SSAB

October 23, 2024

Adam Rhodes
ADEM – Land Division
Solid Waste Branch
Materials Management Section
1400 Coliseum Blvd
Montgomery, AL 36110

RE: SSAB Alabama, Inc – Axis, Alabama
Injection Carbon Optimization Project – Scrap Tire Crumb Rubber

Dear Mr. Rhodes:

As recently discussed, SSAB Alabama, Inc. undertook the initiative to partner with the ADEM Land Division to reduce our carbon footprint and transition to a more environmentally friendly Electric Arc Furnace (EAF) operation through the trial of injected scrap tires (aka crumb rubber) to partially offset some of the carbon and coke additions to the EAF Operations. We were able to complete this trial in June of this year and have compiled the associated data into the following report for your review and comment.

If you have any questions or comments about the information presented in this report, please do not hesitate to contact me at (251) 264-3345 or tony.cooper@ssab.com.

Sincerely,
SSAB Alabama, Inc.

Tony Cooper

Tony Cooper
Senior Environmental Manager

Cc: Andy Bramstedt (SSAB)
Brian Austin (SSAB)
Victor Ornelas (SSAB)
Bryant Mathis (SSAB)
Tyler Govett (Gas Cleaning Technologies, LLC)

SSAB

Project Background

SSAB Steel (SSAB) operates a twin-shell AC Electric Arc Furnace (EAF) meltshop in Axis, Alabama. The meltshop air pollution control (APC) system includes a Direct Evacuation Control (DEC) system to capture the primary gases and a single deep storage canopy hood above the furnaces to collect the secondary emissions associated with EAF operations. The fume collection system also collects gases from the 2 station Ladle Metallurgy Furnace (LMF). The primary and secondary gases are routed through 3 main I.D. fans to a 1,600,000 ACFM positive pressure, reverse-air baghouse system.

SSAB are investigating means to reduce their carbon footprint and transition to a more environmentally friendly EAF operation and have come to an agreement with the Alabama Department of Environmental Management (ADEM) to trial injected recycled scrap tires (aka crumb rubber) to partially offset some of the carbon and coke additions to their EAF operations. Ultimately, the goal is to realize a practical, safe, and environmentally manageable alternative carbon source compared to traditional carbon and coke as well as find a use for waste tires in the state of Alabama by recycling the tires in the form of crumb rubber.

Together, SSAB and ADEM have established a project, deemed the Injection Carbon Optimization trial, which will give a better understanding of the general process viability, impact to the EAF operations, any impact(s) on gas emissions including CO, CO_2, O_2, NO_x, SO_2, and VOCs, and the potential optimized utilization of recycled scrap tire crumb rubber.

To support the trial, SSAB subcontracted Gas Cleaning Technologies (GCT) to assist with testing and assessment of any impact(s) on gas emissions utilizing the scrap tire crumb rubber. GCT specializes in the evaluation, optimization, and design of off-gas systems for the metallurgical industries. Established in 1995, GCT has assisted over 50 meltshops in North America with troubleshooting and optimization of their EAF off-gas systems with most evaluation and optimization projects beginning with gas emission testing and subsequent data analysis. Through this work, GCT has gained a wealth of information on evaluating EAF off-gas system operations and emissions.
At the conclusion of the Injection Carbon Optimization trial, SSAB is required to submit a summary report which shall be submitted to ADEM for review and distribution. This technical paper has been produced to summarize the viability of using recycled scrap tire crumb rubber for carbon injection, the impact to the EAF operations, any impact(s) on gas emissions, the potential optimized utilization of recycled scrap tire crumb rubber, and any other information that will be beneficial for the utilization of recycled scrap tire crumb rubber. The report shall also describe in detail the benefits and/or disadvantages of using crumb rubber for injection carbon.

EAF OPERATION OVERVIEW

The EAF operates a batch melting process producing molten steel in batches or heats. The operating cycle includes the following steps:

- Charging
- Melting
- Refining
- Tapping
- Turn-around

The first step in the operating cycle is charging. During charging, the furnace roof and electrodes are raised and are swung to the side of the furnace to allow scrap steel to be dropped or charged into the furnace via a scrap bucket positioned by overhead crane. Once charging is complete, the roof is repositioned, and the electrodes are lowered into the furnace to begin the melting phase. Some EAF operations, including certain heats at SSAB, utilize a 2nd charge to achieve the desired steel volume once the first batch of scrap is sufficiently melted. Flux, such as lime, and carbon are often introduced with the charge.

The melting phase uses a combination of electrical and chemical energy to melt the steel scrap. Electrical energy is provided by electrodes. Chemical energy is provided by sources such as oxy-fuel burners and oxygen lances.

The refining period is used to remove impurities from the molten steel. Generally speaking, refining occurs once melting is completed, and a “flat bath” is observed. However, there can be some overlap. Oxygen can be introduced during the end of melting to lower the bath carbon content as required and to promote reactions. During refining, carbon injection is used to support slag foaming which is needed to float impurities to the surface. This is relevant to the trial as the scrap tire crumb rubber is being used to supplement some of the traditional carbon that is injected. De-slagging occurs towards the end of the refining phase, where slag is poured off the top of the bath through a slag door into a ladle or pit.

Once the desired steel composition and temperature are achieved in the furnace, the furnace is tilted and tapped into a ladle via the tap hole.

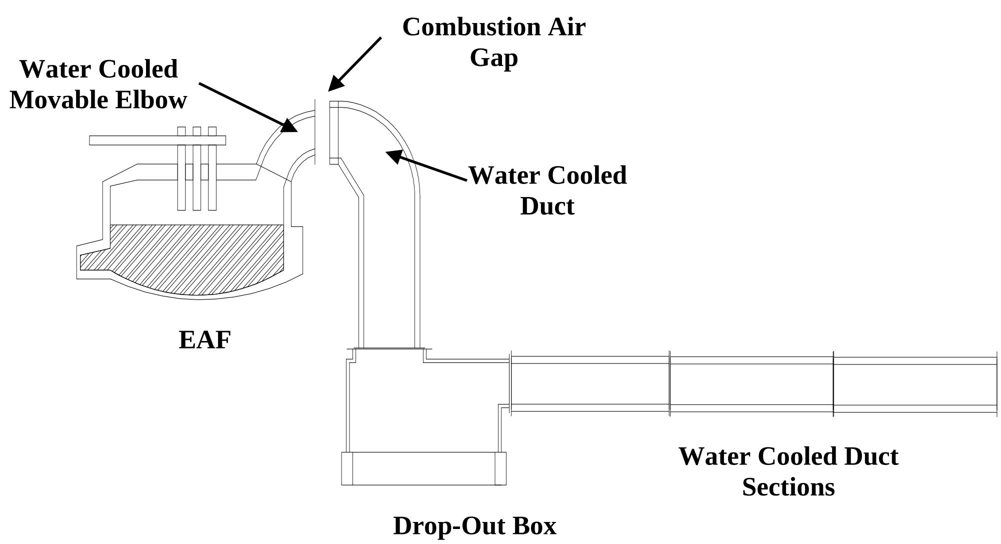
While SSAB operations follow the same general cycle, SSAB operates a twin-shell furnace. The furnaces use a single set of electrodes that are shared between the two furnaces. This means one furnace is operating with power on in the melting or refining stage, while the other furnace is charging, preheating, or holding.

Modern EAF off-gas systems utilize a Direct Evaluation Control (DEC) System to evacuate gases generated during the steel making process. The DEC system allows for collection of emissions at the source during scrap melting to minimize the volume of gases that is required to provide good capture of steelmaking emissions from the furnace. The DEC system is also utilized to efficiently destroy carbon monoxide and hydrogen emissions generated in the furnace, minimize the formation of NOx, and cool the off gas to allow for the removal of entrained particulate.

A typical EAF DEC system consists of the following components:

- A 4th hole located at the furnace roof to ventilate gasses generated in the process
- A water-cooled movable elbow located on the furnace roof
- A combustion air gap
- Water-cooled fixed elbow and vertical water-cooled duct
- A partially water-cooled horizontal drop-out box
- A length of water-cooled ductwork downstream of the drop-out box

EAF DEC System Configuration: The below illustration shows a typical configuration of an EAF DEC system. At SSAB, the DEC components downstream of the combustion air gap are shared between the two furnaces. A damper is used distribute draft between the two furnaces as required.



