Application Note

MGA Process Mass Spectrometer

The MGA™ Analyzer and the Steelmaking Process

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For over three decades Hamilton Sundstrand has successfully supported the operations of steel processing plants by providing MGA process mass spectrometers for reliable real-time monitoring. The MGA analyzer provides quick and accurate analyses of Coke Oven, Blast Furnace (BF), Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) top gases enabling excellent control of combustion operating set points. The end results are significant savings in fuel consumption and operating costs. Each MGA analyzer utilizes a magnetic sector mass spectrometer which is well known for its superior signal stability and sensitivity. By working closely with users, Hamilton Sundstrand's engineers keep abreast of the current trends in steel process operations and continue to enhance the performance of the MGA product line.

Steelmaking Process Overview

During the past couple of decades, steel manufacturers have been able to use the benefits of ever advancing technology to increase the efficiency of their production facilities. While the efficiency of the process has improved, the basic steelmaking process has changed very little.

Figure 1 illustrates the steelmaking process. Coke is produced in the coke oven and is then used in the Blast Furnace. The BF provides molten iron to the BOF, which in turn provides molten steel to the mills.

The MGA process mass spectrometer provides analytical information that the operator can use to optimize all of the processes involved in the production scheme.

The Beginning – Producing Coke from Coal

The production of coke is an integral part of steelmaking as coke is used as a primary fuel for Blast Furnaces. It involves the carbonization of coal at high temperatures (about 1100°C) under an oxygen deficient atmosphere inside a coke oven. The coal-to-coke conversion is intended to produce a carbon-enriched material devoid of chemical impurities normally present in unprocessed coal. Coke production also generates what is called coke oven gas, which consists of hydrogen, methane, nitrogen, carbon monoxide, carbon dioxide, and light hydrocarbons. As it has a high energy content, coke oven gas is conditioned and recycled as a fuel gas for use in other steel processing operations.

Typical Coke Oven Gases Monitored

Hydrogen (H_2)	0-100%
Nitrogen (N_2)	0-100%
Methane (CH_4)	0-30%
Carbon Monoxide (CO)	0-10%
Carbon Dioxide (CO_2)	0-10%
Ethane (C_2H_4)	0-5%
Ethylene (C_2H_6)	0-5%
Oxygen (O_2)	0-2%
Argon (Ar)	0-1%
Propylene (C_3H_6)	0-1%
Propane (C_3H_8)	0-1%
Hydrogen Sulfide (H_2S)	0-1%

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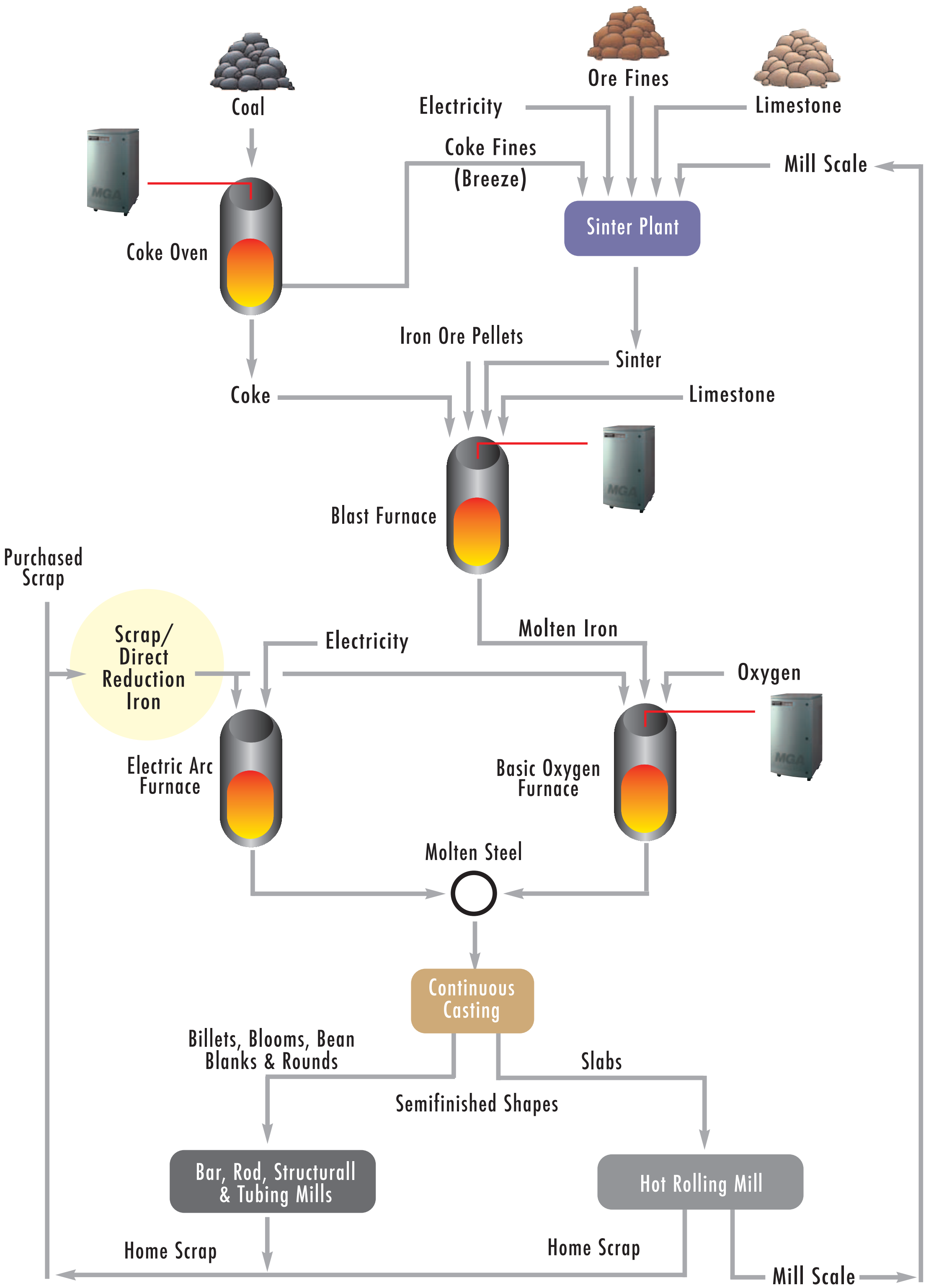
Figure 1: The Steelmaking Process



