

1: Chemical characteristics of iron and steel slag : NIPPON SLAG ASSOCIATION

*The Chemistry of Iron & Steel Making: And of Their Practical Uses [William Mattieu Williams] on www.enganchecubano.com *FREE* shipping on qualifying offers. This work has been selected by scholars as being culturally important, and is part of the knowledge base of civilization as we know it.*

Various chemical reactions are initiated, either in sequence or simultaneously, in order to arrive at specified chemical compositions and temperatures. Indeed, many of the reactions interfere with one another, requiring the use of process models to help in analyzing options, optimizing competing reactions, and designing efficient commercial practices.

Raw materials The major iron-bearing raw materials for steelmaking are blast-furnace iron, steel scrap, and direct-reduced iron DRI. Liquid blast-furnace iron typically contains 3. The phosphorus content depends on the ore used, since phosphorus is not removed in the blast-furnace process, whereas sulfur is usually picked up during iron making from coke and other fuels. It frequently contains about 3 percent unreduced iron ore and 4 percent gangue, depending on the ore used. It is normally shipped in briquettes and charged into the steelmaking furnace like scrap. Steel scrap is metallic iron containing residuals, such as copper, tin, and chromium, that vary with its origin. Of the three major steelmaking processes—basic oxygen, open hearth, and electric arc—the first two, with few exceptions, use liquid blast-furnace iron and scrap as raw material and the latter uses a solid charge of scrap and DRI.

Oxidation reactions The most important chemical reactions carried out on these materials especially on blast-furnace iron are the oxidation of carbon to carbon monoxide, silicon to silica, manganese to manganous oxide, and phosphorus to phosphate, as follows: Unfortunately, iron is also lost in this series of reactions, as it is oxidized to ferrous oxide: The FeO, absorbed into the liquid slag, then acts as an oxidizer itself, as in the following reactions: In the open-hearth furnace, oxidation also takes place when gases containing carbon dioxide CO₂ contact the melt and react as follows: The slag The products of the above reactions, the oxides silica, manganese oxide, phosphate, and ferrous oxide, together with burnt lime calcium oxide; CaO added as flux, form the slag. Usually, a basicity above 3.

Removing sulfur The majority of sulfur, present as ferrous sulfide FeS, is removed from the melt not by oxidation but by the conversion of calcium oxide to calcium sulfide: According to this equation, desulfurization is successful only when using a slag with plenty of calcium oxide—in other words, with a high basicity. A low iron oxide content is also essential, since oxygen and sulfur compete to combine with the calcium. For this reason, many steel plants desulfurize blast-furnace iron before it is refined into steel, since at that stage it contains practically no dissolved oxygen, owing to its high silicon and carbon content. Nevertheless, sulfur is often introduced by scrap and flux during steelmaking, so that, in order to meet low sulfur specifications for example, less than 0.

Removing carbon A very important chemical reaction during steelmaking is the oxidation of carbon. Its gaseous product, carbon monoxide, goes into the off-gas, but, before it does that, it generates the carbon monoxide boil, a phenomenon common to all steelmaking processes and very important for mixing. Mixing enhances chemical reactions, purges hydrogen and nitrogen, and improves heat transfer. Adjusting the carbon content is important, but it is often oxidized below specified levels, so that carbon powder must be injected to raise the carbon again.

2: Chemistry of Steelmaking by Basic Oxygen Furnace | www.enganchecubano.com

The main stages: The main steps in making steel are shown on the left. You can find more information about each step by clicking on it. In this section we'll summarise the chemistry that is important in changing iron ore into steel.

