Emissions Reduction and Process Improvements with the New Anode Furnace Off-Gas System at ASARCO Hayden

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Metallurgical Process Specialists

Presentation Outline

- ASARCO Smelter and Anode Department Overview
- Furnace Operations Before New System
- Benchmarking and Selection of Off-Gas System Concept
- New Off-Gas System Configuration
- System Startup and Commissioning
- Process Optimization

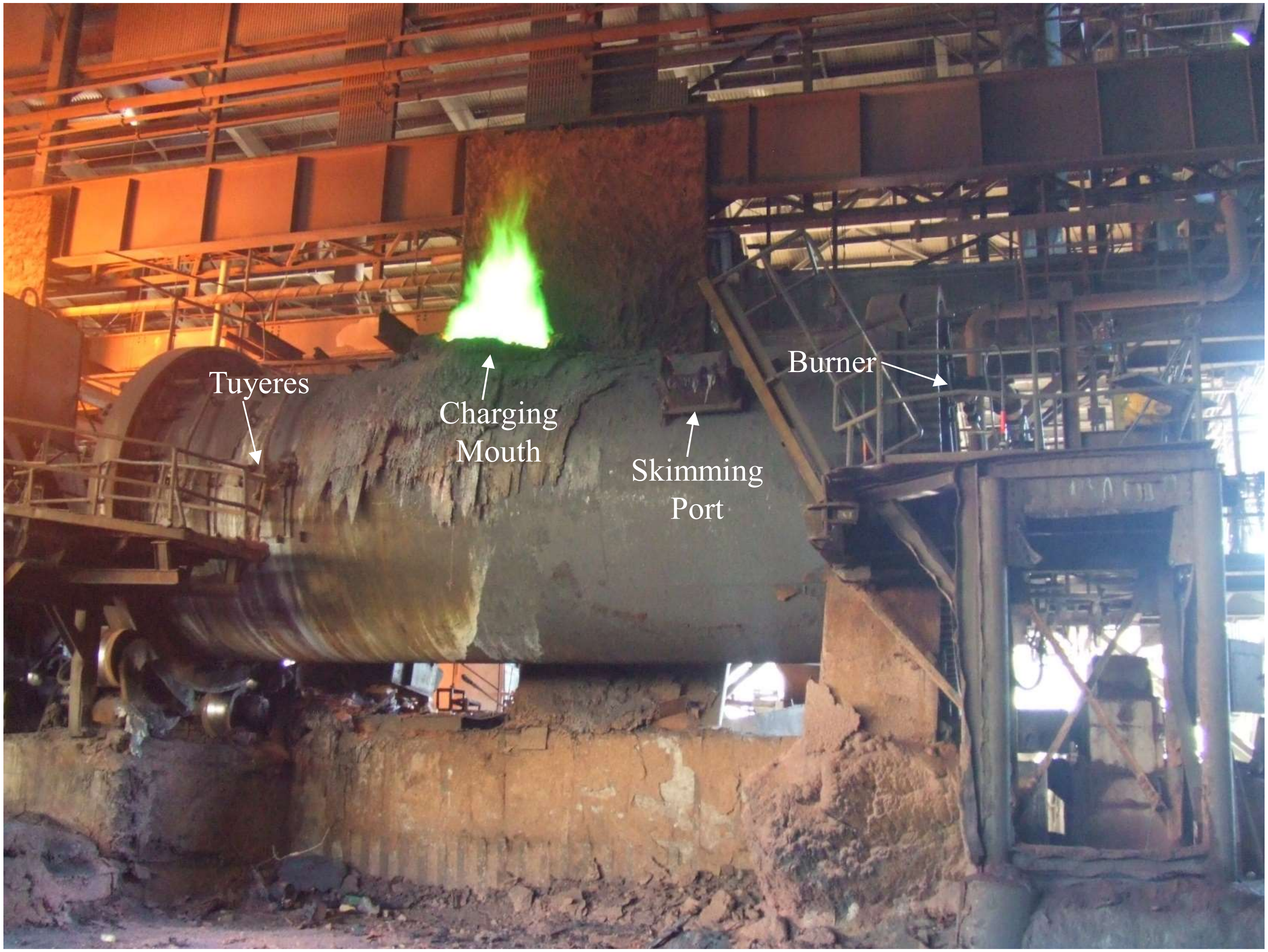
Hayden Operations History

- Construction and operation of the Hayden Smelter and Concentrator commenced 1910-12 under separate ownership.
- The original converters and reverbs were upgraded in size, and natural gas use commenced in 1937.
- A 1966 expansion took capacity from 60,000 to 180,000 stpy blister.
- The 1970 Clean Air Act prompted construction of the first acid plant.
- 1973 saw installation of an anode plant with two furnaces and two casting wheels.
- The Inco flash furnace and new acid plant were installed in 1983.
- In 1986, Asarco purchased the Ray Mines Division (which included the Hayden concentrator) from Kennecott .
- The converter secondary hood bag house was installed in 1996.
- In 1998, the 1983 flash furnace gas handling system (settling chamber, quench towers, ESPs) was replaced with a wet gas scrubbing system.
- In 1999, Asarco was acquired as a wholly owned subsidiary of Grupo Mexico.