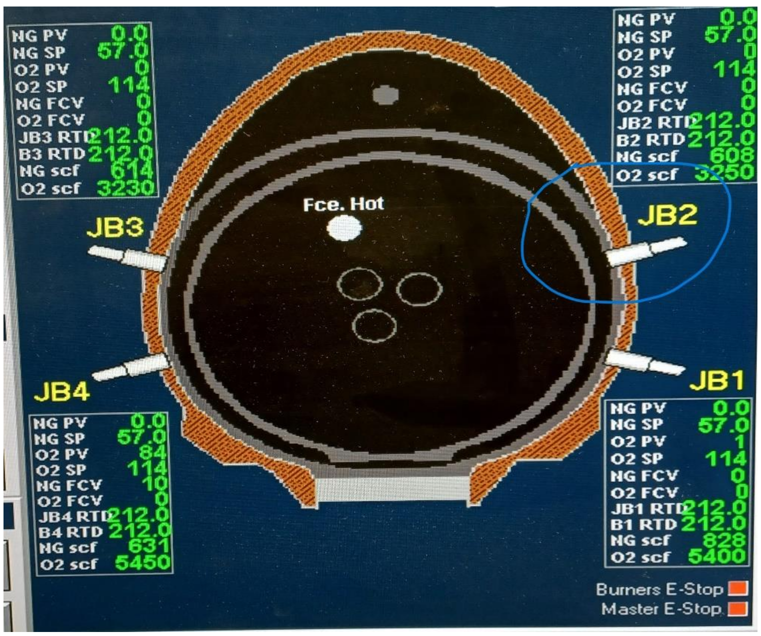
The hot dusty gases generated in the EAF are collected at the 4th hole and transported to the DEC system through a water-cooled fixed elbow located on the furnace roof. Ambient air is introduced at the combustion air gap to ensure volatiles such as carbon monoxide and hydrogen are safely combusted in the system. A Drop-Out Box allows for settling of large abrasive particles to prevent settling in the downstream ductwork and allows for additional residence time for combustion. A length of water-cooled duct (typically 100 to 150 ft. in length) is utilized downstream of the drop-out box.

The water-cooled duct serves two main purposes: transporting the hot gas and providing primary gas cooling. The gas exiting the EAF is typically collected at temperatures near 3,000°F. The water-cooled duct transports this hot gas stream while cooling the gas. In order to promote combustion and avoid drop-out of particulate, the gasses are transported in the duct at high gas velocities.

The primary gases from the DEC combine in main duct with exhaust from EAF canopy (used to capture charging/tapping emissions and fugitive emissions during melting/refining) and other sources, such as a Ladle Metallurgy Furnace (LMF). At SSAB, the process off-gases are vented by 3 (4 total, 3 operating) induced draft fans through a positive pressure, reverse air baghouse for dedusting and then to atmosphere via a stack.

TRIAL METHODOLOGY AND INJECTION SETUP

The Injection Carbon Optimization trial was conducted by installing a crumb rubber injector on the West Furnace. Trials were not conducted on the East Furnace. The carbon, or crumb rubber injector, was located and installed at "position 2" on the West Furnace. Timeframe of the trial was from June 17th 2024 to June 26th 2024.



HMI representation of where injector was positioned

It should be noted, that for a given trial heat, standard charge carbon amounts were utilized. The trials were organized such that 8 trial heats were first conducted at a 5% crumb rubber substitution based on the desired total carbon injection amount. From there, trials were continued up to a 30% substitution of the total desired carbon injection amount based on 5% increments (a total of 51 trial heats were observed).

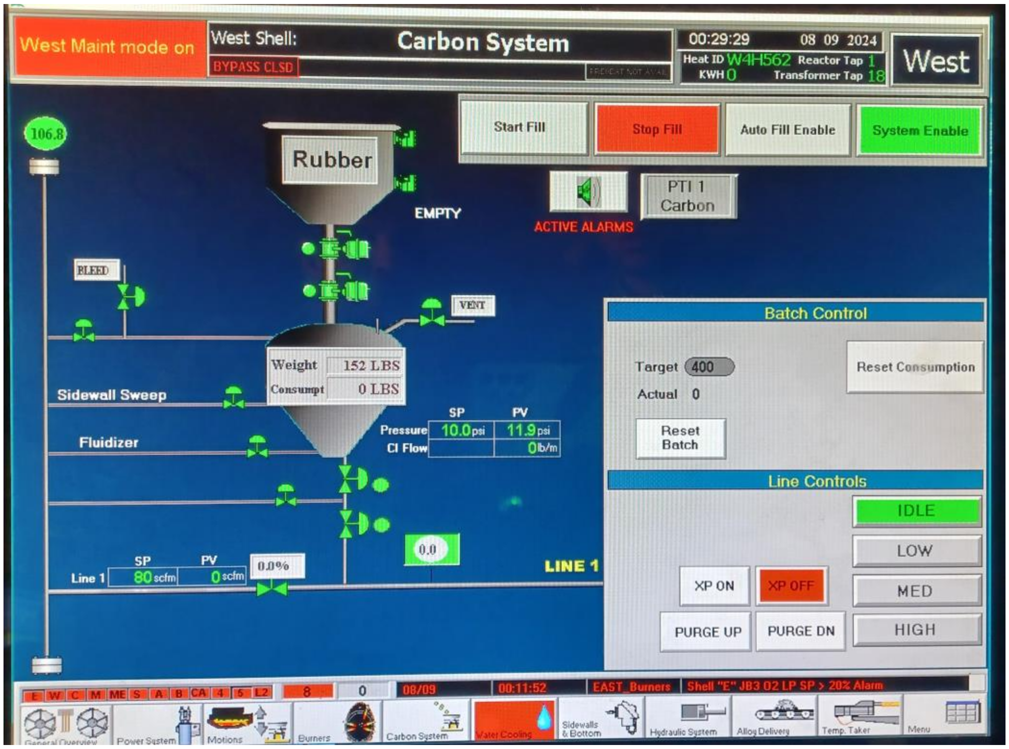
For each trial heat, crumb rubber was loaded into the injection system via bulk bags based on the production plan summarized below:

- 8 heats at 5% of the desired carbon amount – 100 lbs of crumb rubber introduced
- 12 heats at 10% of the desired carbon amount – 200 lbs of crumb rubber introduced
- 9 heats at 15% of the desired carbon amount – 300 lbs of crumb rubber introduced
- 11 heats at 20% of the desired carbon amount – 400 lbs of crumb rubber introduced

- 9 heats at 25% of the desired carbon amount – 500 lbs of crumb rubber introduced
- 2 heats at 30% of the desired carbon amount – 600 lbs of crumb rubber introduced

During the course of each trial heat, an E1 sample was taken right after pushing the slag door and a slag sample was taken to observe slag conditions and any anomalies. Operations were observed to mitigate potential risks with the crumb rubber injection such as higher environmental emissions and slag foaming, inefficient carbon slag forming, higher electrode consumption, refractory wear, high nitrogen content in the steel, etc. Trial heat steel was also monitored by the plan technical services to avoid nonconforming customer products.

150 cubic ft carbon injector with 200 cubic ft capacity portable hopper



HMI screenshot of carbon injector system for trial

The crumb rubber was loaded into a day bin (depicted with rubber in the top picture) which holds roughly 3000 lbs. Then, the rubber would be transported to a hopper unit (depicted with weight/consumption in the top picture) where it holds around 2100 lbs. The operator then types in the desired target amount and feed rate (depicted by low/med/high on the bottom right picture).

OFF GAS SAMPLING EQUIPMENT AND CONFIGURATION

Gas testing was performed by taking a sample of gas from the DEC duct upstream of the tie-in with the main duct to the EAF baghouse. This location was approximately 40 ft upstream of the tie-in point. Figure 1 (below) shows the sampling location.

