Iron - Manufacturing process related to the specified manufacture(s)

December 2013 update: addition of new processes description and some modifications

Related manufacture(s)	Description of manufacturing process
M-1: Iron Powders (Iron Powder made by sponge iron process, atomization processes (gas and water) and electrolysis)	Iron powder via atomization process (gas and water) - A thin stream of molten metal is disintegrated by the impact of high-pressure jets of liquid water or gas (air, nitrogen, argon). Tiny droplets of iron are formed and rapidly solidify into small particles of iron metal. With high-pressure water jets, the shape of the iron particles is irregular. Iron granules are collected, dried and ground to the set size distribution. The iron powder is then reduced in a decarburizing furnace to achieve specific chemical composition and desired metallurgical properties. The powder is finally milled and homogenised. Additives are eventually added before the packaging and the shipping to the customers Sponge iron powder The Höganäs process is a direct reduction method for production of sponge iron powder using magnetite ore (Fe_3O_4) and carbon as raw materials. The reduction process takes place in a gas fired tunnel kiln at around 1200°C for 60 hours producing a sponge iron cake that is crushed, milled and magnetically separated from impurities. The final reduction is made in a continuous furnace under hydrogen atmosphere. Before the packaging, particles are screened to achieve the desired particle size Iron powder via electrolysis The manufacture of iron powder by electrolysis is a batch process. The anodes are usually made of iron or low carbon steel. The electrolyte of the cell consists of a sulphate solution (temperature 50°C). Pure iron is deposited as a brittle lightly adhering sheet on the cathodes. After washing, drying, and stripping, the deposited iron is ground. Further milling and annealing is carried out to meet requirements of specific applications.
M-2: Carbonyl Iron Powders (Iron Powder uncoated, made by thermal decomposition of Iron pentacarbonyl)	Carbonyl Iron Powder - Iron Powder uncoated, made by thermal decomposition of Iron pentacarbonyl Carbon monoxide reacts under pressure with iron powder to form iron pentacarbonyl, $Fe(CO)_5$. Iron pentacarbonyl is purified by distillation (residual metals typically < 10 ppm). Purified iron pentacarbonyl is vaporized by heating and decomposed to Carbonyl iron powder and CO.. During the decomposition process, iron particles grow on nuclei to form spherical iron particles. This process achieves properties (chemical composition, particle shape and distribution) unmatched by water-atomization or gas-atomization processes. The typical size range of Carbonyl Iron Powder is from < 1 to 8 microns (primary particles) . Raw iron powder grades can be sent to finishing processes such as milling, classifying, mixing and coating according to further uses.
M-3: Iron Furnace / Pig Iron	Iron Furnace / Pig Iron - Iron, Furnace in the form of liquid iron [also known as hot metal], pig iron and in various other cold forms is produced in the blast furnace. Pig iron is also produced by smelting ilmenite ore in electric furnaces where the primary product is titanium dioxide slag. • Reduction of iron ore in a blast furnace The blast furnace is a counter-current gas/solids reactor in which the descending column of burden materials [coke, iron ore and fluxes/additives] reacts with the ascending hot gases. The process is continuous with raw materials being regularly charged to the top of the furnace and molten iron and slag being tapped from the bottom of the furnace at regular intervals. • In the upper part of the furnace, free moisture is driven off from the burden materials and hydrates and carbonates are disassociated. • In the lower part of the blast furnace shaft, indirect reduction of the iron