Tapping Matte at INCO Flash Furnace

Transferring Blister Copper From Converters

Furnace Operations Before New Off-Gas System



Casting Anodes

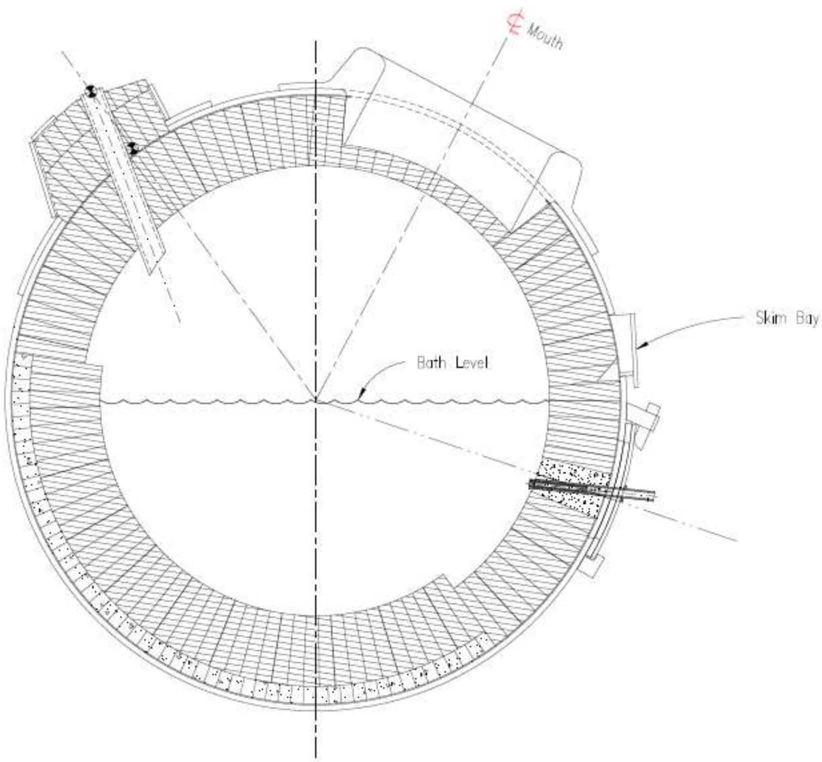
Anode Furnace Department Overview

- 3 Anode Furnaces (2 hot, 1 processing)
  - 13’ D x 35’ L
  - Natural gas plus steam reductant through 2 tuyeres
  - Natural gas and air burner in endwall opposite tuyeres
  - Single mouth for charging and off-gas in center of barrel
  - 240 short tons blister per cycle – 2 to 2.5 cycles per day
- 2 casting wheels (600 tpd design)
  - 16 molds per wheel
  - 830 lb anode