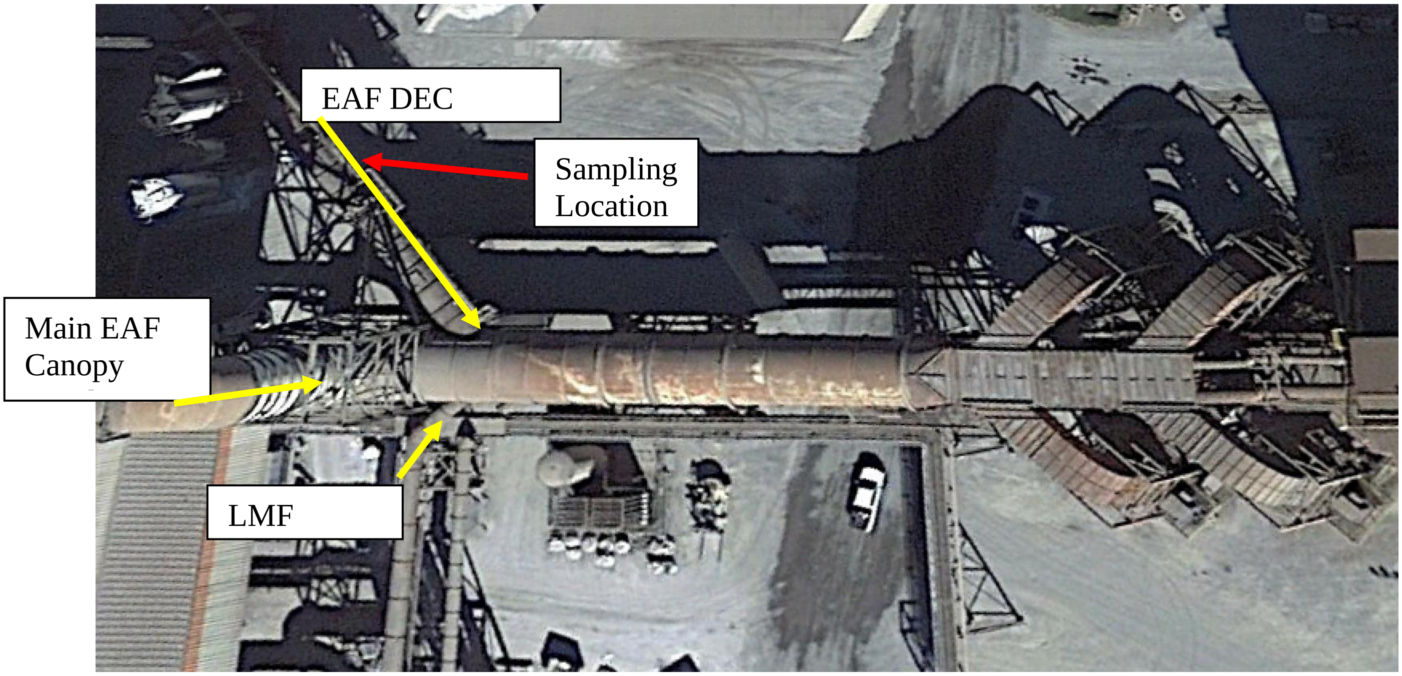


Figure 1
Sampling Location

The sample location was chosen in the DEC duct due to the injection of crumb rubber during power-on operations (melting and/or refining). No crumb rubber was introduced into the furnace during charging, and therefore sampling in the main EAF canopy hood duct or main baghouse inlet duct would have likely produced inaccuracies with CO concentrations or other gaseous emissions caused by carbon in the charge or other operational considerations.

The sample was collected using a ~8ft stainless steel lance that was inserted approximately 5ft into the DEC dry duct to ensure representative collection of gas for sampling. The lance included a particulate filter attached at both ends. A stainless steel frit filter was attached to the insertion end, while a fiberglass filter was attached at the exterior end of the lance. The sample was pulled through ~100 ft of sample line using a pump to extract about 10 lpm of gas. The discharge of the pump was connected to the gas analysis equipment. Figure 2 (below) shows the gas analysis equipment setup.

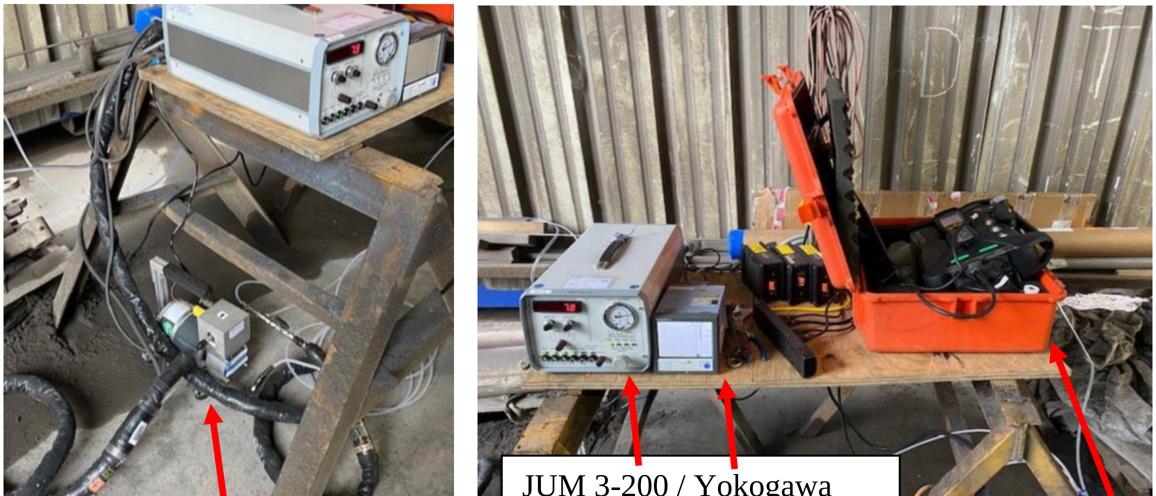


Figure 2

Sample Line / Pump

JUM 3-200 / Yokogawa

Testo 350

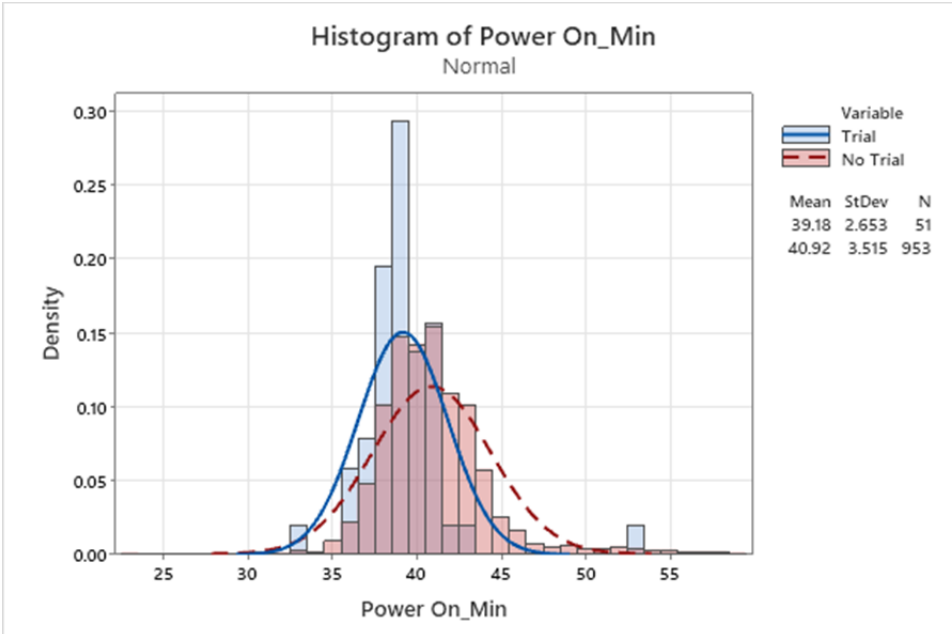
Gas Analysis Equipment Setup

O_2, CO, CO_2, SO_2, and NO_x levels were measured using a Testo 350 portable gas analyzer with internal continuous data logging. The Testo 350 is a US EPA compliant measurement device.

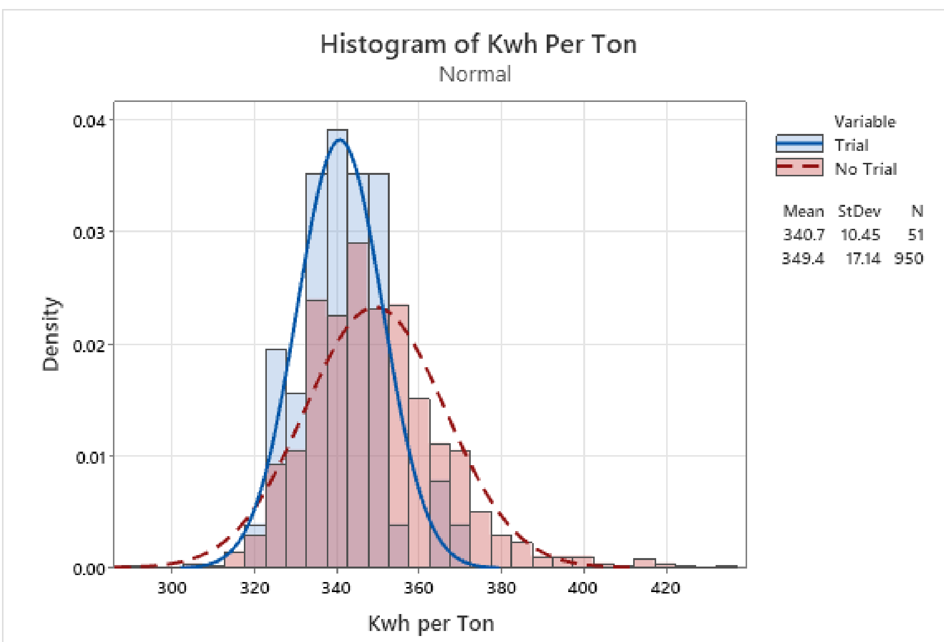
VOC testing could not be conducted using the traditional method of gas chromatography mass spectrometry analysis. This requires samples to be collected and taken to a laboratory for analysis which would be labor intensive, high cost, and not practical for continuous evaluation of the process gas stream. The most practical solution to have a continuous measurement is to measure total hydrocarbons (C_xH_y) using flame ionization technology. The drawback of this method is that the total hydrocarbon (THC) analyzer measures the concentration of not just volatile organic compounds, but also any non-volatile hydrocarbons as well. The THC levels were measured using a JUM model 3-200 FID gas analyzer which uses hydrogen flame ionization to detect total hydrocarbons. The JUM analyzer was connected to a Yokogawa Model GX10 data recorder for continuous data logging.

Both the Testo 350 and the JUM 3-200 / Yokogawa GX10 were set to sample and record at 10 second intervals. Data was downloaded from the analyzers typically on a daily basis, in the morning, by SSAB personnel and forwarded to GCT for further analysis. The specific EAF operating conditions were also forwarded to GCT for review and reconciliation with the gas analysis measurements.