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	oxides by carbon monoxide and hydrogen occurs at 700-1,000 C. • In the Bosh area of the furnace where the burden starts to soften and melt, direct reduction of the iron [and other] oxides and carbonization by the coke occurs at 1,000-1,600 C. Molten iron and slag start to drip through to the bottom of the furnace [the hearth]. • Between the bosh and the hearth are the tuyeres through which the blast - combustion air, preheated to 900-1,300 C, often enriched with oxygen - is blown into the furnace. Immediately in front of the tuyeres is the combustion zone, the hottest part of the furnace, 1,850-2,200 C, where coke reacts with the oxygen and steam in the blast to form carbon monoxide and hydrogen [as well as heat] and the iron and slag melt completely. • Molten iron and slag collect in the furnace hearth. Being less dense, the slag floats on top of the iron. Slag and iron are tapped at regular intervals through separate tap holes. For merchant pig iron production, the iron is cast into ingots; in integrated steel mills, the molten iron or hot metal is transferred in torpedo ladle cars to the steel converters. Slag is transferred to slag pits for further processing into usable materials. The principal reactions are: $2 C + O_2 \rightarrow 2CO$ $C + H_2O \rightarrow CO + H_2$ $CO_2 + C \rightarrow 2 CO$ $3 Fe_2O_3 + CO \rightarrow CO_2 + 2 Fe_3O_4$ $Fe_3O_4 + CO \rightarrow CO_2 + 3 FeO$ $FeO + CO \rightarrow Fe + CO_2$ The additives and fluxes serve to convert the waste or gangue materials in the charge [mainly silica and alumina] into a low melting point slag which also dissolves the coke ash and removes sulphur. For example: $CaCO_3 \rightarrow CaO + CO_2$ $CaO + SiO_2 \rightarrow CaSiO_3$ $FeS + CaO + C \rightarrow CaS + FeO + CO$ • Basic oxygen furnace The main function of the Basic Oxygen Furnace (BOF) is to refine hot metal produced in the blast furnace into raw liquid steel. The hot metal charge is refined by oxidation reactions in contact with the injected oxygen. Iron-containing materials, essentially scrap and ore, are added to adjust the thermal balance and maintain the required steel temperature (at approximately 1600 – 1700 °C). Usually, approximately 190 kg/t liquid steel of scrap is used, but values of 300 kg scrap/t liquid steel and even higher are sometimes reached. • Casting Molten iron and slag collect in the furnace hearth. Being less dense, the slag floats on top of the iron. Slag and iron are tapped at regular intervals through separate tap holes. For merchant pig iron production, the iron is cast into ingots. In integrated steel mills, the molten iron or hot metal is transferred in torpedo ladle cars to the steel converters. Slag is transferred to slag pits for further processing into usable materials. Notes concerning other steel production routes: # Via recycled steel scrap in Electric Arc Furnace (EAF): In the Electric Arc Furnace (EAF), solid raw materials are melted and converted into liquid crude steel by using high-power electric arcs. Crude steel is then refined in subsequent secondary steelmaking processes. The major feedstock for the EAF is ferrous scrap, which may be comprised of scrap from inside the steelworks, cut-offs from steel product manufacturers (e.g. vehicle builders) and capital or post-consumer scrap (e.g. end-of-life products). Steel scrap being a waste falls outside the scope of REACH. # Specialised recycling facilities for iron-rich residues: Iron-rich residues such as iron slags, drosses and scalings can be used as feedstock materials in specialised recycling furnaces to recover iron, which

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	can be further processed into blast furnaces or electrical arc furnaces for steel and alloys production. In recovery processes, the iron substance – intentionally recovered from scraps or iron-rich residues – is exempt from registration (Article 2(7)(d) of the REACH Regulation) when iron was already registered under REACH regulation earlier in the life cycle. • Smelting of ilmenite ore in an electric furnace Pig iron is produced as a by-product [or co-product] by producers of UGI (Upgraded Ilmenite) / Titanium dioxide slag, by smelting ilmenite concentrate [$FeTiO_3$] in electric arc furnaces with coal at high temperature above 1600°C. The molten iron produced undergoes various metal treatment processes before being cast into ingots for sale to customers.
M-4: Iron Furnace / DRI	Iron Furnace / DRI - DRI: Direct Reduced Iron - HBI: Hot Briquetted Iron The majority of the direct reduction processes are gas-based. Feedstock The iron ore feed is either fines in fluid beds or pellets and lump in the other reduction furnaces. The feedstock is prepared to adjust the size to that required in the reduction furnace. This may require screening for separation or grinding to adjust the particle size downward. Reduction process The process gas is formed by different methods to generate H_2 and CO to remove the oxygen from the ore. In some processes, coal is also added to the process gas to actuate the reduction. Natural gas enters the reduction furnaces and is heated to the required temperature for reduction of the oxide feed. • Lump and Pellet Feed processes The principal shaft-based furnace operations are those of Midrex and Tenova/HYL, which together account for 98% of the gas-based processes. In these furnaces, the mixture of lump ore and pellets is introduced for reduction by different systems. The ore flows by gravity downwards and is contacted by upflowing reducing gas. The ore is reduced and heated during the downward flow. In the upwards flow, the reduction of the Fe_2O_3 occurs. Products: Once reduced, the product is either briquetted while hot as HBI (hot briquetted iron) or cooled and discharged as DRI. • Fines Feed processes The principal fines reactor-based furnace operation is that of FINMET, which is the only fines-based process in service in 2010. The fines are maintained in a fluidized condition by upwards flowing reducing gas. Between reactors, the ore flows by gravity downwards and is contacted in each by upflowing reducing gas. The ore is reduced and heated during the downward flow. Products: The fines-based processes must briquette the final product.
M-5: Iron Furnace / HBI	Iron Furnace / HBI - HBI: Hot Briquetted Iron Hot briquetting is applied both for products from pellets and lump ore (shaft furnaces) and from fine ore (fluid bed reactors). Direct Reduced Iron is briquetted at high temperature and pressure with roller presses. Alternative briquette sizes and shapes have been tested in several plants. The typical volume of industrially manufactured briquettes is in the range of approx. 100 cm^3. The entire plant for the hot briquetting of direct reduced iron typically consists of: - Briquetting press with screw feeder and material supply - Briquette string separator (impact separator or tumbling drum)