The change in the carbon content and the bath composition of the bath with the progress of the oxygen blow is shown in the Fig. There are three distinct stages during this decarburization reaction. In the first stage which occurs during first few minutes of the blow, decarburization takes place at a slow rate, since most of the oxygen supplied reacts with the silicon of the bath. During the second stage, which occurs at high carbon content of the bath, decarburization takes place at a higher rate and is controlled by the rate of supplied oxygen. The third stage occurs when the carbon content of the bath reaches around 0. At this stage, the decarburization rate drops since lesser carbon is available to react with all the oxygen supplied. At this stage, the rate is controlled by mass transfer of carbon, and the oxygen will mostly react with iron to form iron oxide. At this stage, since the rate of CO generation drops, the flame at the BOF mouth becomes less luminous and practically disappears when the carbon drops to a level of around 0. A basic slag favours silicon oxidation. In basic, silicon oxidation occurs practically to a very low value since SiO_2 reacts with CaO and decreases activity of silica in the slag. Almost all the Si gets oxidized and removed early in the blow because of a strong affinity of oxygen for Si. The oxidation of Si to silica SiO_2 is exothermic and it produces significant amount of heat which raises the bath temperature. It also forms a silicate slag that reacts with the added lime and calcined dolomite to form a basic slag. Since the oxidation of silicon is the main heat source, it amount in hot metal determines the amount of the cold charge scrap, pig iron etc. It also determines the volume of slag and hence affects the yield and dephosphorization of the bath. As per rule, more slag will result into lower phosphorus but also lesser yield. Iron oxidation Oxidation of iron is the most important since it controls i FeO content of the slag and oxygen content in the steel, ii loss of iron in the slag and hence affects the productivity of the steelmaking process, iii oxidation potential of the slag, and iv FeO helps in the dissolution of lime in the slag. Manganese oxidation Manganese oxidation reaction in oxygen steelmaking is rather complex. In a top blown converter, Mn is oxidized to MnO in the earlier stages of the blow and after most of the silicon is oxidized then Mn reverts back into the bath metal. Finally during the blow end when more oxygen is available for the oxidation then Mn gets reduced in the bath metal. In case of the bottom blowing or combined blowing in the converter, the oxidation of Mn has got a similar pattern but the residual Mn content of the liquid steel in the converter bath is higher than the top blown converter. Phosphorus oxidation The oxidizing conditions in the converter favour the dephosphorization of bath metal. The reaction of dephosphorization takes place due to the interaction of metal and slag in the bath. The removal of phosphorus follows the pattern as shown in Fig 1. The phosphorus content of the bath metal reduces in the beginning of the blow, then during the main decarburization period when the FeO is reduced, P reverts into the bath metal and finally it reduces again at the blow end. Bath stirring improves the mixing of metal and slag and helps in the rate of dephosphorization. Good stirring with the addition of the fluxing agents such as flour spar etc. Sulphur reaction Sulphur removal is not very effective in the BOF steelmaking process due to the highly oxidizing conditions. The remaining sulphur is removed by the following slag $\hat{\text{e}}$ metal reaction. S content of the liquid steel is greatly influenced by the S contained in the hot metal and scrap which is charged in the BOF. Formation of slag Fluxes lime and calcined dolomite that are charged early in the blow dissolve with the developing oxides to form a liquid slag. The rate of dissolution of these fluxes strongly affects the slag metal reactions occurring during the blow. During this period large amount of fluxes are charged in the BOF. The lance is then lowered and the slag starts to foam at around one third of the blow due to reduction of FeO in the slag in conjunction with CO formation. The drop in the FeO content in the slag is shown in Fig 2. As the blow progresses, the CaO dissolves in the slag, and the active slag weight increases. After the blow has progressed around three fourth of the time, the FeO content in the slag increases because of a decrease in the rate of decarburization. During the blow, the temperature of the liquid steel gradually increases from about deg C to deg C at turndown, and the slag temperature is about 50 deg C higher than that of the liquid steel. The slag at turndown may contain regions of

undissolved lime mixed with the liquid slag, since the dissolution of lime is limited by the presence of dicalcium silicate $2\text{CaO} \cdot \text{SiO}_2$ coating, which is solid at steelmaking temperatures and prevents rapid dissolution. The presence of MgO in the lime weakens the coating. Thus, earlier charging of MgO speeds up slag formation due to quicker solution of lime. Fig 2 Formation of slag components in BOF.

3: The Sintering Process of Iron Ore Fines | www.enganchecubano.com

Steelmaking Overview. Steelmaking is the second step in producing steel from iron ore. In this stage, impurities such as sulfur, phosphorus, and excess carbon are removed from the raw iron, and alloying elements such as manganese, nickel, chromium, and vanadium are added to produce the exact steel required.