EAF OPERATION COMPARISON

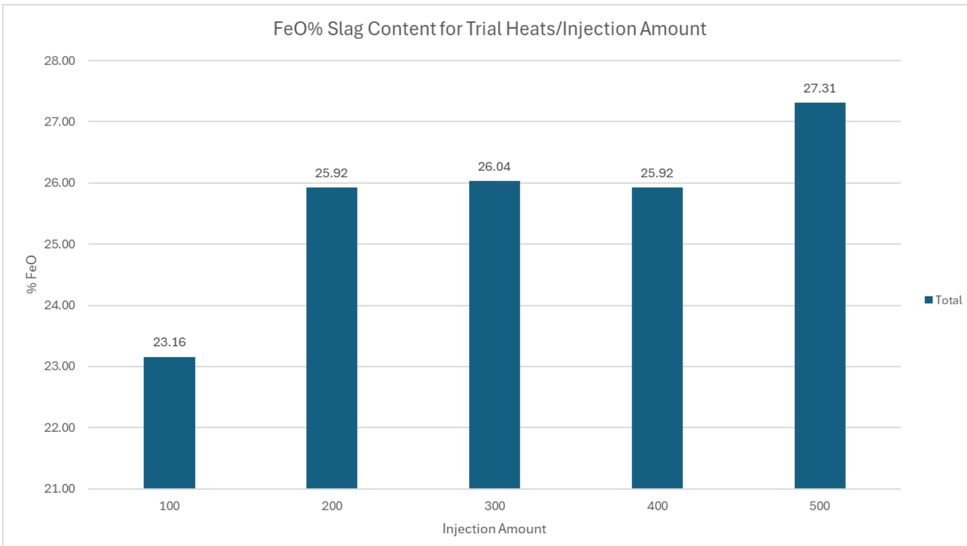


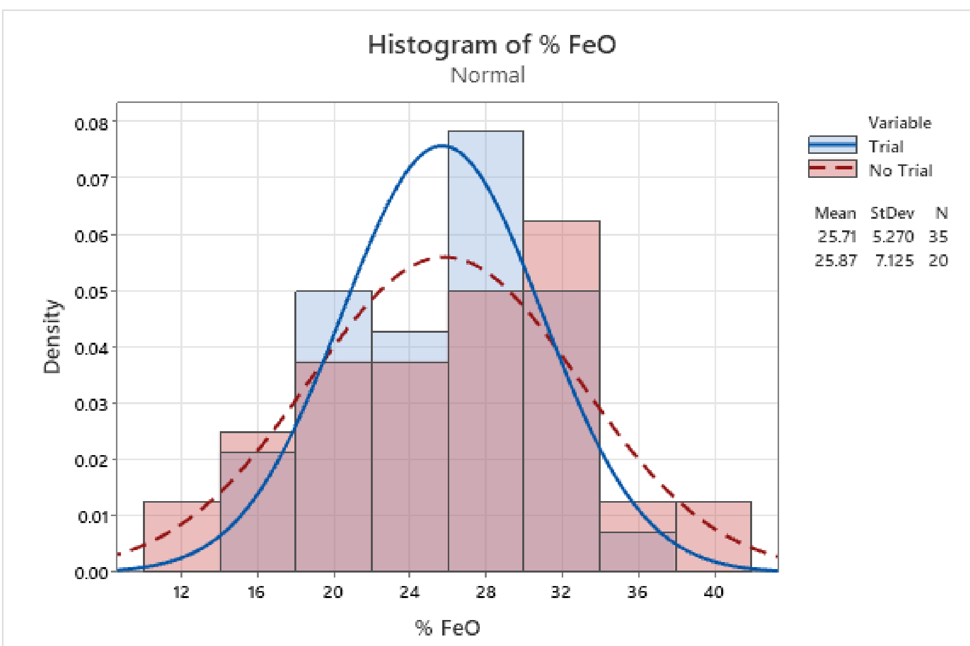
- No significant changes in operation were found in relation to the trial process. An overall average power on time of 40 mins was observed between trial and non-trial heats. A large sample size of non-trial heats was obtained to provide an accurate baseline.



- There was a slight improvement found in Kwh/ton from the trial. As can be seen, the standard deviation was 10.45 for trial heats while 17.14 for non-trial heats. This entails there was less overall variation in the process and encouraged a more stable melt. Thus, there was an improvement in the efficiency of electrical power input to the steel bath.

SLAG AND STEEL ANALYSIS RESULTS





- As can be seen from both graphs above, FeO% in the slag between trial and non-trial heats were similar indicating no detriment to steel quality and furnace conditions..

DUCTWORK GAS FLOW MEASUREMENTS

GCT collected flow rate, temperature, and static pressure measurements during the initial site visit to set up the testing equipment at the following locations:

- Primary off-gas system (DEC) in the dry duct at the gas sampling location
- Upstream of the baghouse ID fans in the 21' main duct

Where possible, GCT utilized the following US EPA test methods to establish the measured flow rates:

- (40 CFR Part 60, Appendix A) Method 1: Sample and Velocity Traverses for Stationary Sources
- (40 CFR Part 60, Appendix A) Method 2: Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

Due to access and safety related restrictions of the sampling point as well as the frequency of discrete traverse measurements, a traverse in only one direction was conducted. This is the only deviation from the EPA Methods. This in-duct testing was not intended for compliance reporting, it was solely for evaluation and comparison purposes. Therefore, the measurements results were validated and used if/as necessary for developing results from the trial.

A summary of these measurements (average, minimum and maximum values) is shown below in

Table 1

Table 1
Summary of Off-Gas Measurements

Main Duct					
6/12/24 10:40 – 11:55		Average	Range		
Flow Rate	ACFM	1,521,000	1,110,000	-	1,836,000
	SCFM	1,125,000	772,000	-	1,284,000
Temperature	°F	243	135	-	335
Static Pressure	in w. g.	-9.5	-13.1	-	-5.8

DEC Duct					
6/13/24 **8:40 - 11:00**		Average	Range		
Flow Rate	ACFM	428,000	185,000	-	601,000
	SCFM	242,000	116,000	-	364,000
Temperature	°F	471	235	-	743
Static Pressure	in w. g.	-9.0	-11.4	-	-4.4

Figure 3 and **Figure 4** summarize the in-duct flow and temperature measurements for the main duct and DEC duct, respectively.

The ductwork measurements were undertaken and summarized here to allow for determination of an approximate emission rate at the stack for the recorded gaseous emissions.