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	- Hot screen for the elimination of fines which occur during briquetting and separation - Product cooler - Bucket elevator for the recirculation of fines to the briquetting press - Chutes and accessories
M-8: Production of elemental iron in Hydrogen-Reduced Powder	Elemental iron in Hydrogen-Reduced Powders - alloyed powders made by reduction under hydrogen gas of a co-precipitated iron containing polymetallic salt or oxide. Solutions of mixed water soluble metal salts, including Fe(II) and Fe(III) salts, are precipitated in the form of insoluble polymetallic oxides and/or hydroxides. After washing and drying, these materials are reduced under a flow of hydrogen gas in a temperature range 400 to 800 °C and de-agglomerated to make iron metal containing micron-size alloyed powders. These raw powders are either sold as such, or blended with other fine grained metal powders, and optionally granulated with additions of organic binders.
M-9: Manufacture of reduced iron catalysts	Reduced Iron Catalyst - The reduced Iron phase within the catalyst is made by the direct reduction (in hydrogen) of a feed material made from fusing (at temperatures exceeding 1400°C) a natural, magnetite (tri-iron tetraoxide) containing ore with inert binders.
M-6: Elemental Iron - Production and use of steel and alloys in massive form	Elemental iron (massive form) - Note concerning steel and alloy production route via steel and alloy recycled scrap • Steel and alloys production route via recycled scraps in Electric Arc Furnace (EAF): In the Electric Arc Furnace (EAF), solid raw materials are melted and converted into liquid crude steel by using high-power electric arcs. Crude steel is then refined in subsequent secondary steelmaking processes. The major feedstock for the EAF are ferrous and alloy scraps, which may be comprised of scraps from inside the steelworks, cut-offs from steel product manufacturers (e.g. vehicle builders) and capital or post-consumer scrap (e.g. end-of-life products). Steel and alloy scraps being a waste falls outside the scope of REACH. Elemental iron (substance intentionally recovered from scraps) is exempt from registration (Article 2(7)(d) of the REACH Regulation) as elemental iron was already registered under REACH regulation earlier in the life cycle. • Vacuum Induction Melting (VIM), Vacuum Arc Remelting (VAR) and Electro Slag Remelting (ESR) processes: Steel and alloys production can also be produced by Vacuum Induction Melting (VIM) and Vacuum Arc Remelting (VAR) processes or Vacuum Induction Melting (VIM) and Electro Slag Remelting (ESR) processes. Primary melting is made under vacuum for high cleanliness. It is followed by Vacuum Arc Remelting (VAR) or Electro Slag Remelting (ESR) which are secondary melting processes for production of metal ingots with elevated chemical and mechanical homogeneity.
M-7: Elemental Iron - Production of alloyed powder by atomisation	Elemental iron (powder form) - Steel and alloy scrap is melted in an induction furnace and the molten metal is gas or water atomized to metal powder. Atomized powders are filled into metallic containers which are evacuated and sealed and then compacted by cold isostatic pressing (CIP) and hot isostatic pressing (HIP) or extrusion to produce either Near Net Shape parts (NNS) or capsules which are subsequently hot processed (forging, hot rolling) to long and flat products. Loose powders are also used for Metal Injection Moulding (MIM), thermal spraying, centrifugal casting and other powder metallurgy applications. Before use, metal powders are optionally sieved to specific grain size fractions.