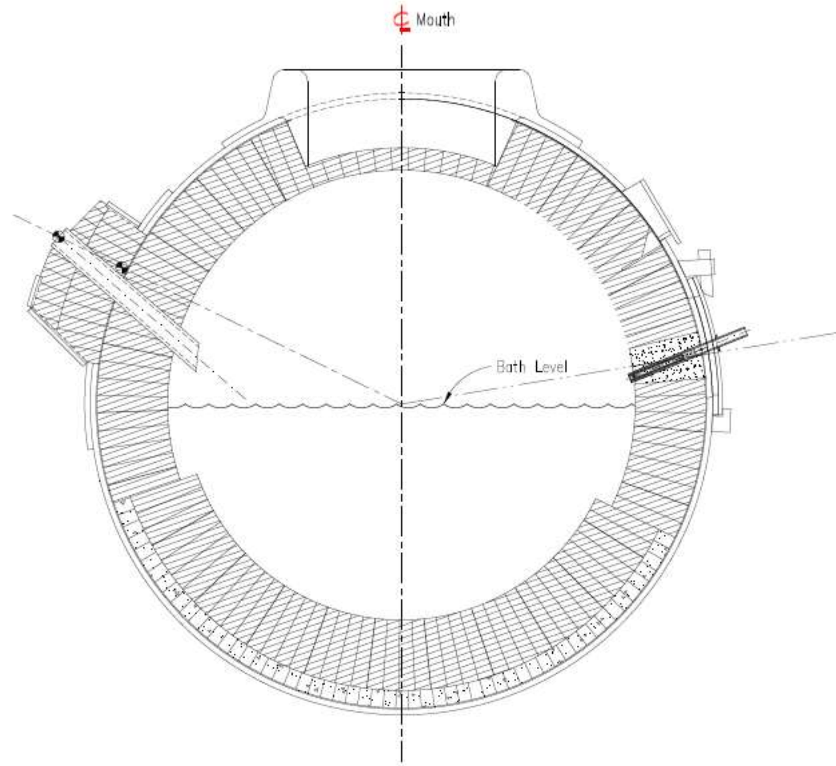
Anode Furnace Process Overview

- Converter charge is finished at the "Worm Copper" stage (> 250 ppm SO_2)
- Usually three converter charges are required to fill an Anode Furnace
- Oxidizing Stage -
  - Air is blown thru the tuyeres to oxidize the copper to less than 50 ppm SO_2
  - Remaining impurities are trapped in oxide slag along with the copper oxide and are skimmed off
- Reducing Stage
  - Natural gas with steam is blown thru the tuyeres to remove excess oxygen from the oxidizing stage producing anode copper

Anode Furnace Process Overview



ANODE FURNACE
POLLING POSITION
1/2" = 1'



ANODE FURNACE
CHARGING POSITION
1/2" = 1'

ASARCO GRUPO MEXICO
GCT Metallurgical Process Specialists

Furnace Operations Before New Off-Gas System

- 300-500 SCFM natural gas plus 70-100 SCFM steam reductant (not measured)
- 500 SCFM natural gas plus >8000 SCFM air to burner throughout cycle (not measured)
- Cycle Time:
  - Filling: 12 hours
  - Final Oxidation: 45 - 60 minutes
  - Reduction: 3.5 - 4 hours
  - Casting: 4.5 hours

Metallurgical Process Specialists

Introduction to GCT

- Gas Cleaning Technologies (GCT) based in Dallas, Texas provides engineering services to ferrous and non-ferrous metals industries

- Performed conceptual and detailed engineering and EPCM services for the new Anode Furnace Off-Gas System

Drivers for New Off-Gas System

- Emissions Reduction
    - Revised Pb National Ambient Air Quality Standard
    - Metal Hazardous Air Pollutants (HAPs)
- Building Integrity – reduced exposure of structure to heat and corrosion

Benchmarking of Anode Furnace Off-Gas Systems

- Benchmarking of several smelters around the world
- Benchmarking parameters:
  - Reductant type
  - Steam use for reforming
  - Batch size
  - Cycle time
  - Burner operations
  - Off-gas ports
  - Off-gas handling technologies
  - System capacity and performance

Benchmarking of Anode Furnace Off-Gas Systems

Parameter	Units	ASARCO Hayden	North America 1	Europe 1	Europe 2	Europe 3	North America 2	Asia 1	North America 3
Anode Heat Size (Anodes)	tons	270	650	400	300	270			325
Oxidation Cycle Time	hrs	0:45	1:00	0:30		0:30		2:00	3:30
Reductant		Natural Gas with Steam	Natural Gas with Steam	Natural Gas	Ammonia	Natural Gas	Natural Gas	LPG	Ammonia
Reduction Cycle Time	hrs	3:30	0:45	2:30	1:20	2:30	3:00	2:00	1:30
Gas Cooling		Spray Cooler	Spray Cooler		Spray Cooler				Spray Cooler
Dust Collector Type		Baghouse	Baghouse	Venturi Scrubber + WESP	Baghouse	Baghouse	Baghouse	Dryer, then ESP	Dryer, then Baghouse
SO_2 Scrubbing		None	Caustic Scrubber	None	None	None			

Benchmarking of Anode Furnace Off-Gas Systems

- Vast majority of benchmarked systems use a baghouse for dust control
- Baghouse is only effective way to control carbon black soot
- Some applications have directed gases to dryers for heat recovery
  - Evaluated for ASARCO but found to not be economically feasible
- SO_2 scrubbing has been used in some applications but typically not used for anode furnace off-gases due to low SO_2 concentration and short generation times

Selected Anode Furnace Off-Gas System Configuration

- Baghouse-based full combustion off-gas system selected
- Install smaller off-gas port on vessel barrels
- Install pneumatically-operated charging mouth covers
- Retrofit building to accommodate new refractory ductwork
- Refractory-lined hoods and off-take ducts with draft control dampers
- Common duct connecting hoods (partially refractory-lined)
- Evaporative spray chamber for gas cooling to 400°F
- 4-compartment pulse jet baghouse for dust removal (designed for 500°F)
- Emergency dilution air damper at baghouse inlet for baghouse protection
- Single ID fan with inlet louver damper and dedicated stack
- Baghouse dust handling system with bagging station

Selected Anode Furnace Off-Gas System Configuration

Selected Anode Furnace Off-Gas System Configuration

Selected Anode Furnace Off-Gas System Configuration

Anode Furnace Off-Gas System Implementation

- GCT provided Preliminary and Detailed Engineering and EPCM
  - Preliminary Engineering completed December 2010
  - Detailed Engineering completed in 2011
  - Construction started in August 2011
  - Baghouse system started with Anode 0 in February 2012
  - Anode 2 tie-in in May 2012
  - Anode 1 tie-in in July 2012
- System passed first compliance test in September 2012

- Project CAPEX: $9.3 million

Anode Furnace Off-Gas System Implementation

Before project

After Commissioning

Troubleshooting of Startup Issues

Burner flame observed coming out of skimming port with charging mouth closed

- Determined that burner input was too intensive and was pressurizing vessel
- Significant reduction in burner inputs eliminated the skimming port flame with a managable draft setpoint of -1 to -2 inwg.