World Steel Association, Manufacture of steel There are two main processes used to make steel. The Basic Oxygen Steelmaking Process, which is used for the majority of steel production, uses iron freshly produced from the blast furnace together with some scrap steel. The Electric Arc Furnace Process uses scrap steel only. These can take up to tonnes of reactants and convert them to steel in less than 40 minutes. An oxygen lance, cooled by circulating water, is lowered into the furnace and high purity oxygen is injected into the vessel at twice the speed of sound which ensures that all the impurities are converted into their oxides. The main chemical reactions are: With the exception of the carbon monoxide, the products react with lime, added during the oxygen blow, to form a slag. The above reactions are all exothermic and controlled quantities of scrap are added as a coolant to maintain the desired temperature. The steel at this stage contains ca 0. The scrap comes from three sources: These electrodes are massive, often 6 m high and 4 m wide, and the furnace can hold over tonnes of liquid steel. An arc is struck by passing an electric current through the metal. The heat generated melts the scrap metal. Lime as calcium oxide or calcium carbonate, fluorspar which helps to keep the hot slag as a fluid and iron ore are added and these combine with impurities to form a slag. When the steel has reached the correct composition the slag is poured off and the steel tapped from the furnace. This photo shows a later stage when the molten slag is poured from the slag pot. The slag is treated so that any iron left is recovered and the residue is then used as an aggregate. By kind permission of World Steel Association. Secondary steelmaking The term secondary production is often used when referring to recycling. However, in steelmaking the term secondary steelmaking refers to the production of steels which are needed for specific purposes and which require the addition of very carefully controlled quantities of other elements. Molten steel from either process is transferred to a ladle where the alloying elements are added. The process provides precise control of harmful impurities particularly sulfur, phosphorus and, in some cases, trace metals and hydrogen by adding materials via ladle injection. For example, aluminium and silicon are added to reduce any oxidized material. Other techniques used to help to improve the quality of the steel include stirring ladle stirring and applying a vacuum to the steel to remove gases vacuum degassing. Casting Steel is produced in three forms, the form chosen being dependent on its ultimate use: The casting is a very precise set of processes. The following descriptions are an outline. Continuous casting In continuous casting, the steel, still molten from the furnace, is poured into a water-cooled mould teeming from which it emerges as a strand which is solidifying at the surface. The strand passes through a series of rollers which are water sprayed to produce a solid a slab, bloom or billet which is then sent to be hot rolled. Ingot casting Molten steel is poured into a cast iron mould to solidify as an ingot. This generally weighs less than 20 tonnes but rotor forgings can weigh up to tonnes. When the ingot has solidified, the mould is removed. Each ingot is of carefully pre-arranged dimensions and mass from which articles of the required size can be rolled. Rolling Steel products are classified into flat products and long products. Slabs of steel are rolled to produce flat products, for example steel sheet for the construction of ships. The sheet is rolled further to produce thinner sheet, used for example in the manufacture of cars. Blooms and billets are used to roll long bars of steel for construction and for drawing into wires. Often there are three stages to this part of the process, hot rolling, cold rolling and drawing. Hot rolling occurs when the slabs, blooms and billets are heated in a furnace until they are red hot ca K and then rolled until they have acquired the desired shape. The speed at which the hot steel is subsequently cooled is a crucial factor, affecting the strength and other properties of the steel. Cooling is done by spraying water as the steel passes through the rollers. During this rolling, oxygen in the air has reacted with the hot iron to form a very thin layer of iron III oxide on the surface. This must be stripped from the surface prior to the next stage, otherwise the final product will be susceptible to rusting and unsuitable for galvanizing with zinc and other surface treatments. The stripping process is known as pickling. The steel is passed through several

baths of hydrochloric acid sometimes sulfuric acid which dissolves the oxide without attacking the metal. The spent acid is recycled. As the name implies, the steel, following hot rolling, is rolled cold and gradually compressed to the required thickness. This improves the quality of the surface and also hardens the steel. On annealing heating the strip very carefully , it can be pressed into shapes without cracking. Such sheet is used, for example, to press out car bodies. Steel cans are pressed out with sides and bottoms as a single entity, needing only the top to be fitted after filling. Very strong wires are produced by cold drawing. It is estimated that recycling one tonne of steel saves 1. Please send these comments to:

