

Fast Reliable Process Gas Analysis in the Steel Industry

Evaluation of AMETEK's ProMaxion Analyzer for Electric Arc Furnaces

Introduction

The conversion of iron containing between 4 and 4.5% carbon to steel containing less than 0.2% carbon is one of the most important industrial processes in the world today. Over 1,300 million tons of steel were produced in 2008 in more than 60 countries around the world.

The process of converting iron to steel is based on the removal of carbon in the form of carbon monoxide and carbon dioxide. Analysis of the carbon oxides in the furnace off-gas is, therefore, a vital part of the process control strategy for the converter.

Historically, Non-Dispersive Infra-Red (NDIR) analyzers were used to measure these gases. However, they suffer from slow response and limited dynamic range. In addition, other techniques such as thermal conductivity and paramagnetics are required to measure the other process gases, such as hydrogen and oxygen. The nitrogen concentration in the gas could not be measured directly and had to be calculated by subtraction, an extremely inaccurate process.

The Importance of Fast Gas Analysis in Steel Processes

The fundamental process step is the removal of carbon by oxidation. Oxygen is blown into molten steel where it reacts with the carbon to form carbon



Typical Electrical Arc Furnace (EAF)

monoxide and carbon dioxide. It is important to control the residual carbon content of the final product. Mild steel typically contains 0.15–0.3% carbon, while specialty steel can contain less than 0.05%. At the same time, it is important to control the residual content of other elements, such as chromium, and manganese etc. The process is extremely dynamic and fast gas analysis is needed to ensure the correct end point is achieved first time, every time.

As well as the carbon oxides, steel process gas will contain nitrogen, argon, oxygen, hydrogen and water. Fast, accurate multi-component gas analysis is required for optimized process control.

Benefits of Mass Spectrometry

Analysis Speed

AMETEK quadrupole mass spectrometers can measure and report the steel process gas components in as little as three seconds, allowing the plant control system to be updated virtually in real time.

Wide Dynamic Range

Mass spectrometry's wide dynamic range allows gas species to be measured accurately from ppm to percentage levels. Other techniques require multi-point calibrations to cover the component ranges that are found in the analysis.

Complete Stream Analysis

Only mass spectrometry provides the ability to measure all process gas components quickly and reliably.

Steelmaking: BOS and EAF

The **Basic Oxygen Steel (BOS)** process accounts for 65% of world steel production. In an integrated steel mill, the BOS is charged with molten iron directly from the blast furnace. The term ‘Basic’ refers to the furnace’s refractory lining, typically magnesia, which wears through contact with hot slags. These slags are required to remove phosphorus and sulfur from the molten charge. Pure oxygen at very high pressure and supersonic velocity is injected into the molten iron to oxidize the carbon to CO and CO₂.

The **Electric Arc Furnace (EAF)** method has the advantage that it does not need to be charged with molten iron. It is charged with solid feedstock, typically scrap metal or pig iron.

The EAF converts this scrap material to steel using a combination of electrical and chemical energy. Electrical energy is provided by electrodes which ignite an arc on the surface of the cold metal. Steel is produced not only in AC electric arc furnaces, which operate with three graphite electrodes, but also in direct-current arc furnaces fitted with just one electrode. A schematic of a DC furnace is shown in Figure 1.

Natural gas fuelled burners assist in the melting process and oxygen is injected to promote the combustion of CO to CO₂ in the furnace. Any CO that leaves the furnace is burnt in the vent, but this means the furnace is losing heat.

A typical EAF will produce around 200 tons of steel per melt and the annual output will be around 1.5 million tons.

The gas from the EAF consists of H₂, CH₄, CO, N₂, O₂, Ar, CO₂ and H₂O. In addition, Helium may be added as a tracer gas to assist in process modeling.

reliable data to the plant control system to ensure the control model is continuously updated and optimized.

Need for Multi-Component Gas Analysis

Carbon Monoxide and Carbon Dioxide Analysis

The CO/CO₂ ratio gives a clear indication of carbon removal during the blowing phase and is used to predict the beginning and end of decarburization. This reduces the need for re-blows (restarting the process) and extra additions to the process, reducing costs and improving productivity. In EAF, it is extremely important to minimize the amount of CO leaving the furnace, as stated above.