Unevaporated spray water collecting in bottom of spray chamber

- Nozzle positions and angles were modified based on CFD modeling and field observations, and one nozzle was shut off.
- Thermowells were replaced with more responsive thermocouples and thermowells.
- Booster pump turn on setpoint was reduced below gas outlet setpoint, and gas outlet temperature setpoint was raised from 350°F to 400°F, eliminating surging and water collection in hopper.

Draft control damper seizing and breaking when exposed to very high temperature

- A secondary temperature control loop was added to protect the dampers from excessive temperature and has proven effective

Process Optimization

- Drivers for Process Optimization
  - Anode furnace reduction time (3.5 hours) was still longer than other similar operations
  - Dust collected by baghouse showed high soot formation
  - Higher draft required than expected to prevent burner flames escaping from skimming port
- ASARCO and GCT worked together to optimize the anode furnace and off-gas system operations
- Flowmeters were added to tuyere and burner air and gas lines to quantify injection and burner rates
- A series of trials performed from March to August 2012 to optimize operations

Process Optimization

Trial Series #1 – Burner and Hood Draft Setpoints

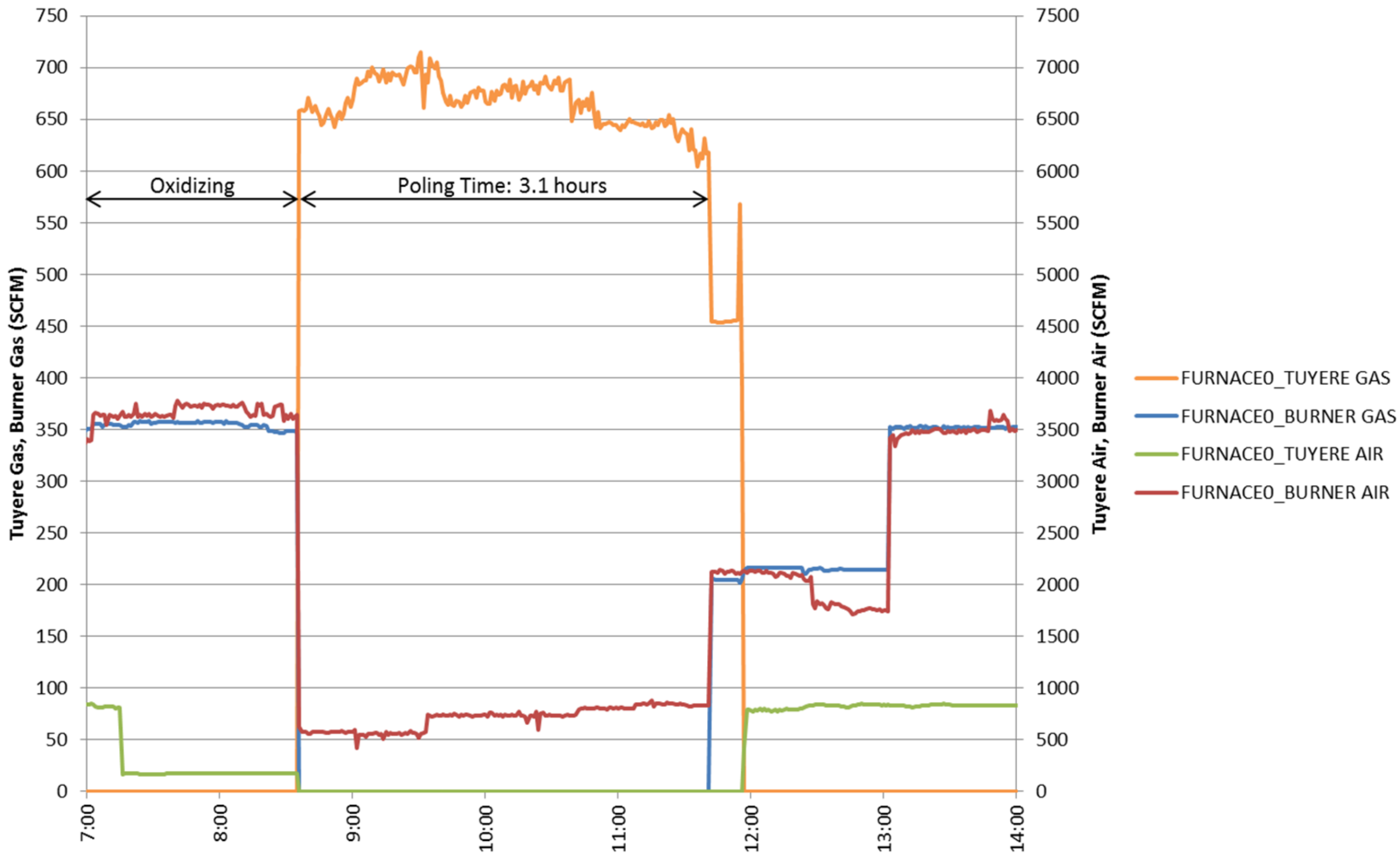
- Burner air-to-gas ratio reduced to 10:1
- For each stage of operation, burner setpoints were reduced and then hood draft setpoints reduced to match conditions
- Operations were observed to detect any fugitive emissions during processing
- Goal was to find minimum burner heat input that would maintain bath temperature or provide timely heat up for each stage of operation
- Once burner heat input setting defined, the next goal was to determine optimum draft setpoint to maintain acceptable hood temperature range and exhaust rate with no visible emissions from vessel