4: Iron and steel making - www.enganchecubano.com

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Known about since ancient times Iron is the first element in the eighth column of the periodic table. It is classified as a transition metal. Iron atoms have 26 electrons and 26 protons with 30 neutrons occurring in the most abundant isotope. It is the sixth most abundant element in the universe. Characteristics and Properties In its pure form iron is a fairly soft, grayish metal. It is very reactive and will readily corrode or rust. It is malleable and a decent conductor of electricity and heat. Iron is the most naturally magnetic of the elements. Other naturally magnetic elements include cobalt and nickel. Iron becomes significantly harder when alloyed with other elements such as carbon. Iron can be found in four allotropic forms. The most stable form of iron at normal temperatures is alpha iron which is commonly known as ferrite. Where is iron found on Earth? Iron is the most abundant element in the Earth. Because iron oxidizes when it comes into contact with air, most of the iron that is found on the surface of the Earth is in iron oxide minerals such as hematite and magnetite. Iron is also found in meteorites which can sometimes contain a large percentage of iron. How is iron used today? Iron is used more than any other metal for producing metal alloys. The most important iron alloys include cast iron, pig iron, wrought iron, and steel. There are various alloys of steel, but they all contain iron as the main metal. Carbon is one of the main alloying elements mixed with iron to make steel. Other elements common in steel include manganese, phosphorous, sulfur, and silicon. Steel from iron is both inexpensive and very strong. It is used in the production of all sorts of items including cars, ships, buildings, and tools. Stainless steel is used in household appliances, cookware, surgical instruments, and industrial equipment. Iron also plays an important role in biology. It is important in plants for photosynthesis. In the human body iron is a major component of the blood which carries oxygen throughout the body from the lungs. How was it discovered? Iron has been used by people since ancient times. Smelted iron was first used in Ancient Mesopotamia and Ancient Egypt. Iron began to replace bronze during the Iron Age which began around BC. Where did iron get its name? Iron gets its name from an Anglo-Saxon term. The symbol Fe comes from the Latin word for iron, "ferrum. Interesting Facts about Iron Cast iron is when an iron alloy is heated to liquid and then is poured into a mould. It was invented in Ancient China in the 5th century BC. Iron is mentioned in the Book of Genesis in the Bible. Louis are both clad with stainless steel. Good sources of iron in food include red meat, beans, fish, and green leafy vegetables. Although a certain amount of iron is important for good health, too much iron can be bad for you. More on the Elements and the Periodic Table.

5: Steel - Primary steelmaking | www.enganchecubano.com

Key words: Steel making, deoxidation, iron oxidation, desiliconization Introduction In steelmaking the impurities in hot metal like carbon, silicon, manganese, phosphorus and sulphur are.

