine the effectiveness of the welder awareness training.

Marine Barge Products

- The mean employee exposure to manganese following the welding awareness training was 0.359 mg/m³ or a **31%** reduction from the baseline mean of 0.521 mg/m³.
- The results were not statistically significant.

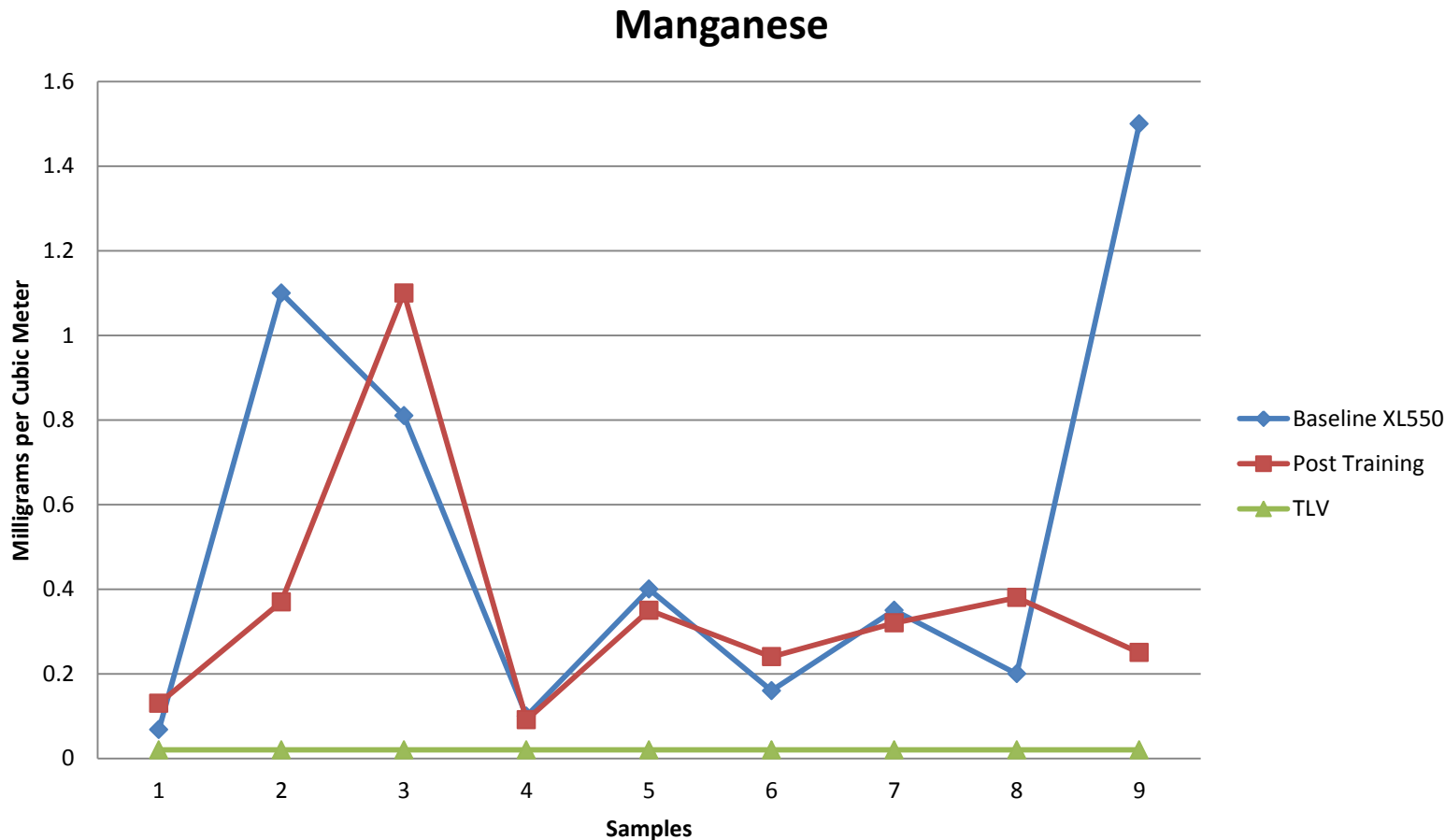
Marine Barge Products

- Baseline Exposure vs. Post Training Exposure – ESIS HS&E Samples

Descriptive Statistics	July 8, 2014 ESAB Dual Shield 7100LC Flux Core Wire (Standard Wire Used) Baseline	July 10, 2014 ESAB Dual Shield 7100LC Flux Core Wire (Standard Wire Used) Post Training	Comment
Number of Samples (n)	9	9	All samples were obtained from under welding helmet
Maximum	1.5	1.1	
Minimum	0.068	0.091	
Range	1.432	1.009	---
Mean	0.521	0.359	31% reduction from 7100LC
Median	0.35	0.32	8% reduction from 7100LC
Standard Deviation	0.505	0.296	---
