

Real-Time Monitoring of Electric Arc Furnace Exhaust Using the VG Prima δ B

Key Words

- Mass Spectrometry
- Electric Arc Furnace
- Furnace Exhaust Gas Analysis
- Post-Combustion Control

Thermo Industrial Solutions Note

Introduction

Process Mass Spectrometers in general, and the VG Prima δ B system in particular, have been used with great success on many iron and steel processes around the world — Blast Furnaces, Basic Oxygen Steel, AOD, VOD, Coke Ovens, etc. This paper details the latest successful application, “*Electric arc furnace gas analysis.*”

Electric arc furnaces produce steel using a combination of electrical energy and chemical energy, the latter being

associated with oxy-fuel burners using natural gas introduced at a rate of typically 1,000 m³/h and oxygen introduced with oxygen lances. The electrical energy is typically supplied from a 100MW transformer. The raw material is normally steel scrap; other forms of raw material are available which have been produced from iron ore. These include iron (DRI), iron carbide, and pig iron.

The amount of oxygen introduced by the oxygen lances is important for ensuring complete combustion of carbon monoxide (termed post-combustion). Any carbon monoxide which leaves the



Typical Electric Arc Furnace

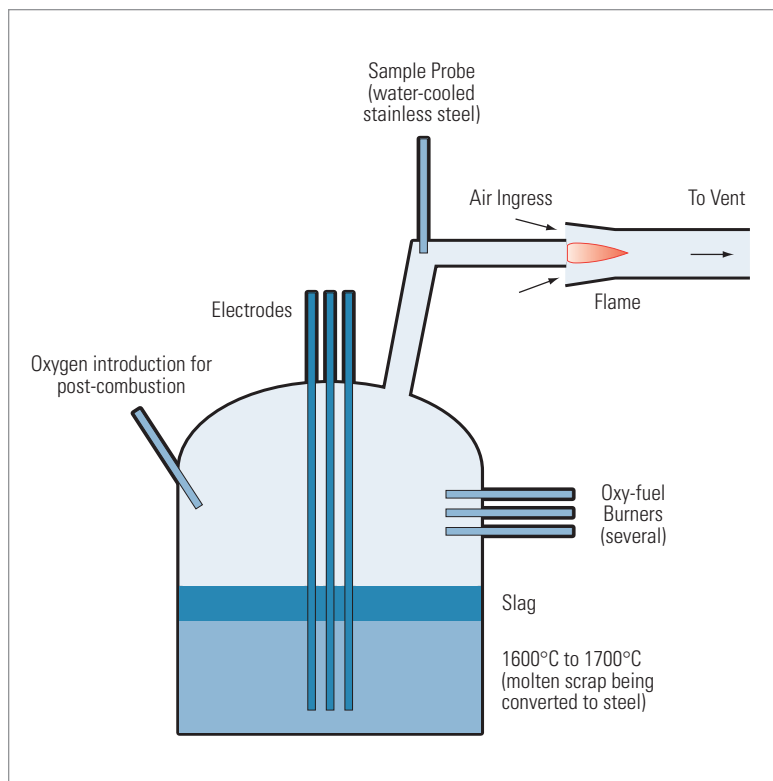


figure 1 – Typical Electric Arc Furnace Schematic

furnace non-oxidized is lost to the vent where it is burnt; however, the heat is effectively lost to the process. The amount of oxygen introduced is typically 3,500 m³/h. The total quantity of gas evolved from the furnace is in the range of 10,000-100,000 m³/h and consists of H₂, CH₄, CO, N₂, O₂, Ar, CO₂ and H₂O. The furnace is shown in *figure 1* at left. The steel production rate is typically about 180 tons/hour.

The gas is sampled at the top of the furnace using a water cooled stainless steel sample probe at a temperature of 1,500°C. The dust loading is very high about 100 g/m³; also the gas sampling is difficult due to the presence of metal vapors (e.g zinc).

The probe life is typically four months before it needs unblocking which is compatible with the normal maintenance schedule for an electric arc furnace.