History[edit] The basic oxygen process developed outside of traditional "big steel" environment. It was developed and refined by a single man, Swiss engineer Robert Durrer, and commercialized by two small steel companies in allied-occupied Austria , which had not yet recovered from the destruction of World War II. Schwartz , Belgian John Miles and Swiss Durrer and Heinrich Heilbrugge engineers proposed their versions of oxygen-blown steelmaking, but only Durrer and Heilbrugge brought it to mass-scale production. In the s steelmakers introduced bottom-blown converters and introduced inert gas blowing for stirring the molten metal and removing the phosphorus impurities. In , the Russian physicist Pyotr Kapitsa perfected the design of the centrifugal turboexpander. The process was put to use in Steel and Bethlehem Steel introduced the oxygen process only in Basic oxygen steelmaking is a primary steelmaking process for converting the molten pig iron into steel by blowing oxygen through a lance over the molten pig iron inside the converter. Exothermic heat is generated by the oxidation reactions during blowing. The basic oxygen steel-making process is as follows: Molten pig iron sometimes referred to as "hot metal" from a blast furnace is poured into a large refractory-lined container called a ladle. The metal in the ladle is sent directly for basic oxygen steelmaking or to a pretreatment stage. Pretreatment of the blast furnace hot metal is done externally to reduce sulphur , silicon , and phosphorus before charging the hot metal into the converter. In external desulphurising pretreatment, a lance is lowered into the molten iron in the ladle and several hundred kilograms of powdered magnesium are added and the sulphur impurities are reduced to magnesium sulphide in a violent exothermic reaction. The sulfide is then raked off. Similar pretreatments are possible for external desiliconisation and external dephosphorisation using mill scale iron oxide and lime as fluxes. The decision to pretreat depends on the quality of the hot metal and the required final quality of the steel. Filling the furnace with the ingredients is called charging. The BOS process is autogenous, i. Maintaining the proper charge balance, the ratio of hot metal from melt to cold scrap is therefore very important. Molten iron from the ladle is added as required for the charge balance. A typical chemistry of hotmetal charged into the BOS vessel is: This melts the scrap, lowers the carbon content of the molten iron and helps remove unwanted chemical elements. It is this use of pure oxygen instead of air that improves upon the Bessemer process , as the nitrogen a particularly undesirable element and other gases in air do not react with the charge and also decrease efficiency of furnace. During "blowing", churning of metal and fluxes in the vessel forms an emulsion , that facilitates the refining process. Near the end of the blowing cycle, which takes about 20 minutes, the temperature is measured and samples are taken. A typical chemistry of the blown metal is 0. The BOF vessel is tilted towards the slagging side and the steel is poured through a tap hole into a steel ladle with basic refractory lining. This process is called tapping the steel. The steel is further refined in the ladle furnace, by adding alloying materials to give it special properties required by the customer. Sometimes argon or nitrogen is bubbled into the ladle to make the alloys mix correctly. After the steel is poured off from the BOS vessel, the slag is poured into the slag pots through the BOS vessel mouth and dumped. Variants[edit] Earlier converters, with a false bottom that can be detached and repaired, are still in use. Modern converters have a fixed bottom with plugs for argon purging. The Energy Optimization Furnace EOF is a BOF variant associated with a scrap preheater where the sensible heat in the off-gas is used for preheating scrap, located above the furnace roof. The lance used for blowing has undergone changes. Slagless lances, with a long tapering copper tip, have been employed to avoid jamming of the lance during blowing. Post-combustion lance tips burn the CO generated during blowing into CO₂ and provide additional heat. For slag-free tapping, darts, refractory balls and slag detectors are employed. Modern converters are fully automated with auto blowing patterns and sophisticated control systems.

6: Chemistry for Kids: Elements - Iron

Steel is an alloy of carbon and iron. However, it can contain other chemical elements to enhance strength, corrosion resistance or other properties. As an alloy, it is a mixture of chemical compounds, not a chemical compound in and of itself.

People in India and Sri Lanka were making small amounts of steel more than 1, years ago. It was very expensive and was often used to make swords and knives. In the Middle Ages , steel could be made only in small amounts since the processes took a long time. In the time since, there have been many changes to the way steel is made. In about the year steel started to be made in England , and the way it was made got better and cheaper over the next years. Cheap steel helped start the Industrial Revolution in England and in Europe. The first industrial process for making cheap steel was the Bessemer process , followed by Siemens-Martin open-hearth process. Today the most common way of making steel is the basic-oxygen steelmaking. It uses a large turnip-shaped vessel called converter. Liquid raw iron called "pig iron" is poured in and some scrap metal is added in to balance the heat. Oxygen is then blown into the iron. The oxygen burns off the extra carbon and other impurities. Then enough carbon is added to make the carbon contents as wanted. The liquid steel is then poured. It can be either cast into molds or rolled into sheets, slabs, beams and other so-called "long products", such as railway tracks. Today steel is made in huge buildings called steel mills, and is most often made by machines. It is a very cheap metal today and is used to make many things. Steel is used to making buildings and bridges, and all kinds of machines. Almost all ships and cars are today made from steel. When a steel object is old, or it is broken beyond repair, it is called scrap. The scrap can be melted down and re-shaped into a new object. Steel is recyclable material; that is, the same steel can be used and re-used.

Iron and steel chemistry Steel is a metal alloy which includes iron and often some carbon. Every material is made up of atoms which are very small parts. Some atoms hold together quite well, which is what makes some solid materials hard. Something made of pure iron is softer than steel because the atoms can slip over one another. If other atoms like carbon are added, they are different from iron atoms and stop the iron atoms from sliding apart so easily. This makes the metal stronger and harder. Changing the amount of carbon or other atoms added to steel will change those things that are interesting and useful about the metal. These are called the properties of the steel. How hard it is, If it can be made into thin wires, Its strength, If it will rust or corrode

Steel with more carbon is harder and stronger than pure iron, but it also breaks more easily brittle.