Oxygen Analysis

The oxygen measurement helps ensure the lance is positioned correctly for the beginning and end of the oxygen blow. It also indicates how much slag is being produced in the furnace.

Hydrogen Analysis

Hydrogen is monitored to check for leaks in the furnace cooling system.

Nitrogen Analysis

Problems can occur if the slag level exceeds the height of the vessel and overflows, causing metal loss, process disruption and environmental pollution. It is important to avoid this ‘slopping’; and to do this, the producer needs to know how much oxygen is in the converter. As well as oxygen, the MS measures nitrogen, so the amount of air leaking into the converter hood can be calculated. This, in turn, gives a precise measurement of the oxygen leaving the converter.

Accurate nitrogen concentration measurement also assists in predicting the residual carbon, phosphorous and manganese content in the steel.

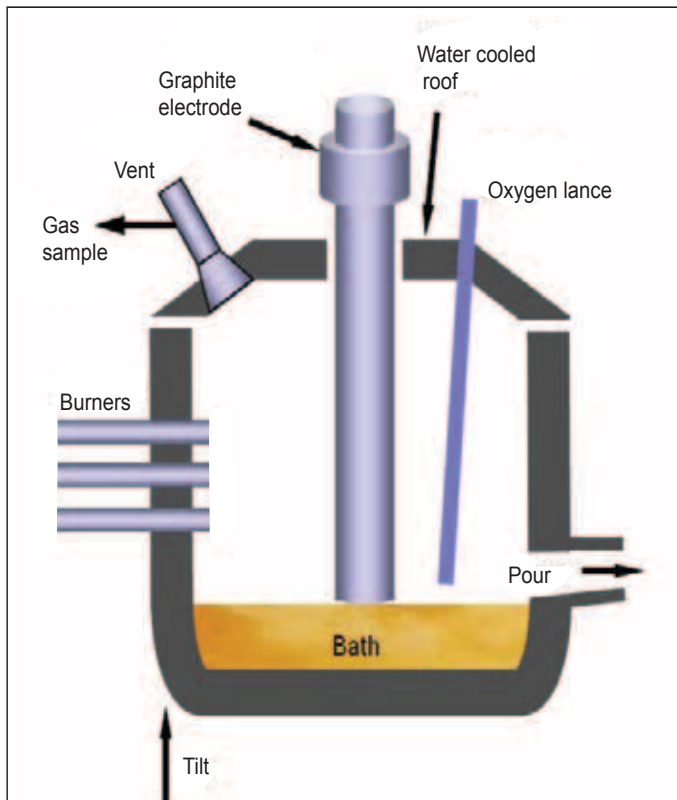


Figure 1: Electric Arc Furnace (EAF) schematic

Like the BOS, the EAF is a batch melting process. Each batch of molten steel is known as a ‘heat’. The EAF’s operating cycle is called the tap-to-tap cycle and is typically between 40 and 60 minutes. The wide variation in scrap metal used in each batch produces wide variations in the gas composition profile, so the gas analysis system must provide dynamic, accurate and

Evaluation of AMETEK MS on an Electric Arc Furnace

AMETEK was recently approached by Georgsmarienhütte Steel (GMH), an independent, medium-size state-of-the-art steel maker based in Georgsmarienhütte near Osnabrück, Germany. In 2007, they signed a license agreement with the German steel systems integrator Messen-Regeln-Steuern (MRS) to promote the TETHYS® gas analysis system for Electric Arc Furnaces. TETHYS® comprises a gas sampling system with water-cooled probes capable of withstanding temperatures up to 1800°C and dust concentrations up to 500 g/Nm³. A mass spectrometer is used to analyze the conditioned gas and this data is used to drive a control system to optimize process efficiency. GMH and MRS wished to evaluate the AMETEK MS as a potential MS analyzer for the TETHYS® system.