Geometric Mean	0.325	0.285	12% reduction from 7100LC
Geometric Standard Deviation	2.94	2.03	---

Marine Barge Products

- Baseline Exposure vs. Post Training Exposure – ESIS HS&E Samples



Marine Barge Products

- Additional Findings from ESIS HS&E Samples
 - The mean iron oxide concentrations decreased **2%** from the baseline with the standard wire having a mean of 2.13 mg/m³ for iron oxide versus a mean of 2.08 mg/m³ for the low manganese flux core wire. Basically, there was no change in the concentration.
 - Aluminum, cadmium, chromium, copper, lead, nickel, tin and zinc oxide were not detected at concentrations at or above the applicable occupational exposure limits.

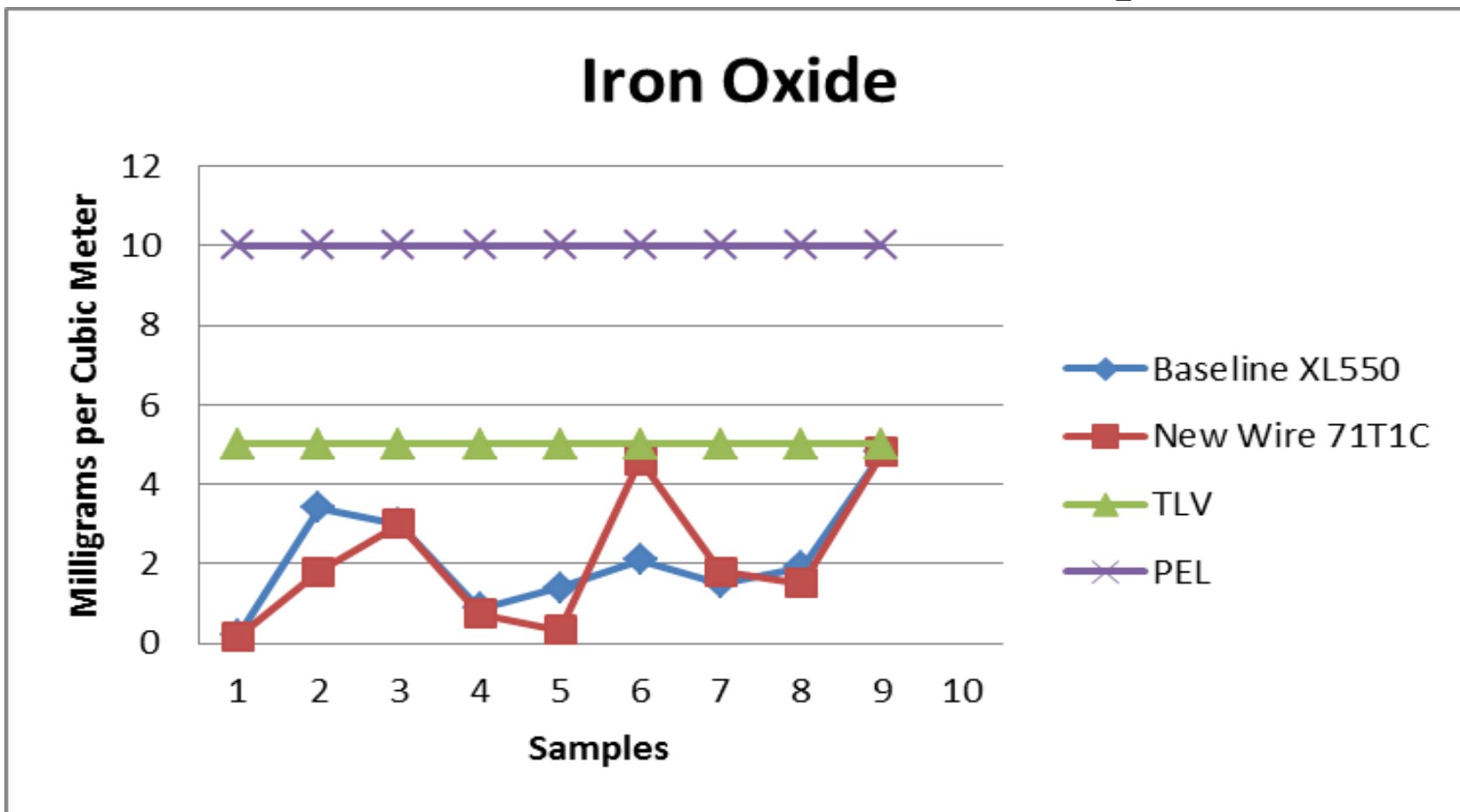
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Standard vs. Low Manganese Flux Core Wire –Iron Oxide Results – ESIS HS&E Samples