Process Optimization

Trial Series #1 – Burner and Hood Draft Setpoints - Results

- Reducing the burner air-to-gas ratio allowed the burner to provide much faster bath heat-up at reduced burner fuel consumption
- Burner gas input was reduced from 500 SCFM to 250 – 350 SCFM for filling, oxidizing, and casting.
- Burner gas input was eliminated for reduction with <500 SCFM burner air for post-combustion
- Draft setpoints were able to be reduced to -1 to -2 inwg, reducing hood air infiltration while still maintaining no visible emissions

Process Optimization



Process Optimization

Trial Series #2 – Define Sources of High Soot Formation

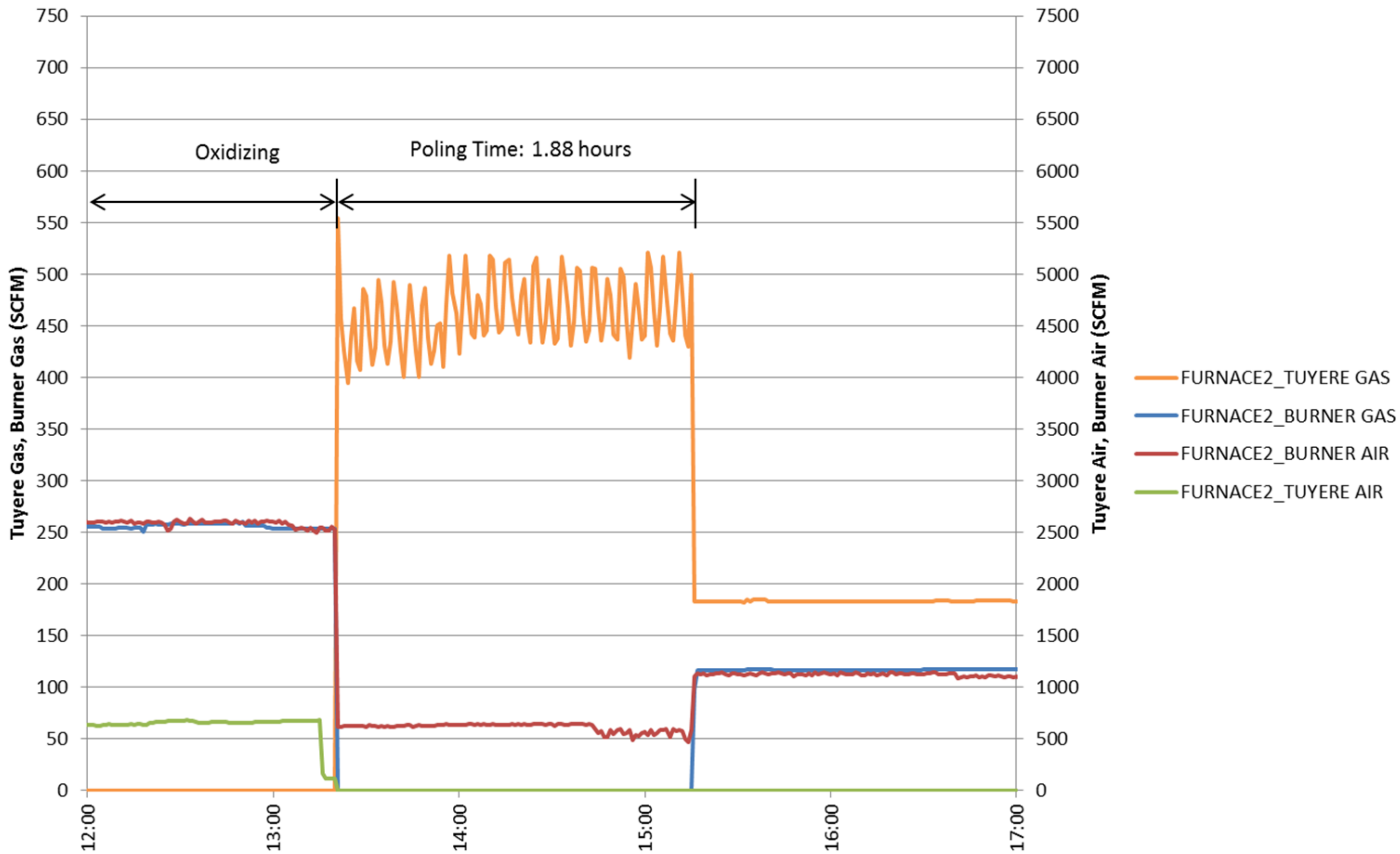
- Isokinetic sampling performed at baghouse inlet to measure dust loading for each stage of operation
- Carbon content analysis of isokinetic sample performed to quantify soot formation in each stage
- Bath samples collected and analyzed every 30 minutes during reduction to evaluate the reduction efficiency profile
- Goal was to determine primary cause of high soot formation and to develop further testing program to reduce formation