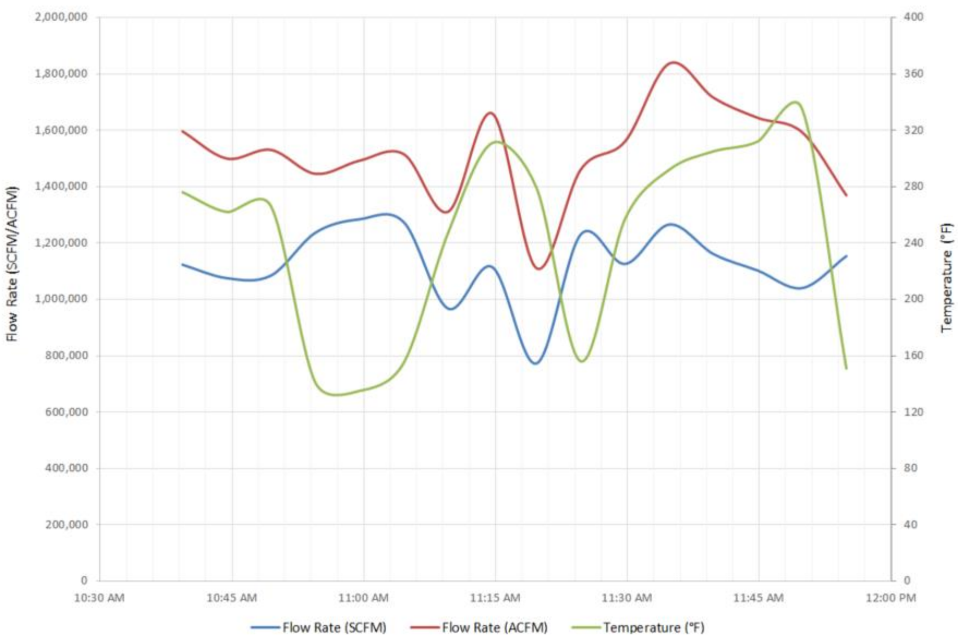


Figure 3
Main Duct Flow and Temperature Measurement Summary – June 12, 2024

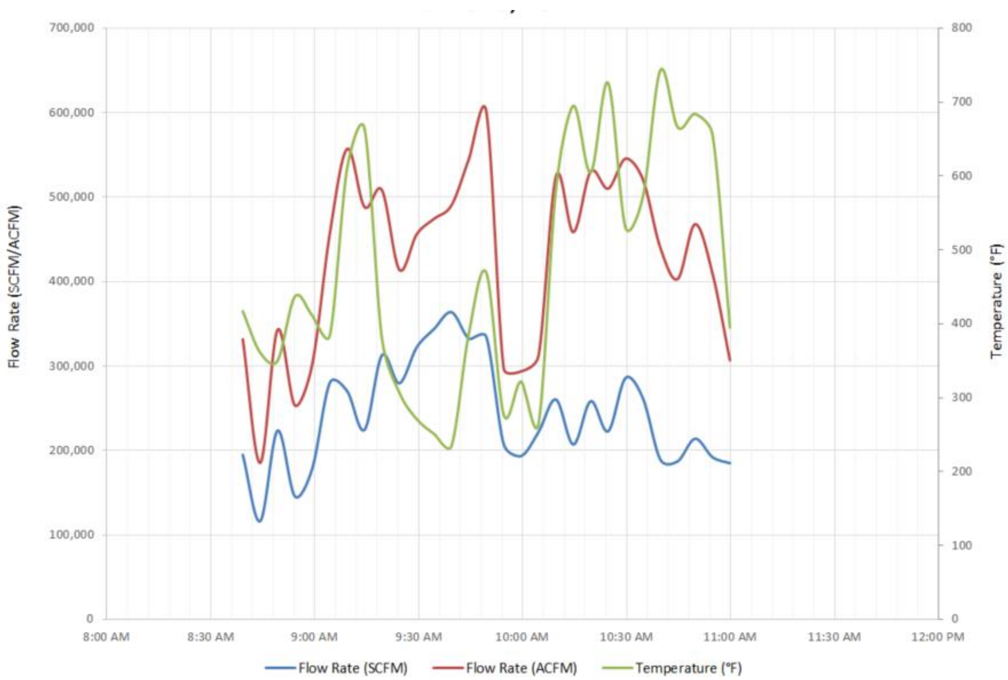


Figure 4
Main Duct Flow and Temperature Measurement Summary – June 12, 2024

GAS ANALYSIS SUMMARY

Gas analysis measurements were recorded in the DEC duct to monitor CO, CO_2, O_2, NO_x, SO_2, and VOC concentrations across multiple baseline (non-trial heats) on both the East (EAFE) and West (EAFW) furnaces as well as trial heats on the West furnace. It should be noted that VOC concentrations are reflected as THCs in the data summaries presented in this section (see "OFF GAS SAMPLING EQUIPMENT AND CONFIGURATION" for further information).

Testing was performed from the period of June 14, 2024, at approximately 14:00 to June 28, 2024, at approximately 8:00. Other than minor periodic testing equipment disruptions, rinse/calibration cycles of the equipment, and/or periods were data was downloaded from the Testo analyzer and Yokogawa data logger, data was logged continuously during this period in 10 second intervals. The logged data has been filtered accordingly to delineate between operating heats at the two furnaces and down time as well as to remove periods where testing equipment disruptions occurred.

Table 2 below presents a general summary of the overall recorded data.

Table 2
Summary of Off-Gas Measurements

Furnace	Trial Heat (Yes/No)	Parameter	Gas Concentrations					
			% O_2	ppm CO	% CO_2 IR	ppm NOx	ppm SO_2	ppm THC
Both	No	Min	11.9	0.0	0.0	0.0	0.0	0.0
		Max	21.3	1,200	11.2	671	96.0	136
		Avg	19.0	99.0	2.3	17.9	0.7	6.2
EAFE	No	Min	11.9	0.0	0.0	0.0	0.0	0.0
		Max	21.3	1,200	11.2	671	96.0	136
		Avg	19.1	95.2	2.2	16.8	0.5	5.7
EAFW	No	Min	12.8	0.0	0.0	0.0	0.0	0.0
		Max	21.3	1,052	11.2	671	96.0	136
		Avg	18.7	108	2.4	21.0	1.3	7.8
EAFW	Yes	Min	11.9	0.0	0.1	0.0	0.0	0.0
		Max	21.3	7,694	11.3	622	98	101
		Avg	19.1	105	2.3	16.8	0.1	5.0

Looking at the overall measured ranges and averages, no discernable differences can be detected between the trial heats and the base line heats on EAFW. Values are also similar when comparing the base line heats for EAFE and EAFW, as expected. The one major outlier is the maximum CO concentration (7,700 ppm) recorded during one of the trial heats on EAFW; however, this peak occurred prior to the crumb rubber injection and is discussed further below. It is worth noting that slightly lower THC concentrations were observed during trial heats although the difference is not significant and could be contributed to a variety of factors (e.g.: scrap composition, target steel grade) and not necessarily differences between traditional carbon and the scrap tire crumb rubber.

Table 3 below presents a general summary of the gas analysis data recorded for the trial heats using differing amounts of crumb rubber where each amount represents a percentage of the overall injected carbon (between 5% and 30%, in 5% increments).

Table 3
Summary of Off-Gas Measurements

Furnace	Crumb Rubber Injected (lbs)	Parameter	Gas Concentrations					
			% O_2	ppm CO	% CO_2 IR	ppm NOx	ppm SO_2	ppm THC
EAFW	100	Min	11.9	0.0	0.2	0.0	0.0	0.0
		Max	21.3	1,200	10.8	573	28.0	85.8
		Avg	19.2	107	2.3	15.6	0.1	4.3
	200	Min	15.7	1.0	0.2	0.0	0.0	0.5
		Max	21.0	1,064	7.9	291	14.0	59.0
		Avg	19.4	86.0	2.0	13.1	0.1	5.0
	300	Min	15.2	1.0	0.1	0.0	0.0	0.0
		Max	21.0	933	8.8	388	17.0	44.8
		Avg	19.4	81.3	2.0	16.8	0.1	4.7
	400	Min	14.2	0.0	0.1	0.0	0.0	0.5
		Max	21.1	7,694	8.8	622	98.0	101
		Avg	18.7	164	2.7	21.6	0.2	5.9
	500	Min	12.7	0.0	0.1	0.0	0.0	1.6
		Max	21.0	1,462	11.3	393	13.0	73.2
		Avg	18.9	80.1	2.5	16.6	0.1	5.1
	600	Min	14.0	2.0	0.2	0.0	0.0	1.9
		Max	21.0	1,207	10.7	379	12.0	52.1
		Avg	18.7	169	2.8	23.2	0.2	4.8

A gas analysis data comparison between trial heats at varying crumb rubber amounts also shows no distinct differences or trends when comparing averages. The highest CO concentration peaks observed did occur during trial heats of 400 and 500 lbs of crumb rubber. However, the aforementioned peak of 7,700 ppm during the 400 lb. trial heat occurred prior to crumb rubber injection. A spike in SO_2 also occurred during one of the 400 lb. crumb rubber trial heats, but this peak value is similar to those observed during the base line heats.

Figure 5 below presents the average recorded data comparing base line and various trial heats in chart format.

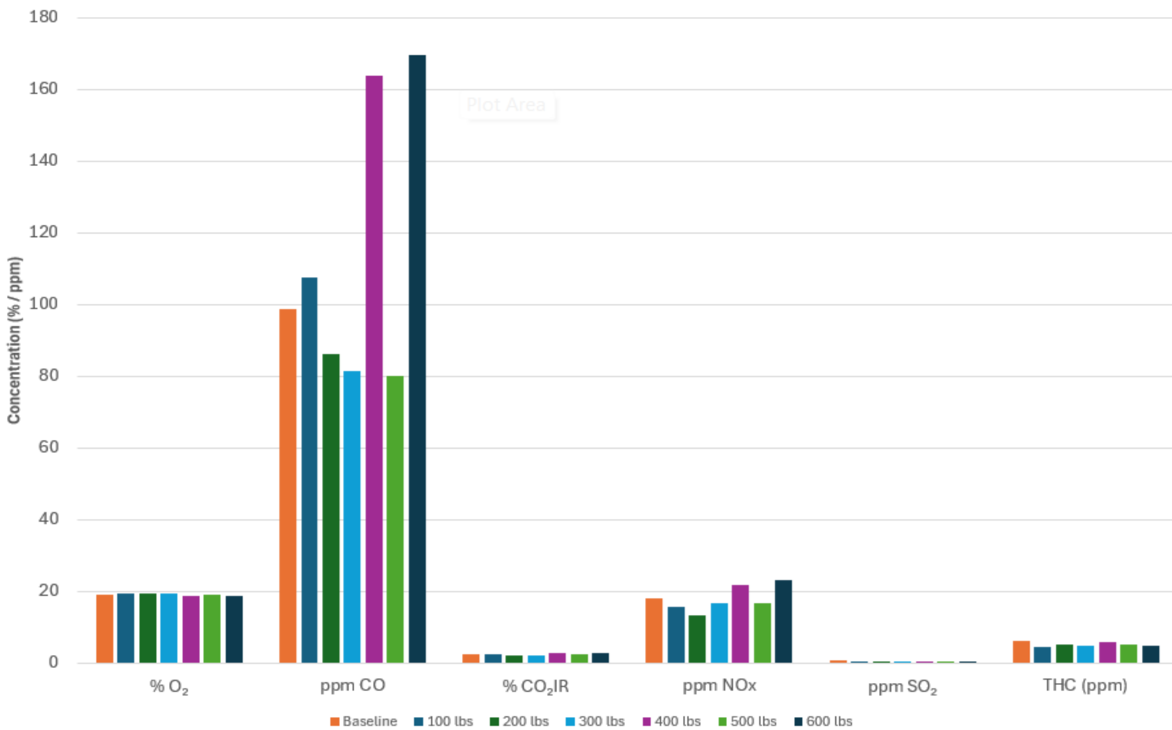


Figure 5
Comparison of Average Gas Concentrations for Baseline vs. Various Trail Heats

The chart depicts very similar gas concentration levels for all gas constituents although the higher CO concentration peak observed during the 400 lb. trial likely skewed the average. A higher average CO concentration was observed during the 600 lb. trials, meaning longer periods of higher concentrations were observed. However, the observed peak during these trials was very similar to the baseline heat results. The higher average could be attributed to a period of poor post combustion in the downstream DEC or reduced combustion in the furnace freeboard.