Descriptive Statistics	July 8, 2014 ESAB Dual Shield 7100LC Flux Core Wire (Standard Wire Used)	July 9, 2014 Element 71T1C Flux Core Wire (Low Manganese Wire Tested)	Comment
Number of Samples (n)	9	9	All samples were obtained from under welding helmet.
Maximum	4.8	4.8	
Minimum	0.22	0.16	
Range	4.58	4.64	---
Mean	2.13	2.08	2% decrease from 7100LC
Median	1.9	1.8	5% decrease from 7100LC
Standard Deviation	1.4	1.72	---
Geometric Mean	1.62	1.32	18% decrease from 7100LC
Geometric Standard Deviation	2.48	3.21	---

Marine Barge Products

Standard vs. Low Manganese Flux Core Wire
 –Iron Oxide Results – ESIS HS&E Samples



Combined Results

Rail and Barge

- Based upon ESIS HS&E sample results the mean (average) employee exposure using the low manganese flux core wire was 0.278 mg/m³ which represent a **63%** reduction from the baseline XL-550 wire mean of 0.784 mg/m³.
- The results were statistically significant.

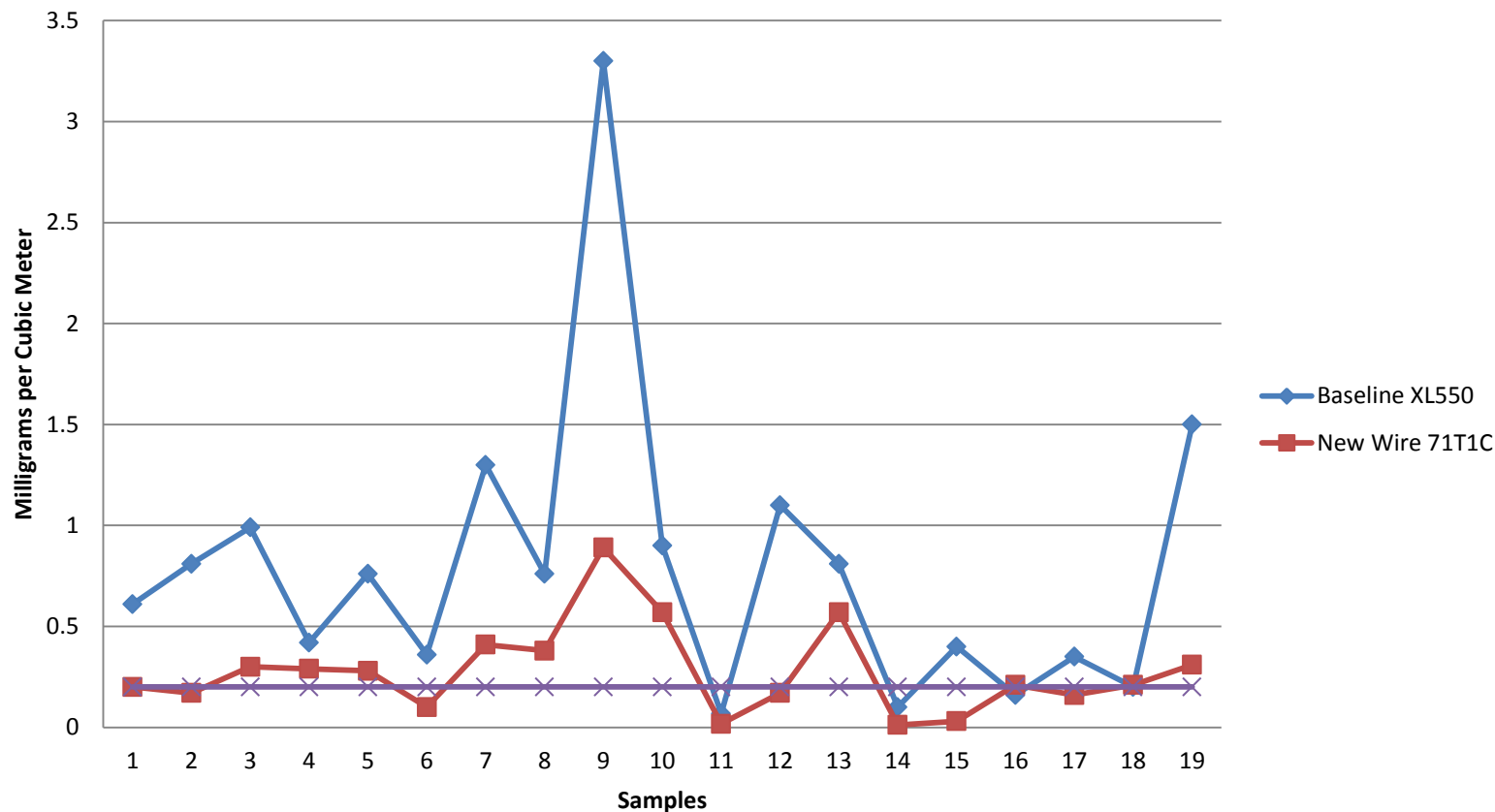
Combined Results Rail and Barge

Standard vs. Low Manganese Flux Core Wire – ESIS HS&E Samples

Descriptive Statistics	Combined Formula XL-550 Flux Core Wire (Standard Wire Used)	Low Manganese Wire Tested	Comment
Number of Samples (n)	19	19	All samples were obtained from under welding helmet.
Maximum	3.3	0.89	
Minimum	0.068	0.012	
Range	3.2	0.878	---
Mean	0.784	0.278	64% reduction from XL-550
Median	0.76	0.21	72% reduction from XL-550
Standard Deviation	0.732	0.218	---
Geometric Mean	0.534	0.182	66% reduction from XL-550
Geometric Standard Deviation	2.64	3.17	---

Combined Results Rail and Barge

Manganese
Standard vs. Low Manganese Flux Core Wire
Combined Results



Combined Results Rail and Barge

- The mean employee exposure to manganese following the welding awareness training was 0.566 mg/m³ or a **31%** reduction from the baseline mean of 0.521 mg/m³.
- The results were not statistically significant.