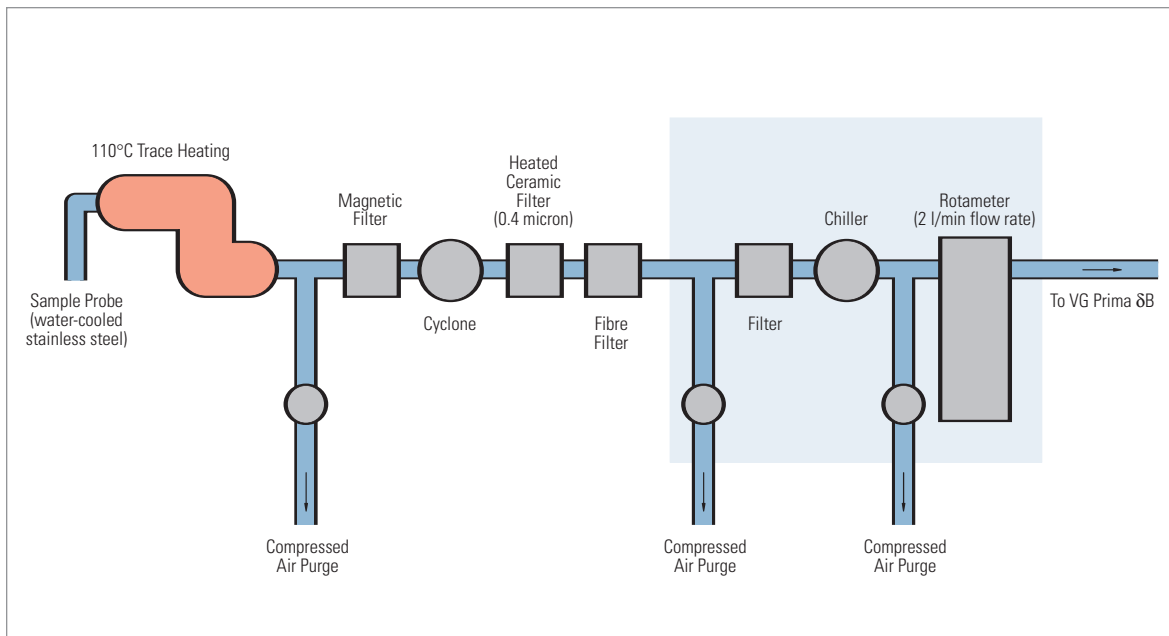


figure 2 – Sample conditioning system

The sample conditioning system is shown in *figure 2*. The response time is about 20 seconds. The electric arc process called a ‘cast’ typically takes one to two hours.

The VG Prima δB system has been used to monitor the furnace exhaust for process control modeling to optimize post-combustion. The optimization is complicated because of the so called ‘water shift reaction.’



As well as monitoring the furnace gases, helium monitoring can be used to determine actual volumetric flow rates (by measuring the helium concentration resulting from a known introduction rate of helium).

System Set-up

The Prima has replaced discrete analyzers measuring CO, CO₂, and O₂. Typical Prima analysis time is 5 seconds, but this can easily be adjusted through the software according to the actual analysis speed and precision

requirements. Longer analysis times might be used for more precise measurements, while shorter analysis times might be used where precision requirements are less or fewer components need to be analyzed for more efficient closed-loop process control. VG Prima δB’s Windows®-based GasWorks software suite allows a wide variety of instrument parameters to be monitored and modified to optimize analytical performance:

- Electron energy — to optimize the analytical performance for CO/N₂.
- Dual resolution — to ensure optimum performance for both low MW and high MW species (e.g. H₂ and CO₂).
- Inlet settling time, analyzer and detector delay, and integration times — to optimize speed of analysis.

Quantitative analysis of the furnace exhaust involves analyzing complex overlapping spectra. GasWorks allows an unlimited number of components and peak fragments to be monitored and the magnetic

sector analyzer’s stability and precision means even small molecular fragments can be accurately measured. A typical Cracking Pattern Matrix is shown in *figure 3*.