Figure 2: AMETEK ProMaxion Process MS in GMH analyzer shelter

AMETEK ProMaxion Process MS

AMETEK supplied a ProMaxion system which was installed in GMH's analyzer shelter (Figure 2). The shelter and sample conditioning system providing the sample to the MS were designed and built by MRS. Results from the AMETEK system were correlated against an existing MS belonging

to GMH, sampling at the same point as the ProMaxion. A second MS could also be used to monitor the EAF process from a different sample point.

The ProMaxion is a fast scanning quadrupole MS in a rugged stainless steel fan-cooled enclosure. The enclosure was found to be resistant to the high EMC fields generated by the EAF.

AMETEK's Process 2000 process MS software was used to acquire gas composition data; this was transferred to the GMH control system by analog outputs. Process 2000 also supports OPC and Modbus serial protocols.

Before shipment, the system underwent a series of stability tests. An example is shown in Figure 3.

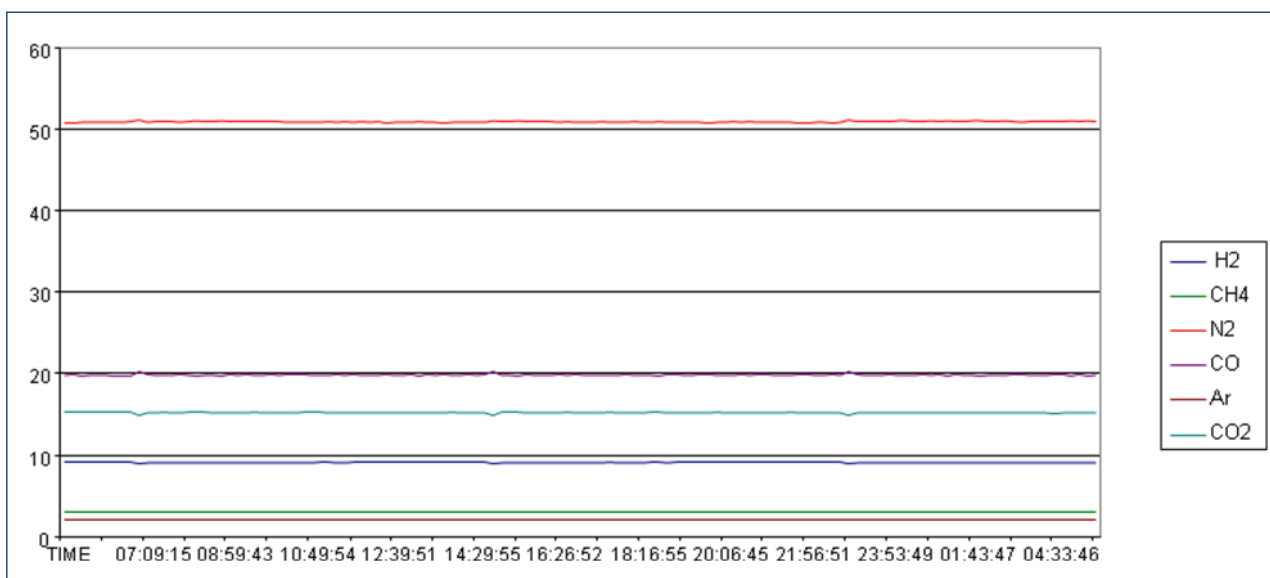


Figure 3: 24 hour stability test on ProMaxion MS in AMETEK factory prior to shipment to GMH