The previous tables and pictures provide a general summary of the overall gas concentrations observed during baseline and trial heats. During the trials, however, crumb rubber is only injected for a very short duration, therefore it is important to isolate the operating periods leading up to and after the injection on EAFW. Table 4 below presents an average off-gas concentrations 20 minutes prior to and 20 minutes after injection. The table is inclusive of all trial heats, regardless of crumb rubber weight.

Table 4
Summary of Off-Gas Concentrations Before and After Crumb Rubber Injection

		Average Off-Gas Concentration					
		% O_2	ppm CO	% CO_2IR	ppm NOx	ppm SO_2	THC (ppm)
Time From Injection Start (min)	**-20**	18.9	134.5	2.5	18.9	0.1	4.7
	-15	18.9	128.0	2.6	18.7	0.1	4.7
	-10	18.8	123.1	2.7	17.3	0.1	4.6
	-5	18.7	116.2	2.8	14.8	0.0	4.1
	5	18.3	116.1	3.4	14.8	0.0	3.8
	10	18.3	101.5	3.4	15.3	0.0	3.5
	15	18.4	99.7	3.2	16.9	0.0	3.5
	20	18.5	100.2	3.1	19.7	0.1	3.7

Table 4 shows similar oxygen levels leading up to and after crumb rubber injection. Reduced average levels, albeit minor, were noted for CO and THCs. CO_2 concentrations did rise by approximately 1% following crumb rubber injection, which in correlation with reduced CO levels, could imply improved CO combustion. NO_x concentrations remained rather consistent, although the highest average was observed 20 minutes after injection. This is likely due to changes in furnace operation independent of the crumb rubber injections.

While the information in **Table 4** is important for understanding the emissions impact of the scrap tire crumb rubber injection, it also worth comparing the gaseous emissions between baseline and trial heats during the same point in a given heat. As electrical power is introduced, cumulative kilo-Watt hours (kWh) are tracked and reset heat to heat. **Figure 6** highlights the kWh count when crumb rubber injection started during the SSAB trial heats.

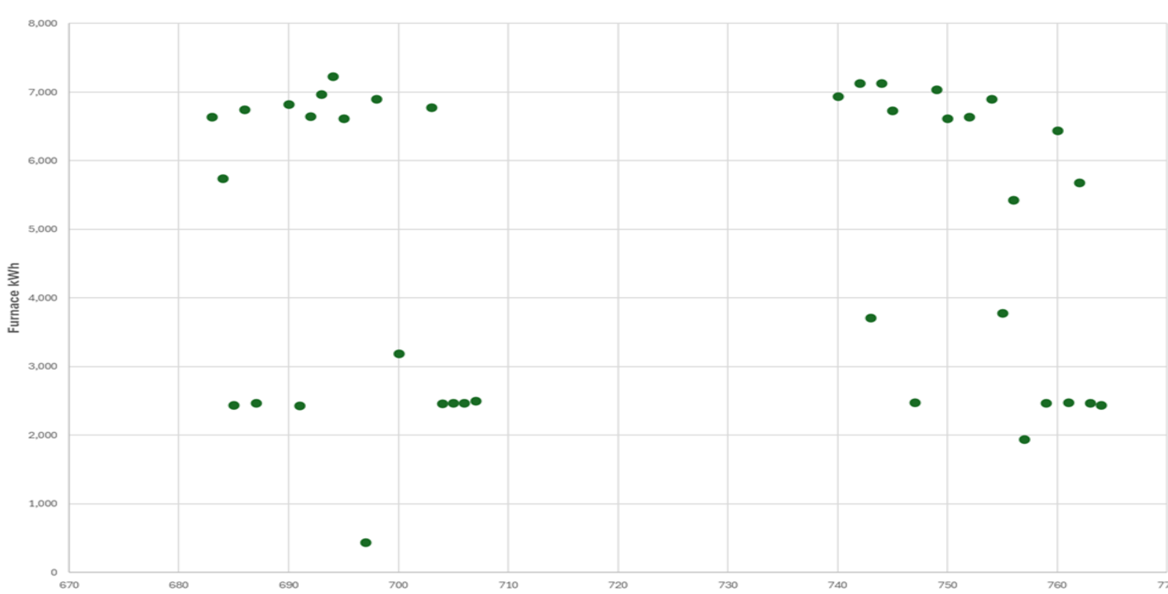


Figure 6

Crumb Rubber Injection Timings Based on kWh Count

Figure 6 shows that crumb rubber was generally injected around the 2,500 kWh count and 7,000 kWh count. This is likely towards the end of the 1st melt cycle following 1st charge and again during the bulk of carbon injection during refining. Using this information, additional figures (**Figure 7** and **Figure 8**) were generated comparing average gas concentrations for baseline and trial heats (at all crumb rubber weights) based on ranges centered around the two kWh counts.

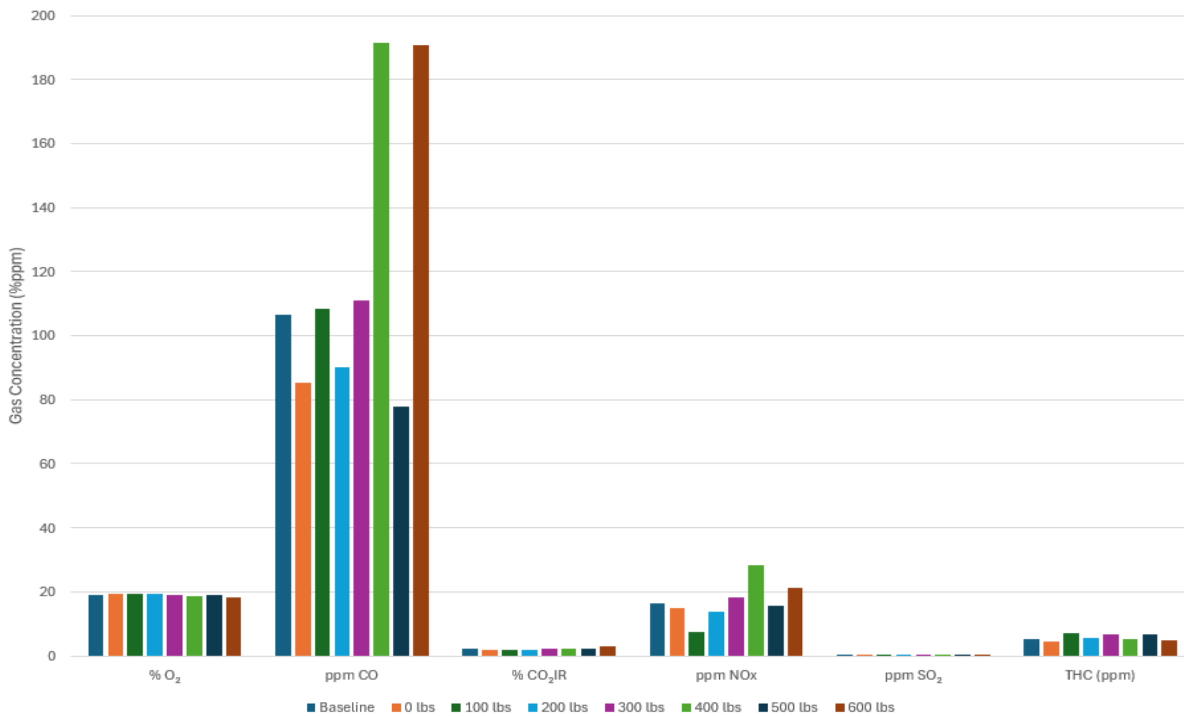


Figure 7
Comparison of Average Gas Concentrations for Baseline vs. Various Trial Heats Melting 1 – 2,500 – 3,500 kWh