The Middle – Producing Molten Iron

The steelmaking process begins at a Blast Furnace, where iron oxide (Fe_2O_3), a primary component of iron ore, is chemically reduced to molten iron (called pig iron) by reaction with carbon monoxide. The series of chemical reactions involved in producing molten iron occurs at temperatures between about 850°C and 1500°C. The energy required to achieve these reaction temperatures is obtained from the heat evolved during exothermic reactions, the heat generated by the combustion of coke in air, and the heat content of the hot (>1000°C) air blasts.

Typical Blast Furnace Gases Monitored	
Hydrogen (H_2)	0-50%
Nitrogen (N_2)	0-75%
Carbon Monoxide (CO)	0-50%
Methane (CH_4)	0-30%
Oxygen (O_2)	0-1%
Carbon Dioxide (CO_2)	0-1%
Argon (Ar)	0-1%

At about 850°C carbon from coke reacts with oxygen in air and forms carbon dioxide. In the next step carbon dioxide is reduced to carbon monoxide in the presence of excess carbon. The reducing (carbon-rich) atmosphere in a BF is achieved by maintaining the required material balance between air and coke. This reaction takes place at about 1100°C. Finally, at about 1300°C the extraction of iron metal from iron ore occurs. Carbon monoxide reacts with iron (III) oxide to yield elemental iron and carbon dioxide. Because the temperature near the bottom of the BF is 1500°C or higher, the iron metal is produced in a molten state and tapped at the bottom as a liquid. The hot metal is about 95% iron and contains residual contaminants such as carbon, sulfur, manganese, phosphorus, and silicon. Iron metal and slag, both in liquid state, are the final products. They collect in two separate layers at the bottom of the furnace; the low-density slag floats on top of the heavier molten iron. The slag and molten iron exit the BF through the tap holes and undergo further refining steps. The molten iron is transported to a BOF where it is refined into different grades of steel.

The End – Producing Steel in the Basic Oxygen Furnace

The hot metal (pig iron) that leaves the BF contains about 5% carbon and other trace impurities. The impurities, particularly carbon, impart an undesirable brittleness to the iron; therefore, further processing is employed to reduce their levels. The charge to a BOF includes hot metal (from the BF), steel scraps and calcium oxide (burnt lime). Typically, the metal charge consists of about 75% BF iron and 25% steel scraps. The refining is initiated by melting the steel scraps with the molten iron. Then pure oxygen is introduced through a lance into the furnace where it reacts with the chemical impurities in the hot metal pool, yielding oxides. During the formation of oxides the impurities are stripped off the metal leaving refined steel. Subsequently, the oxides react with lime (calcium oxide) to produce the BOF slag. At the end of the cycle, the furnace is tilted and molten steel is poured through a taphole into a ladle. At this point the collected steel is ready for casting.

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Producing Steel in the Electric Arc Furnace

The EAF is used to produce steel primarily from steel scraps. Its basic configuration includes a tiltable furnace, moveable roof for entry of charges, graphite electrodes, tap hole and gas exhaust system. The EAF operation involves a batch melting process consisting of charging, melting, refining, tapping, and slag handling. A cycle (or batch) takes less than one hour to complete and is referred to as a "heat." A heat is started by dumping a charge consisting of steel scraps, carbon and fluxes into the furnace through the furnace's roof. Then the roof is replaced over the furnace and electrodes are lowered to strike an arc on the pile of scraps; this starts the melting process. Once all the scraps are melted, pure oxygen is lanced directly into the molten pool of steel to initiate reactions with the impurities present in the steel. The impurities (aluminum, silicon, manganese, phosphorus, carbon, iron) combine with oxygen to generate metallic oxides, which conglomerate into a slag. Additional carbon may also be injected during the heat. Carbon reacts exothermally with oxygen to form carbon monoxide (CO). The heat liberated by the formation of CO supplies part of the energy requirement for EAF operation. CO also aids the formation of "foam" in the slag bath. The foam helps bury the arc in the bath, resulting in improved furnace thermal efficiency. In addition, CO aids in removing nitrogen and hydrogen, thereby resulting in better grades of steel. The excess CO either vents to the exhaust handling system or combusts in the furnace. The end product in an EAF operation is refined steel which is tapped into a ladle after the heat is concluded.

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