Process Optimization

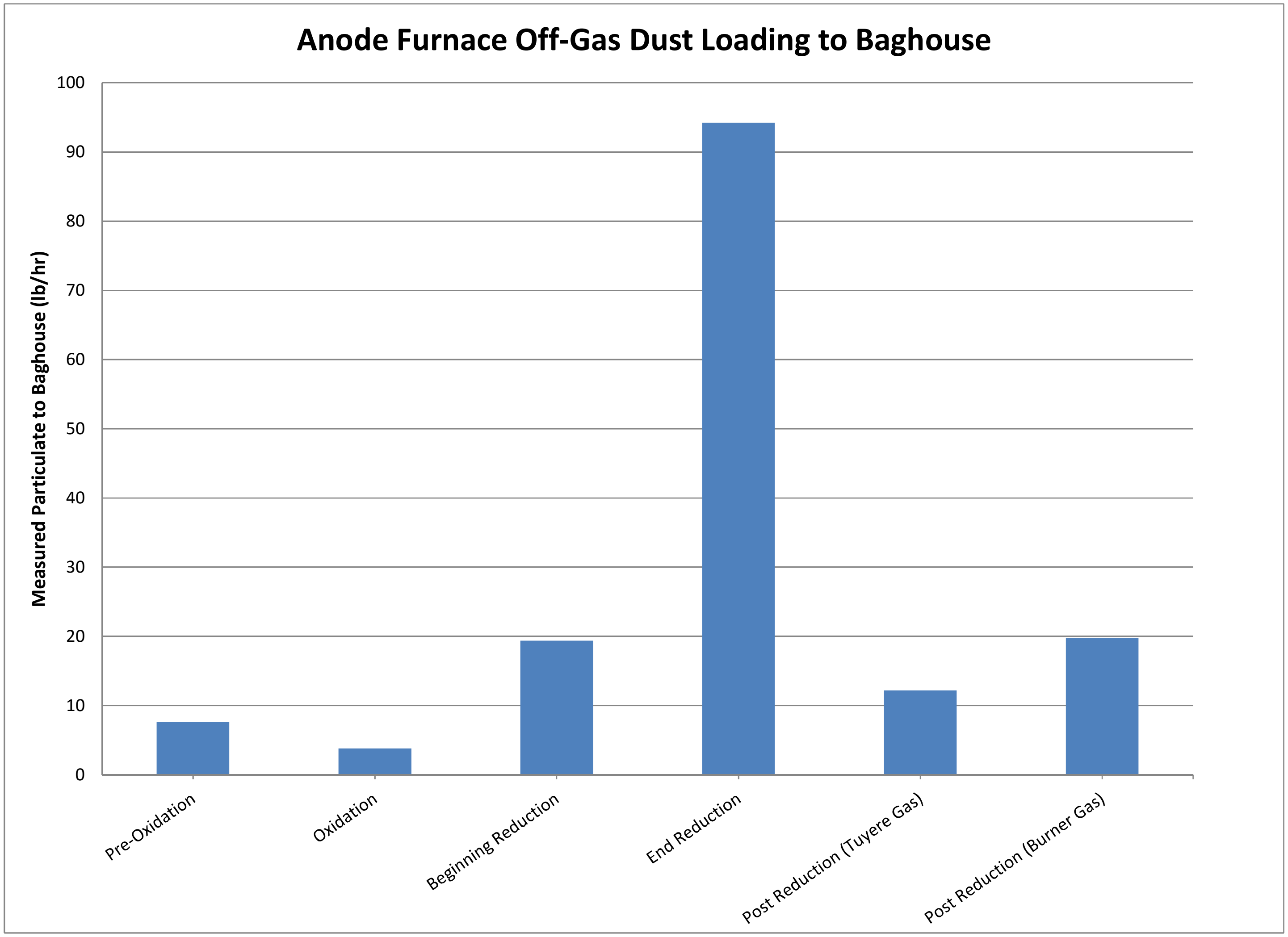
Trial Series #2 – Define Sources of High Soot Formation - Results

