The Procal 2000 infra-red gas analyser provides an economical and robust CEM system that is capable of simultaneously measuring CO_2, CO and H_2O with performance accuracy equal to 2% of the full scale gas range. The varied processes involved in steel manufacturing account for between 3% and 4% of global man-made greenhouse gas emissions. In the manufacture of pig iron, coke and coal are combusted to provide the necessary carbon monoxide that acts as the reducing agent reducing the iron oxides to iron. The iron produced has a high carbon content which is lowered in a further process to produce the final steel product. This process involves injecting oxygen into a furnace in order to oxidise the carbon present in the iron and produce the steel. A necessary by-product of the production process is CO_2 and the amount emitted is directly related to the volume of iron and steel produced with the majority of CO_2 emissions occurring from blast furnace operations.

Continuous Emission Monitoring systems (CEMs), such as the Procal 2000, are required in many locations employed in Iron and Steel production. The Procal 2000 systems are used from initial sintering of ore, coke production & blast furnace emissions, through to roll-mill reheat furnace emissions. CEM systems are used to optimise processes not only to conserve energy and raw materials, but also to monitor compliance with strict pollution limits. The Procal 2000 CEM system can also be implemented on air pollution control equipment such as scrubbers to monitor their efficiency and help to maintain low emissions.

Of particular concern in steel processes are the very high particulate loading and extreme temperatures. Gases can often be both highly concentrated and highly corrosive. The Procal 2000 analyser range is well suited to applications with a high dust load. The combination of patented sintered filter technology, which is used to pre-clean the sample gas, and highly corrosion resistant probe allows for deployment in harsh industrial environments such as are encountered in steel manufacturing processes. The probe is normally installed in-situ where it can be used in temperatures up-to 350°C (662ºF). An in-situ cooler accessory is available for operation of the analyser in higher temperature environments. Alternative accessory options such as in-situ heaters are available that allow constant temperature control of the sample being analysed and help reduce measurement errors due to sample temperature drift.

The Procal 2000 analyser requires very little maintenance during operation achieving a class-beating up time of over 98% in demanding applications. No additional consumables are required, ensuring a simple and well tested solution offering up-time for control of the plant. The combination of reliability, corrosion resistance and flexibility of application enables the multi-component in-situ analyser to meet the requirements of the end-user and local Environmental Agencies.

Significant efficiency improvements have been achieved by the steel industry over the past twenty five years through increased re-cycling and improved efficiency of both energy and material usage. However, further reduction in the amount of CO_2 emitted from steel plants is being demanded and solutions such as implementing ultra low CO_2 emitting processes and carbon capture and sequestration technology are currently being investigated.

Sources of Gas Emissions in Steel Production

Steel is an alloy composed of mainly of iron with a small percentage of carbon added. The addition of carbon improves the engineering properties of the alloy such as its tensile and shear strengths in comparison to pure iron. Steel is produced using a blast furnace in which iron oxides are first reduced to crude iron by burning coke, coal and limestone. Carbon monoxide is produced in the combustion of the coke and coal and the CO gas acts to reduce the iron oxides to iron.

The primary emission point for CO gas at coke plants is in the combustion stack of the coke battery. Typical coke plant gas emission ranges measured by the Procal 2000 are as follows

Coke Plant		
CO	0-1500	ppm
NO	0-600	ppm

Carbon dioxide (CO_2) emissions are also produced as the coal and coke mix is oxidised. Limestone ($CaCO_3$) and magnesium carbonate ($MgCO_3$) are used as fluxes (cleaning agents) to assist the removal of impurities in the iron such as sulphur and phosphor. Further CO_2 emissions occur as the limestone and magnesium carbonate are calcinated to form lime (CaO) and magnesium oxide (MgO).

Optimisation of the blast furnace process, the use of high quality raw materials in the form of iron ore pellets and high quality coke can lead to a reduction in the amount of coke and coal used and subsequently to lower CO and CO_2 emissions.