System Results

Typical EAF process data is shown in *figures 4 and 5*, where a cast takes place up to 73 minutes and then, after recharging the furnace, another cast commences about 8 minutes later.

The main objective of the analysis is to provide data for control of post-combustion to minimize the loss of carbon monoxide from the furnace. This requires accurate carbon monoxide and carbon dioxide monitoring to confer significant energy savings.

Note that the hydrogen trace resembles the carbon monoxide trace, indicating that it is formed as a result of the water shift reaction.

Reliable analytical data on the formation of hydrogen is important for highlighting water ingress from cooling water which can cause severe energy loss (latent heat and heat capacity of water).

In *figure 6*, we show a typical result of the check gas to verify system precision.

Note: if helium analysis is not required the analysis time reduces to 3.5 seconds (for the same precision as indicated above). The precision values are worsened by a factor of approximately 1.5 if the analysis time is further reduced to 2.5 seconds.

Summary

The VG Prima δB 's unique combination of high speed and excellent long-term stability make it ideal for monitoring electric arc furnace exhausts. A calibration mixture containing H₂, CO, N₂, O₂, Ar, and CO₂ run as a daily check gas on a VG Prima δB will typically remain within 2% relative tolerance for each component for more than one month without re-calibration. A quadrupole MS cannot achieve this level of stability. Typically the drift is at least a factor of 10 worse.

Consequently, there is considerable uncertainty in the ability of a quadrupole to measure the concentrations of a given gas mixture without very frequent and time-consuming recalibration. The VG Prima δB is a magnetic sector mass spectrometer with magnetic and electrostatic focusing of high energy ion beams giving highly reproducible drift-free analysis.

Quadrupole mass spectrometers have no focusing properties. The ion beams have 100x less energy and are very susceptible to interference (e.g. space and surface charging, temperature, and electrical and magnetic interference.)

The EAF process also requires a wide dynamic measurement range and here again the magnetic sector analyzer is superior.

Mass	H ₂	He	CH ₄	CO	N ₂	O ₂	Ar	CO ₂
2.0	100.0							
4.0		100.0						
12.0			0.9	100.0				1.1
14.0			9.9	0.3	100.0			
15.0			100.0					
32.0						100.0		
40.0							100.0	
44.0								100.0