Results of Evaluation

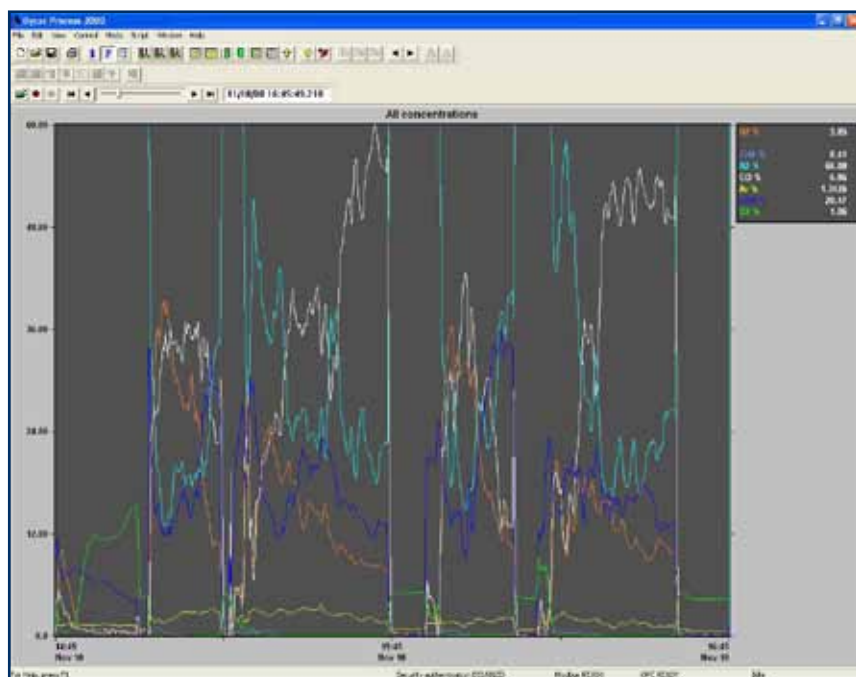


Figure 4 shows an example of a trend display from Process 2000. The system monitored CO, CO₂, H₂, O₂, CH₄, N₂ and Ar at percentage levels with the Faraday detector and He tracer gas at ppm levels with the MCP multiplier detector. Two 'casts' are displayed.

EAF runs are characterised by dramatic differences in the off-gas profile of each cast, caused by variations in the type and quality of scrap metal feedstock. The speed of the AMETEK MS ensures the plant control model is continuously updated with accurate gas analysis information.

Figure 4: Process 2000 trend display

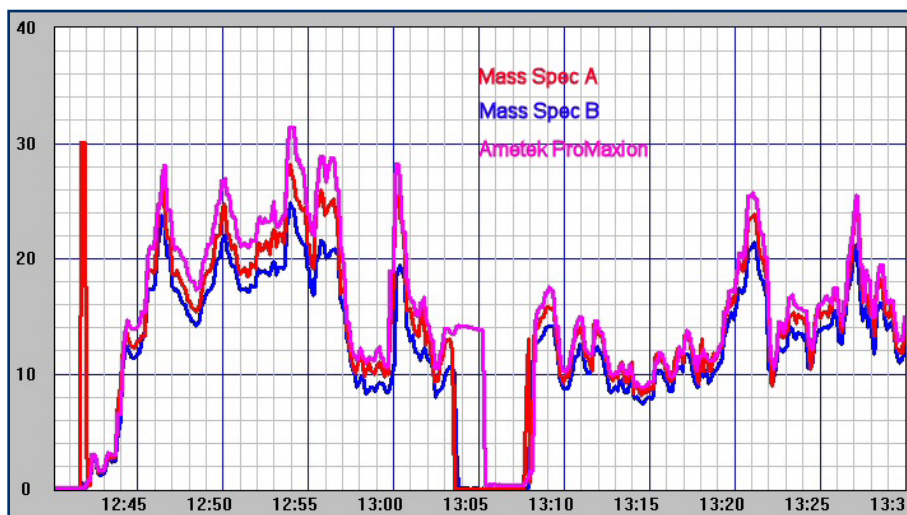


Figure 5 shows a comparison of the CO₂ reading from the AMETEK MS compared to the readings from the existing mass spectrometers.

This and similar comparisons for the other process gases over many casts proved there was excellent correlation between the three mass spectrometer systems.

Figure 5: MS comparison

Summary

Process MS is the proven method for measuring furnace gases in the BOS and EAF steelmaking processes. The recent evaluation of the Ametek MS by GMH and MRS has shown that the ProMaxion provides accurate, reliable gas composition data for steelmaking process control.

In addition, these highly experienced steelmaking engineers were extremely impressed with the ProMaxion's ease of use (both hardware and software), reliability and rugged design.

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