Emissions of other gases such as oxides of nitrogen and sulphur dioxide also occur due to combustion processes. The Procal 2000 is an established analyser with proven experience in the measurement of both NO_X and SO_2. The most significant sources of NO_X and SO_2 emissions result from under-firing of coke ovens, firing of heating apparatus for the blast furnaces and preheating of slabs prior to rolling. The Procal 2000 can measure upto six gases so that NO_X and SO_2 can be measured along side CO_2 and CO. The Procal 2000 analyser can also be configured to provide low and high range measurements of a single gas species. Measurement data from the Procal 2000 can be used for precise control and adjustment of burners resulting in reduced nitrogen oxide emissions. The use of low sulphur containing coal can minimize sulphur dioxide emissions.

Particulates are also emitted in steel production. New plants that are built to more stringent standards are equipped with more widespread particulate measurement equipment that has led to a reduction in particulate emissions. Flue gas filter systems retrofitted to existing plants have also led to reduction in particulate emissions.

Emissions also occur, although to a much lesser extent, during the production of steel in the basic oxygen furnace (BOF). The CO_2 emissions occur as carbon present in the iron is oxidized to CO_2 or CO. The carbon content of the crude steel produced is reduced from approximately 4% on entering the BOF to 0.5% to 2% carbon content by weight on exiting the BOF.

Steel Making Processes

Large scale steel manufacturing facilities operate a number of processes that can include coke production, sinter production, and iron and steel production as shown in figure 1.

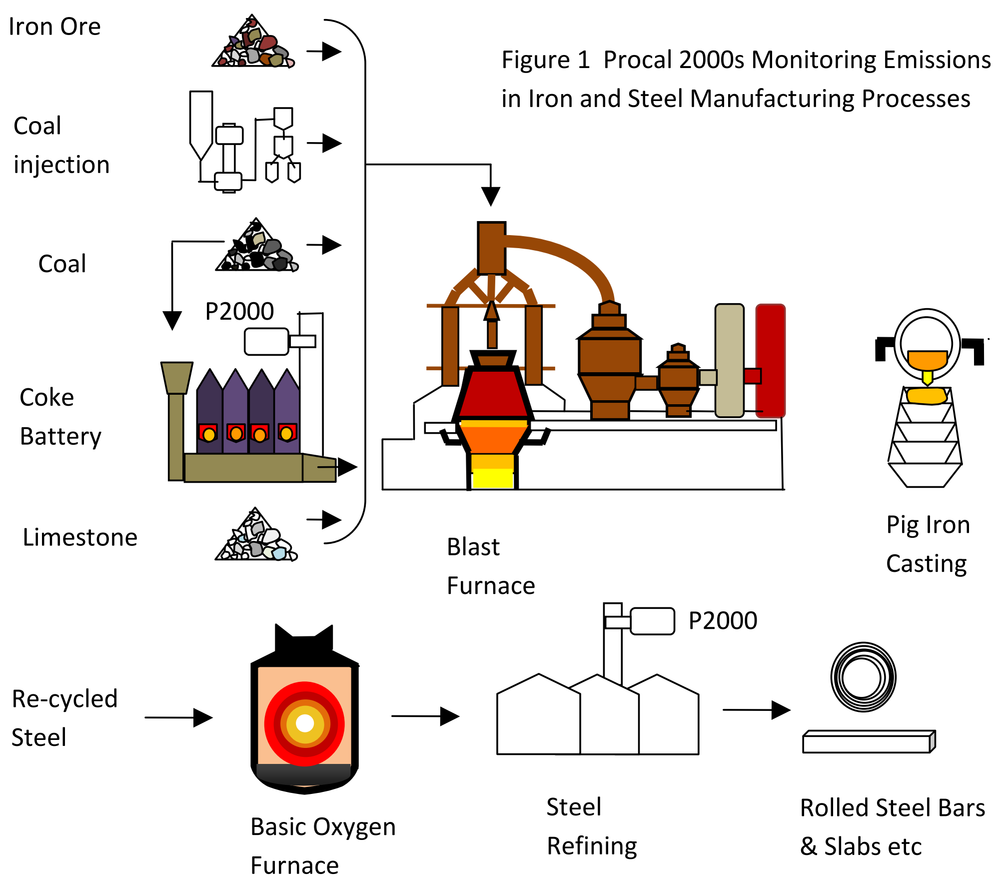

Figure 1 Procal 2000s Monitoring Emissions in Iron and Steel Manufacturing Processes