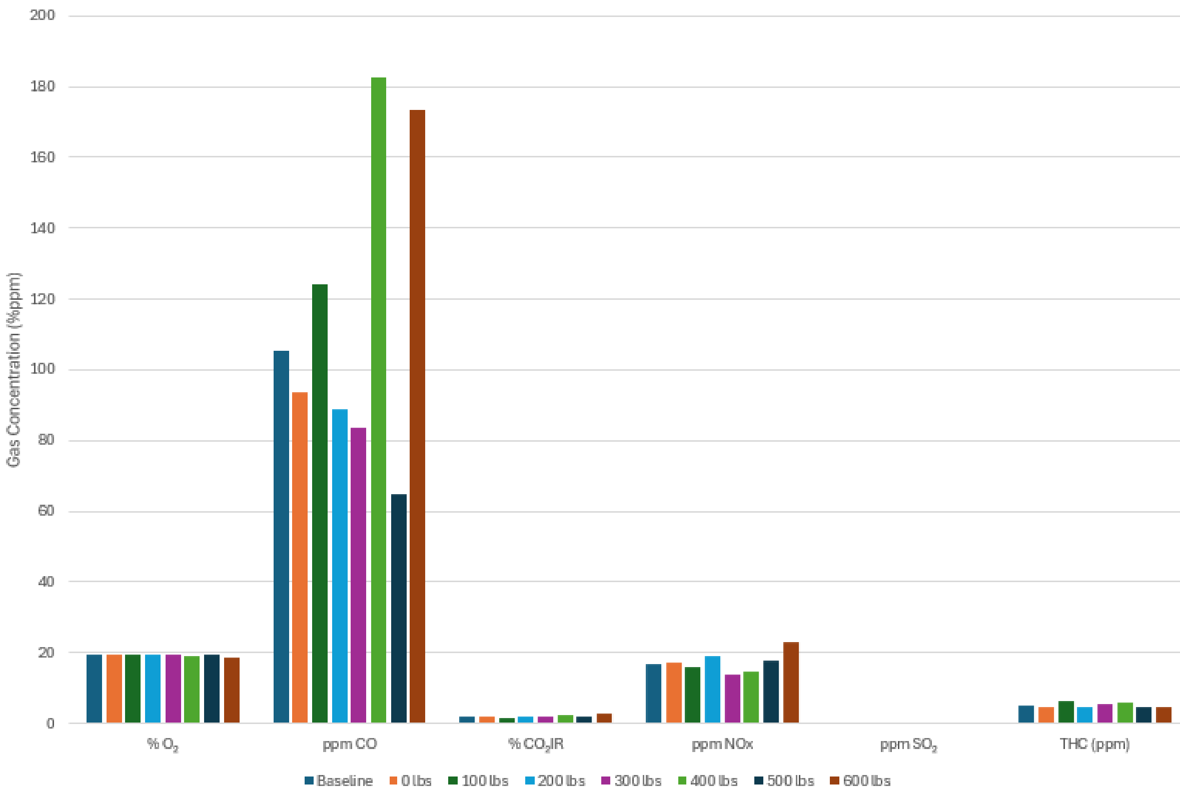


Figure 8
Comparison of Average Gas Concentrations for Baseline vs. Various Trial Heats Refining – 6,500 – 8,000 kWh

Both **Figure 7** and **Figure 8** show similar results. O_2, CO_2, NO_x, SO_2, and THC average levels remained similar comparing baseline and all trial heats within the kWh count ranges outlined. Higher CO average levels can be observed for the 400 and 600 lb. trials, as previously discussed.

Because these two trial types reflect higher CO concentration averages, figures have been generated to take a closer look at the specific heats where CO peaks where observed during these trials. The figures below reflect 5-minute rolling gas concentration averages to minimize noise in the data and help with clarity, therefore the true peak values as previously mentioned are not directly reflected.

Figure 9 highlights the overall heats for the 600 lb. crumb rubber trials. For the two heats shown, higher CO levels were observed after crumb rubber injection, but this could also be attributed to additional conventional carbon injection to fulfill the total carbon requirements and/or reduced combustion in the DEC. Based on the information presented, GCT does not detect any clearly discernable issues attributed directly to the injection of crumb rubber.

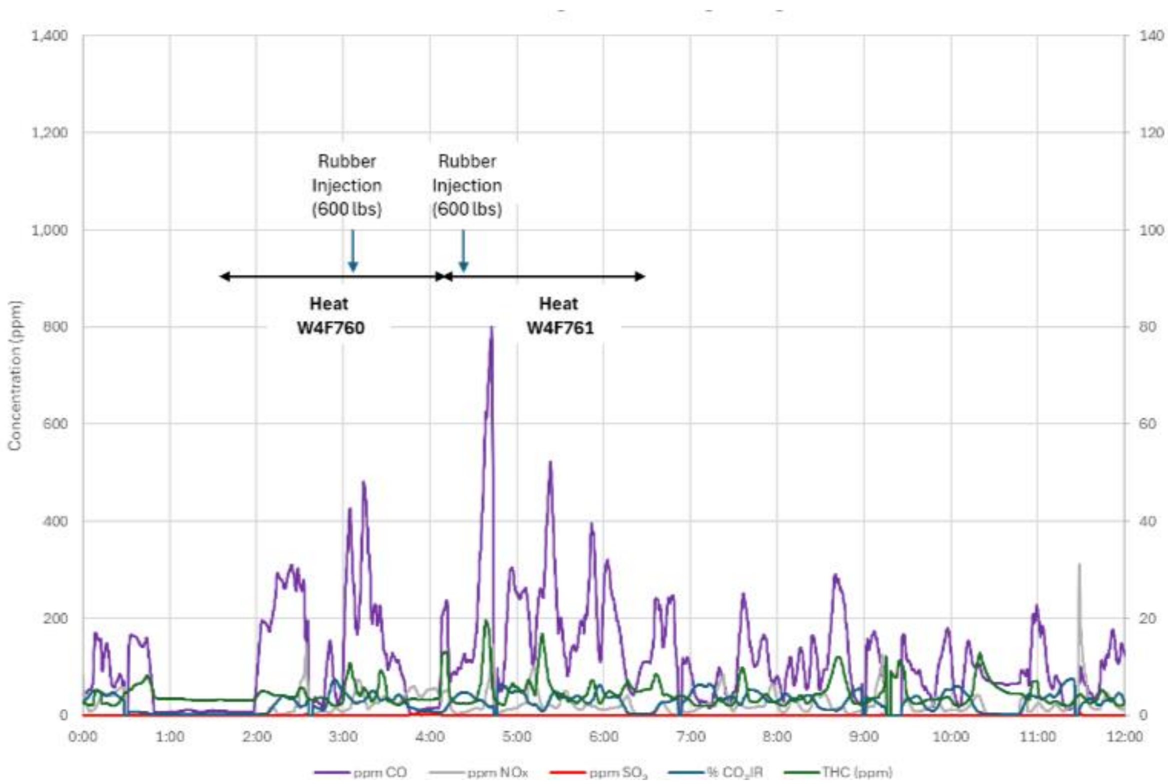


Figure 9
EAFW Heats W4F760 and W4F761 – 600 lb. Trials (5-Minute Rolling Average)
June 26, 2024

Figure 10 and **Figure 11** highlight the overall heats for the 400 lb. crumb rubber trials. For the heats shown, periods of higher CO levels can be observed after crumb rubber injection; however, there are other periods following injection where no peaks were observed. Again, GCT does not detect any clearly discernable issues attributed directly to the injection of crumb rubber. The highest measured CO concentration peak measured during the testing campaign of 7,694 ppm occurred at approximately 16:00 on June 24, 2024, during heat W4F744. Figure 11 shows that the spike in the 5-minute rolling average at this time is well before crumb rubber injection.