- Isokinetic sampling indicated soot generation rate was significantly higher during reduction and particularly during the last 30 minutes of reduction
- Results indicate that soot formation caused primarily by reductant tuyere injection and not by burners, since
  - Reductant gas injection only occurs during reduction
  - Burner gas is shut off during reduction
- Bath sampling analysis inconclusive on reduction efficiency profile
- From system start-up to end of Trial Series #2, reduction time had been reduced from 3.5 hours to 2 hours

Process Optimization



Process Optimization



Process Optimization

Trial Series #3 – Further Optimize Reduction

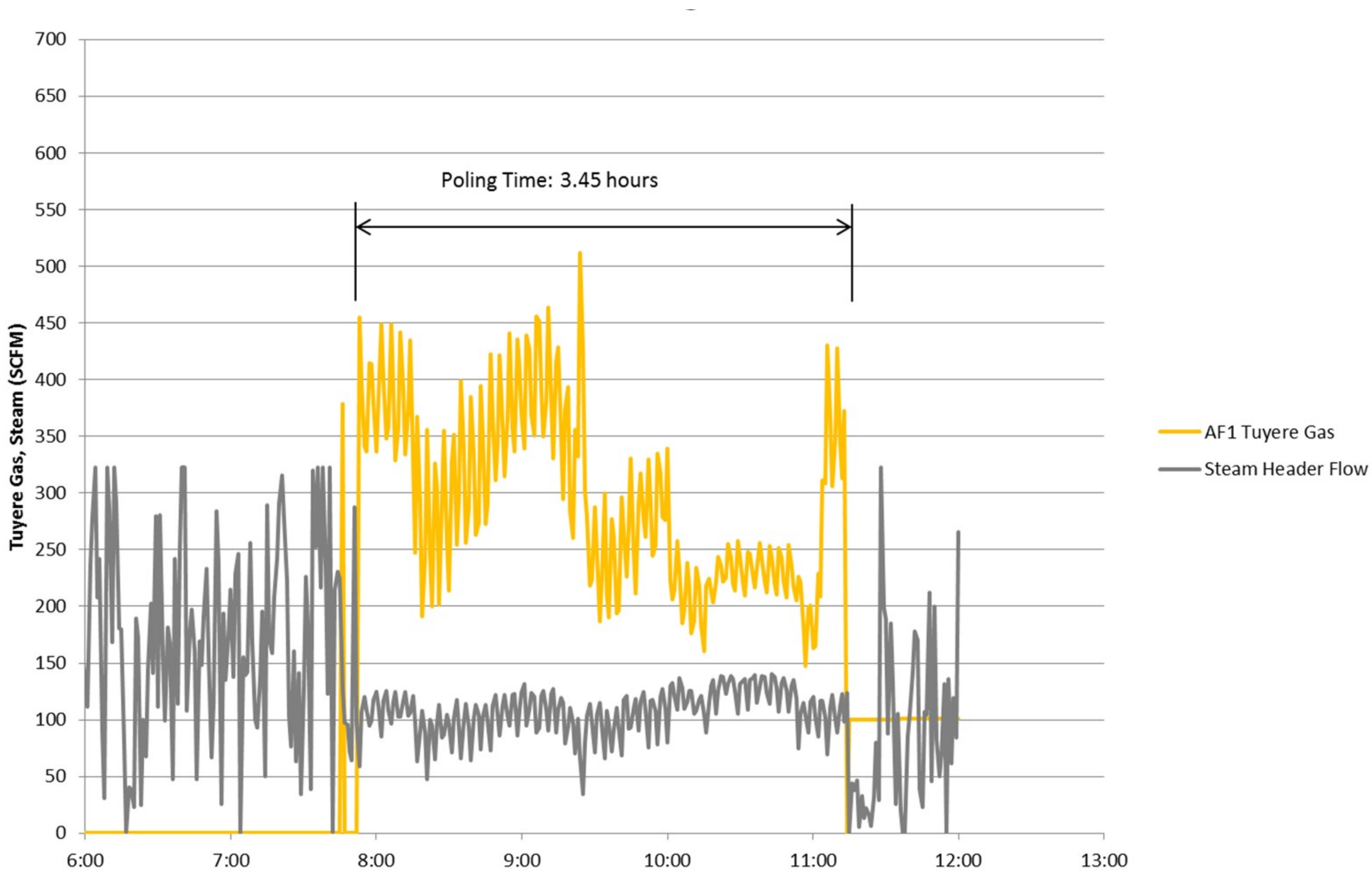
- Steam addition rate now monitored and shown to be low (70 – 110 SCFM) for reduction
- Perform reduction at normal injection rates and with lower gas/higher steam rates
- Isokinetic testing at baghouse inlet to determine impact on soot formation during reduction
- Bath samples to be collected and analyzed every 15 minutes during reduction to evaluate the reduction efficiency profile and end point
- Goal was to determine if reduction time and/or soot formation could be reduced