Coke Production

Coke is used as a fuel and as a reducing agent in the smelting of iron ore. Coke is formed by the thermal distillation of coal at high temperatures in the absence of air. Coke production takes place in coke oven batteries where volatile constituents of the coal including water, coal-gas and coal tar are driven off in the furnace at temperatures up-to 2000ºC (3632ºF). There are several stages to coke manufacturing including coal grinding and blending; heating of the coke oven; carbonisation of coal; coke quenching; cleaning the coke oven gas and finally wastewater treatment. During the pyrolysis process the primary gas leaving the coke oven contains a large amount of tarry matter, considerable moisture and various hydrocarbon compounds.

In modern plants the coke oven gas together with blast furnace gases are recovered as fuel gases as they contain methane and other hydrocarbon components. These gasses are typically used for oven under-firing and as a combustion gas for the furnaces and boilers used to provide electricity and steam to the plant.

Sinter Production

The sintering process is used to recover waste materials generated from the iron and steel production. Recovered material includes ore fines, reverts (including blast furnace dust, mill scale, and other by-products of steel making) and recycled hot and cold fines from the sintering process.

In the sintering process particles, often in a powder form, are fused together to create a solid object. In most sintering processes the powdered material is held in a mould and then heated to a temperature below the melting point. Iron ores together with the recovered waste materials, stats mixed with other substances such as solid fuels (usually coke or coal), dolomite and lime. The sintering of the iron ores takes place prior to the entry into the blast furnace by passing the sinter feed mix under an ignition hood where hot combustion gases ignite the solid fuel in the sinter mix. The fuels used in the ignition hood are usually gaseous fuels, such as natural gas or coke oven gas. Once the fuel in the sinter mix is ignited, the sintering process begins.

Calcination of carbonate fluxes and the combustion of fossil fuels are a primary source of CO_2 emissions resulting in the sinter plant being a significant source of pollution. Typical sinter plant gas emission ranges measured by the Procal 2000 are as follows

Sinter Plant		
NO	0-600	mg/Nm^3
SO_2	0-300	mg/Nm^3
NH_3	0-100	mg/Nm^3

Emissions from the sintering process depend on operational conditions and these can change significantly when different types of fuels and recycled wastes are used in the process. The Procal 2000 with its fast T90 response time of 180 seconds can monitor rapid changes in emission level as the operational conditions change.

Iron Production

Iron production takes place in the blast furnace. The furnace, which is refractory lined, is continuously supplied with iron ore pellets, sintered material, fluxes (limestone and dolomite) and coke through the top, while pre-heated air is injected at the bottom of the chamber. The pre-heated air reacts with the carbon in the form of coke to produce CO. The CO acts as the reducing agent reacting with the iron oxide to produce molten iron and carbon dioxide. Modern blast furnaces inject pulverised coal or other sources of carbon to reduce the amount of coke required. Chemical reactions take place throughout the furnace resulting in the formation of molten iron and slag which are removed from the base of the furnace in a process known as “tapping”.

Blast furnace gas (BFG) is collected at the top of the furnace and recovered for use as fuel in the blast furnace stoves and other parts of the steel plant. Heat is recovered from the hot gases exiting the furnace. The gases are cleaned using a venturi scrubber before being released or recovered.