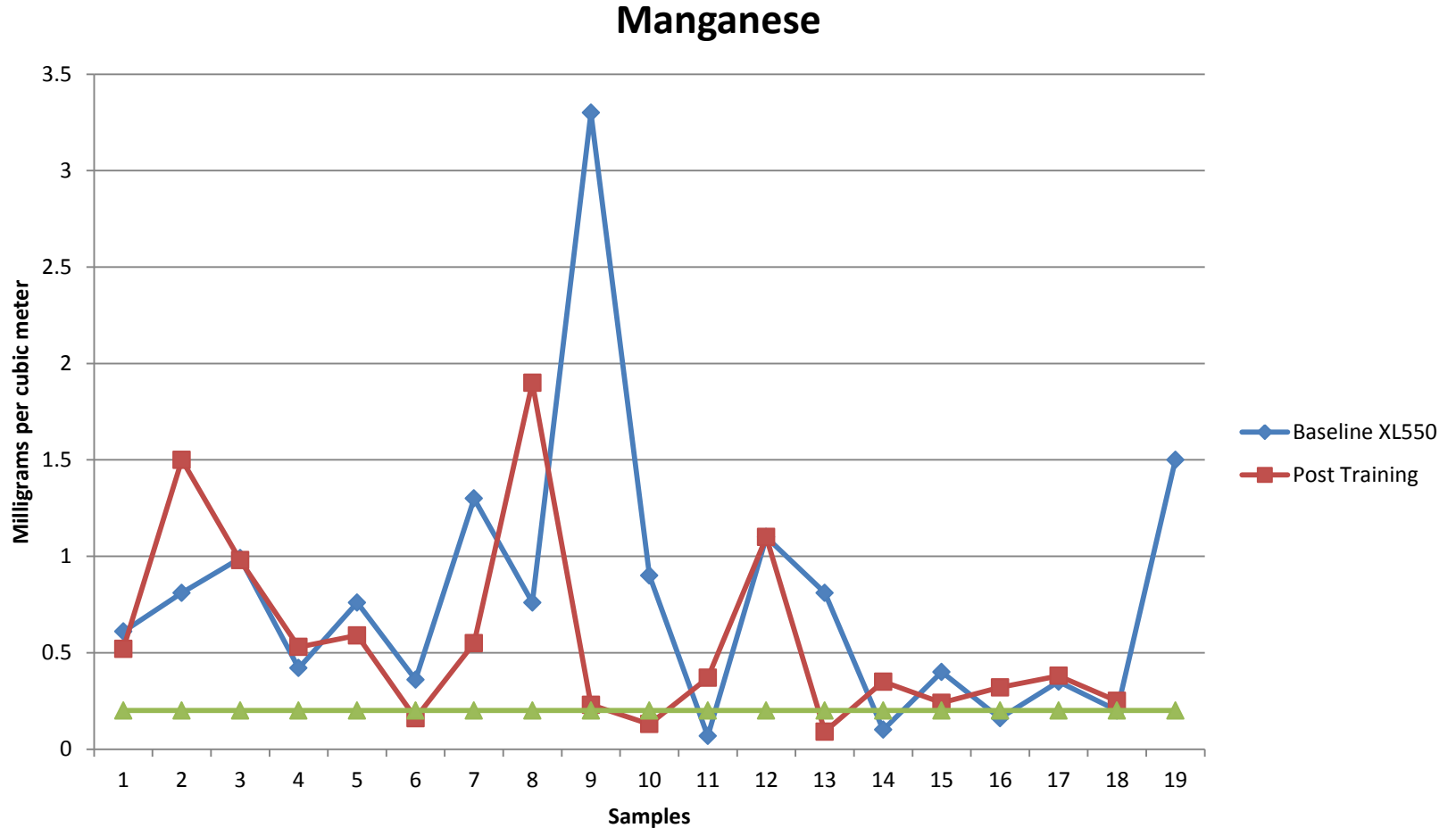
Combined Results Rail and Barge

- Baseline Exposure vs. Post Training Exposure

Descriptive Statistics	Combined Formula XL-550 Flux Core Wire (Standard Wire Used)	Low Manganese Wire Tested	Comment
Number of Samples (n)	19	18	All samples were obtained from under welding helmet.
Maximum	3.3	1.9	
Minimum	0.068	0.091	
Range	3.2	1.8	---
Mean	0.784	0.566	28% reduction from XL-550
Median	0.76	0.375	51% reduction from XL-550
Standard Deviation	0.732	0.497	---
Geometric Mean	0.534	0.411	23% reduction from XL-550
Geometric Standard Deviation	2.64	2.28	---

Combined Results Rail and Barge

- Baseline Exposure vs. Post Training Exposure



Conclusions

- The low manganese flux core wire did have a statistically significant desired outcome of reducing employee exposure to manganese.
- While not statistically significant; the training program also appeared to have a positive effect.

Recommendations

- It is recommended that combination of the low manganese emissions flux core wire coupled with welder training be used as part of a welding fume control program. Before switching welding wire a determination of effects on weld quality and operational efficiency should be made.
- The use of low manganese (Mn) emissions flux core will aid in reducing welders' exposure to manganese welding fume.