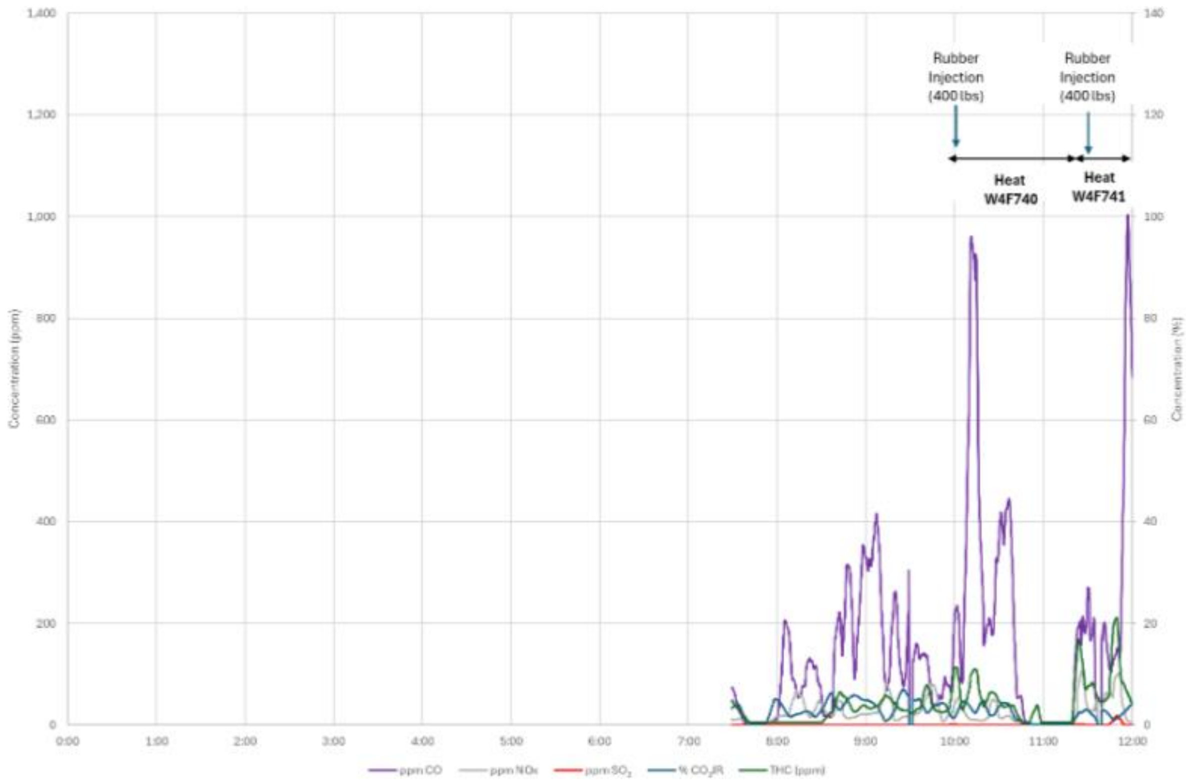


Figure 10
EAFW Heats W4F740 and W4F741 – 400 lb. Trials (5-Minute Rolling Average)
June 24, 2024

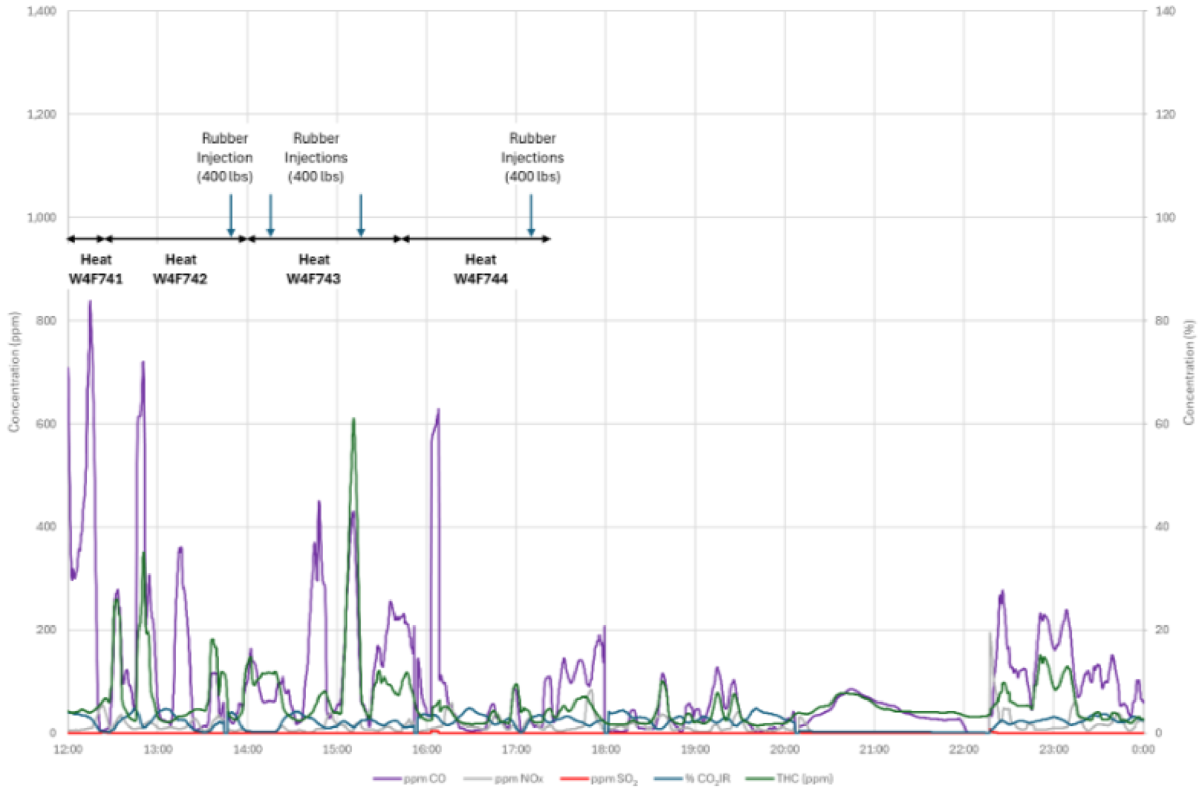


Figure 11
EAFW Heats W4F741, W4F742, W4F743, and W4F744 – 400 lb. Trials (5-Minute Rolling Average)

June 24,2024 - CONCLUSIONS

One area of concern that operations mentioned while running this trial was the possibility of the crumb rubber melting within the injector system. Out of the 51 heats trialed, there were only a few circumstances where the material “gummed up”. However, this did not negatively impact the operation because this inconvenience lasted for a few seconds until the material freed itself up.

As far as steel quality is concerned, there were no visible concerns seen with the chemistry of the final product. Customer satisfaction was met with specifications fulfilled both internally and externally. Slag conditions were favorable while utilizing the crumb rubber material. The viscosity was “creamy” in appearance indicating an increase in overall yield, requiring less overall flux consumption, and maintaining refractory integrity in the furnace.

Another key question driving this Injection Carbon Optimization trial was the impact on gaseous emissions when using scrap tire crumb rubber in lieu of conventional carbon. GCT did not find any discernable impacts to gaseous emissions with the use of crumb rubber.

GCT did find that crumb rubber injection occasionally led to an increase in CO in the DEC duct, but even then, nothing was noted that discernably points to crumb rubber injection as problematic. It is possible that the impact is minimal with overall results skewed by the twin shell operation or other furnace operating parameters such as scrap composition and target steel grade. CO and CO_2 peaks are expected during at the end of the 1^{st} melt cycle and during refining when carbon injection is occurring. Generally, the data reflects this during both baseline and trial heats. Oxygen levels in the DEC duct, which impact CO combustion and CO_2 formation, were typical for EAF operations during both trial and baseline heats.

Even with some observed increases in CO in the DEC duct, GCT only recorded one potentially dangerous spike in CO in the DEC duct, which as noted in this report, occurred well before crumb rubber injection during the specific heat. CO levels in the DEC could be a concern if they are high enough and there is enough oxygen present due to higher temperatures. Ideally, GCT would expect to see DEC CO levels below 1,000 ppm with peaks of no more than 2,000 to 3,000 ppm. There is some risk for explosions between 3,000 to 5,000 ppm, but above 5,000 ppm poses a real concern. Average levels were typically around 100 to 150 ppm for both baseline and trial pointing to no concerns related to rolling stack emission estimates.

GCT did not see nor expect any correlation between the use of crumb rubber and SO_2 or NO_x emissions. SO_2 in the stack off-gas is typically from the LMF operation due to the additions of varying alloys. NO_x emissions can be due to burner usage, although it appears most emissions are from the initial bore in of the electrodes following a charge.

GCT did not observe any significant impacts to VOC or THC emissions. The collected data actually points a marginal reduction in average THC emissions. It is expected THC levels will remain largely dependent on the charge scrap mix.

Lastly, SSAB contracted with a consultant to complete a preliminary analysis on potential CO2 emissions reductions associated with offsetting the current injection carbon with the scrap tire derived crumb rubber. Based on a theoretical analysis using life cycle analysis (LCA) modeling software, calculations showed that from a 5% to 30% offset would equal a reduction of approximately 180 to 1,078 tons of CO2e emissions annually.

In summary, GCT has not noted any off-gas conditions that would hinder production, lead to a safety concern, or lead to higher environmental emissions. Average emissions seemed environmentally acceptable, and no major variations were detected between scrap tire crumb rubber heats and base line heats using conventional carbon. Based on the data available to date and trials conducted, GCT believes crumb rubber to be a suitable alternative to conventional carbon when looking at gas emissions. With that said, the conclusions from this report indicate that supplementing up to 30% traditional carbon with crumb rubber can be safely considered for future operation, but additional study is recommended if SSAB or ADEM wish to increase the utilization of crumb rubber.

To summarize the trial results: there were no detrimental findings observed with utilizing the crumb rubber material at SSAB. Steel quality was not impacted in any negative way and the furnace efficiency performed suitably. A few recommendations for future work:

- Trial a larger sample size. Even though this trial set did not show harmful conditions in the process, statistically it does not completely satisfy the overall metrics of a population.
- Varying the amount of charged carbon in the scrap bucket which is the primary source of C added into the furnace. For this trial, it was kept constant per furnace conditions.
- Possibly utilizing a second injection point to see if there is variation in operating conditions.

If you have any questions or comments about the information presented in this report, please do not hesitate to contact Tony Cooper at (251) 264-3345 or tony.cooper@ssab.com.