Steel Production

The "pig iron" produced in the blast furnace has a relatively high carbon content of around 4–5%. The high carbon content makes the material very brittle and further processing to reduce the carbon content is required to produce steel. Steel has more commercial uses compared to iron with steel; being used in construction materials, automobiles, ships and machinery.

Steel may be produced in a basic oxygen furnace (BOF), open hearth furnace (OHF) or an electric arc furnace (EAF). Low-carbon steel is produced in a BOF which is a large open mouthed, pear shaped vessel lined with a basic refractory material. In the BOF a mixture of crude iron and scrap steel (typically 70% molten iron and 30% scrap) is converted into steel by injecting a jet of high purity oxygen, which oxidizes the carbon and the silicon in the molten iron, removes these products, and provides heat for melting the scrap. The carbon in the exhaust gas comes mostly from the iron and scrap steel. Carbon may also be introduced into the BOF to a much smaller extent from the addition of fluxing materials.

Direct emissions occur from BOF plants during the reduction of the iron ore by the coke and oxygen in the blast furnace.

In BOFs equipped with open hoods air from outside the furnace is drawn into the mouth of the furnace and oxidises the CO produced in the BOF to CO_2. In BOFs with closed hoods large quantities of CO are converted to CO_2 by flaring. The major emission point for CO_2 from the BOF is the furnace exhaust gas that is discharged through a stack after gas cleaning.

Carbon and alloy steels are produced in an EAF, which uses electric heating of scrap steel through graphite electrodes. The EAF is refractory lined with the carbon electrodes being raised and lowered through the top compartment of the furnace. Indirect emissions arise from electric arc plants by means of the electricity generators that provide the electricity to power the process. Direct emissions of CO_2 also occur as the electrodes are consumed.

Oxy-fuel burners that burn natural gas and oxygen are also used to heat the scrap metal. Small speciality EAF plants use the technique of argon-oxygen decarburization (AOD) to produce low carbon steel. In this method, argon and oxygen are blown into the bottom of the vessel where the oxygen reacts with the carbon to form CO_2 and CO. The CO_2 and CO gases are then removed from the vessel and sent to the baghouse where particulate matter is removed. CO_2 emissions from EAFs mainly occur during the smelting and refining processes.

The open hearth furnace is an outdated method with low production volumes and high emissions due to the carbon intensity of the process.

Finishing Stage

After the molten steel is tapped from the BOF or EAF, the steel is subjected to further refining processes that are collectively termed ladle metallurgy. These processes include de-oxidisation, de-gassing, de-sulphurisation, micro cleanliness (removal of undesirable non-metallic elements) and inclusion morphology where the composition of the remaining impurities is changed to improve the microstructure of the steel.

The steel is then transferred to the continuous caster where the steel is cast into semi finished shapes (e.g. slabs, booms, billets, rounds and other special sections). The steel is processed in rolling mills to produce coiled strips, rails, sheets and bars. The rolling mills are a source of indirect emissions as they are electricity intensive in their operation. Further processing such as annealing, hot forming, cold rolling, heat treatment (tempered steel), pickling, galvanising, coating and painting also take place. Heat treatment usually requires furnaces fired by natural gas resulting in further emissions. Typical gas emission ranges from a Rolling Mill measured by the Procal 2000 are as follows

Rolling Mill		
NO	0-500	ppm
CO	0-500	ppm
CO_2	0-1200	ppm

References: Mittal Steel, BHP, Esfahan Steel, TZ Steel, Corus, Tata Steel, Svoboda, Bethlehem Steel, Unist, OKD

Application

Corus Steel Works Scunthorpe United Kingdom

6 x Procal 2000 analysers on the Turbofan Boiler House monitoring

H2O 0-30%, CO2 0-30%, CO 0-1000/0-5000ppm, SO2 0-200ppm, NO 0-300ppm and

2 x Procal 2000 on Central Power Station monitoring

H2O 0-30%, CO2 0-30%, CO 0-1000/0-5000ppm, SO2 0-2000mg/Nm3, NO 0-1000mg/Nm3