Process Optimization

Trial Series #3 – Further Optimize Reduction - Results

- Reduction of tuyere gas injection rate did not result in steam injection increase as hoped
- Reduction time increased as a result of the injection rate changes
- It was determined that the process had been optimized as much as possible with current configuration and equipment

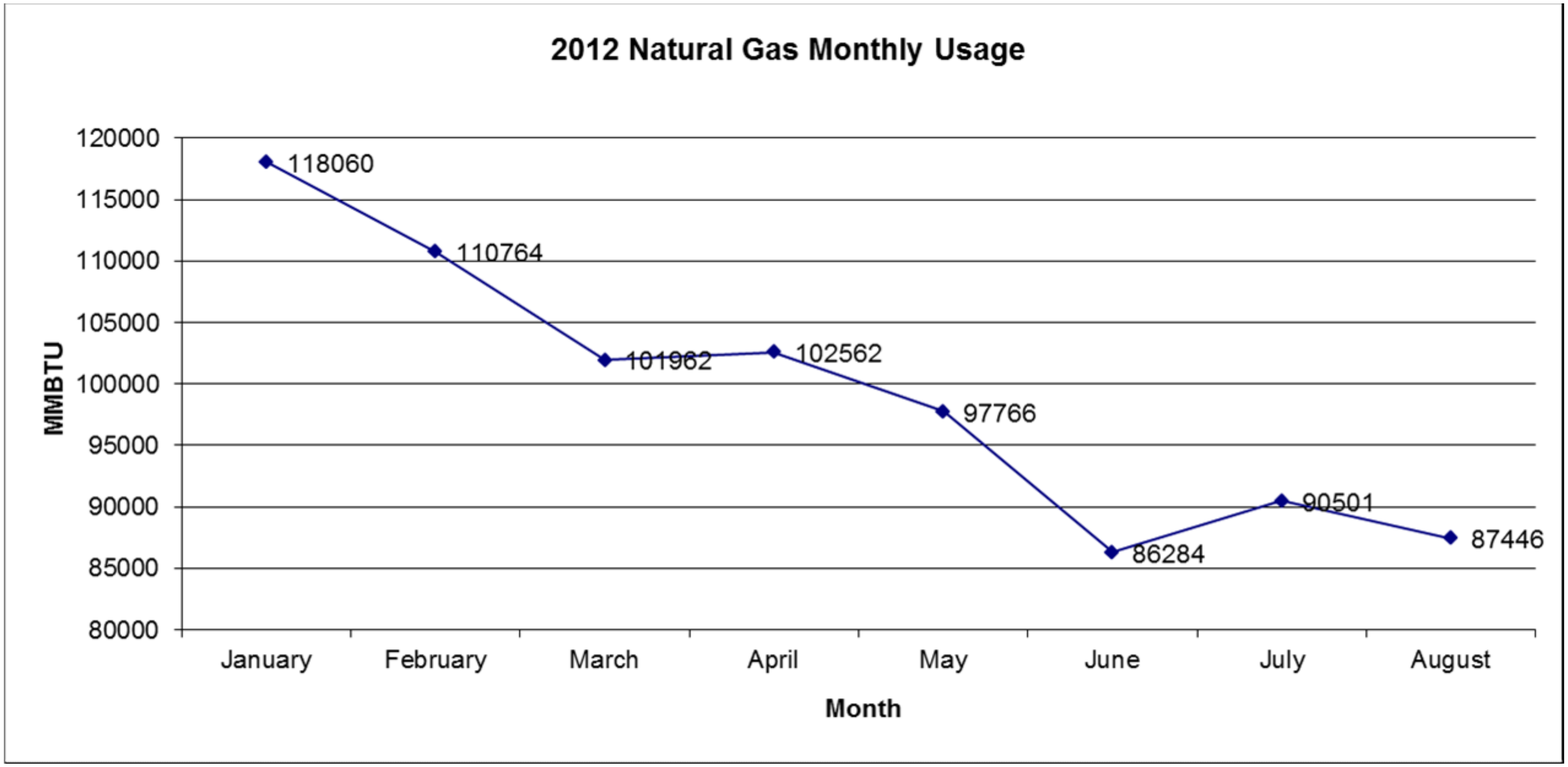
Process Optimization



Process Optimization – Summary of Results

- Burner gas rates were able to be reduced significantly or eliminated in all operating stages
- Significant burner gas consumption savings were achieved (>25% savings)
- Reduction time was reduced from 3.5 hours to 2 hours on average
- Tuyere gas injection found to be primary cause of soot formation

Process Optimization – Summary of Results



Process Optimization – Path Forward

- Intend to install new burner package on each furnace to optimize flame profile and to provide better and automatic controls
- Troubleshooting of steam boiler system to increase steam rate available to anode furnaces to further reduce soot formation

Thank You!

Questions?