figure 3 – Typical Cracking Pattern Matrix

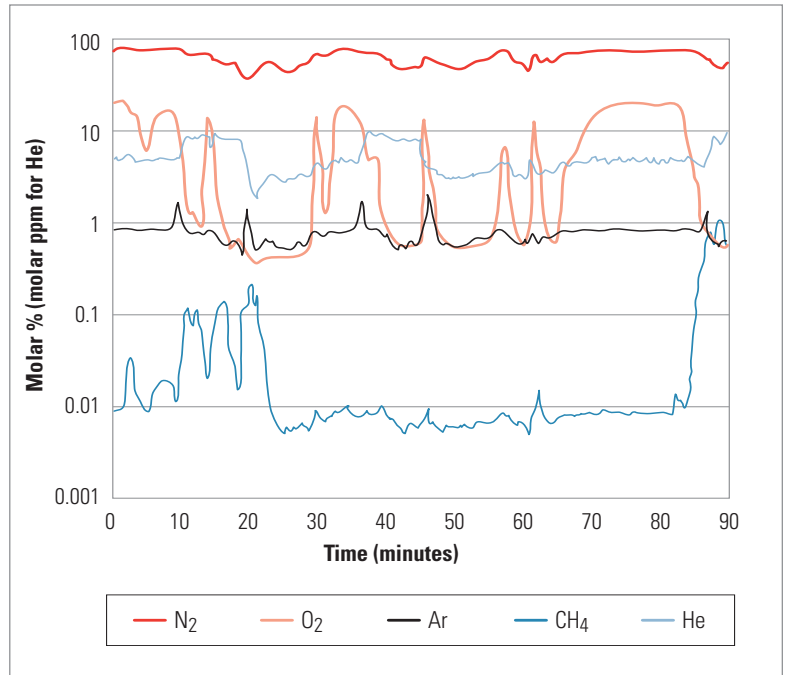


figure 4 – Typical EAF process data

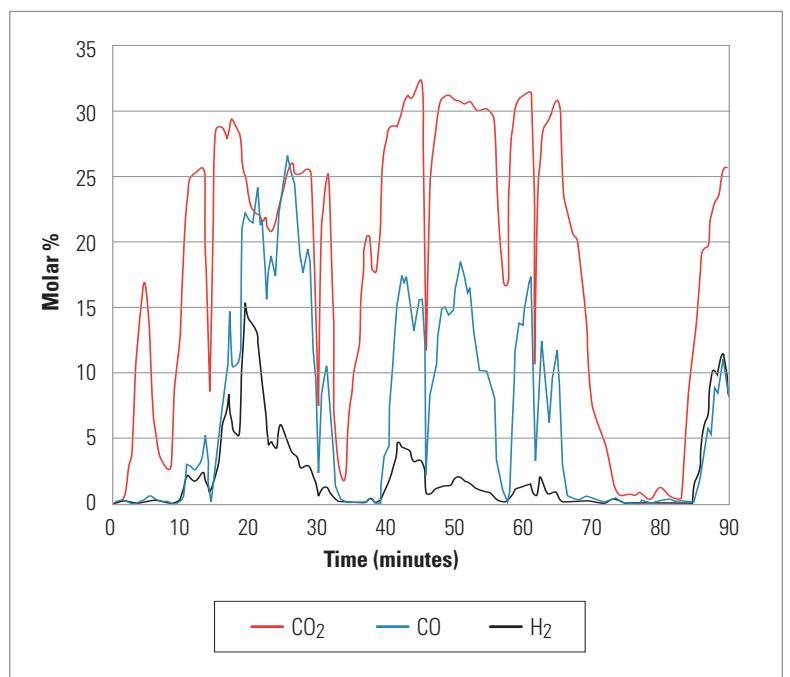


figure 5 – Typical EAF process data

The 12/44 cracking pattern for CO₂ is linear with a VG Prima δB (better than 1% over a decade) but can be very non-linear on a quadrupole MS (e.g. 15% over a decade). Quadrupole mass spectrometers cannot reliably measure CO in the presence of CO₂ due to the uncertainty of the contribution of CO₂ to mass 12 (the mass used for determining CO).

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Analyte	Units	Mean	Std. Dev.	Minimum	@Time	Min. Date	Maximum	@Time	Max. Date
Hydrogen	%	10.103	0.0102	10.068	11:19	06 Mar	10.122	11:19	06 Mar
Helium	ppm	8.460	0.3601	7.778	11:19	06 Mar	9.480	11:19	06 Mar
Methane	%	1.002	0.0018	0.997	11:17	06 Mar	1.005	11:16	06 Mar
Carbon Monoxide	%	21.519	0.0503	21.426	11:20	06 Mar	21.623	11:15	06 Mar
Nitrogen	%	50.213	0.0384	50.104	11:17	06 Mar	50.303	11:20	06 Mar
Oxygen	%	1.197	0.0021	1.193	11:19	06 Mar	1.202	11:15	06 Mar
Argon	%	0.984	0.0012	0.981	11:19	06 Mar	0.986	11:16	06 Mar
Carbon Dioxide	%	14.981	0.0170	14.948	11:15	06 Mar	15.027	11:17	06 Mar
Analyzer Pressure	mbar	7.817	0.0386	7.752	11:19	06 Mar	7.839	11:19	06 Mar
Filament Current	Amps	2.749	0.0609	2.642	11:18	06 Mar	2.860	11:17	06 Mar
Source/Trap Ratio	Ratio	2.945	0.0679	2.840	11:15	06 Mar	3.086	11:15	06 Mar
Internal Temperature	°C	18.199	0.0000	28.199	11:15	06 Mar	28.199	11:20	06 Mar

figure 6 – Statistical report for 4.5-second analysis. Statistical report method: EAF. Samples from 06-March 11:15:31 to 06-March 11:20:47. Number of samples: 70