Types of steel These are a few of the many types of steel: Carbon steel - the most common type, but it must be painted or covered or it will rust Stainless steel - which will usually not rust much, the " stain " in the name is the red colour of rust Galvanized steel - which is steel covered with zinc , to prevent rust Steel rope or cable , made of many thin steel wires

Uses of steel There are a huge number of things that people make from steel. It is one of the most common and useful metals. A lot of items made from iron in the past are now made of steel. Some of them are:

7: Iron processing | www.enganchecubano.com

A symposium on the physical chemistry of iron and steelmaking held at MIT in This volume contains the papers presented at the Conference on The Physical Chemistry of Iron and Steelmaking which was held at MIT in

Remoteness has disguised the staggering scale of the iron ore deposits. Production seems to have started in the copper-producing regions of Anatolia and Persia, where the use of iron compounds as fluxes to assist in melting may have accidentally caused metallic iron to accumulate on the bottoms of copper smelting furnaces. When iron making was properly established, two types of furnace came into use. Bowl furnaces were constructed by digging a small hole in the ground and arranging for air from a bellows to be introduced through a pipe or tuyere. Stone-built shaft furnaces, on the other hand, relied on natural draft, although they too sometimes used tuyeres. In both cases, smelting involved creating a bed of red-hot charcoal to which iron ore mixed with more charcoal was added. This may have weighed up to 5 kilograms (11 pounds) and consisted of almost pure iron with some entrapped slag and pieces of charcoal. The manufacture of iron artifacts then required a shaping operation, which involved heating blooms in a fire and hammering the red-hot metal to produce the desired objects. Iron made in this way is known as wrought iron. Sometimes too much charcoal seems to have been used, and iron-carbon alloys, which have lower melting points and can be cast into simple shapes, were made unintentionally. The applications of this cast iron were limited because of its brittleness, and in the early Iron Age only the Chinese seem to have exploited it. Elsewhere, wrought iron was the preferred material. Although the Romans built furnaces with a pit into which slag could be run off, little change in iron-making methods occurred until medieval times. By the 15th century, many bloomeries used low shaft furnaces with water power to drive the bellows, and the bloom, which might weigh over kilograms, was extracted through the top of the shaft. The final version of this kind of bloomery hearth was the Catalan forge, which survived in Spain until the 19th century. The blast furnace appeared in Europe in the 15th century when it was realized that cast iron could be used to make one-piece guns with good pressure-retaining properties, but whether its introduction was due to Chinese influence or was an independent development is unknown. Both had square cross sections, and the main changes required for blast-furnace operation were an increase in the ratio of charcoal to ore in the charge and a taphole for the removal of liquid iron. The product of the blast furnace became known as pig iron from the method of casting, which involved running the liquid into a main channel connected at right angles to a number of shorter channels. The whole arrangement resembled a sow suckling her litter, and so the lengths of solid iron from the shorter channels were known as pigs. Despite the military demand for cast iron, most civil applications required malleable iron, which until then had been made directly in a bloomery. The arrival of blast furnaces, however, opened up an alternative manufacturing route; this involved converting cast iron to wrought iron by a process known as fining. Pieces of cast iron were placed on a finery hearth, on which charcoal was being burned with a plentiful supply of air, so that carbon in the iron was removed by oxidation, leaving semisolid malleable iron behind. From the 15th century on, this two-stage process gradually replaced direct iron making, which nevertheless survived into the 19th century. By the middle of the 16th century, blast furnaces were being operated more or less continuously in southeastern England. Increased iron production led to a scarcity of wood for charcoal and to its subsequent replacement by coal in the form of coke—a discovery that is usually credited to Abraham Darby in 1709. Because the higher strength of coke enabled it to support a bigger charge, much larger furnaces became possible, and weekly outputs of 5 to 10 tons of pig iron were achieved. Next, the advent of the steam engine to drive blowing cylinders meant that the blast furnace could be provided with more air. This created the potential problem that pig iron production would far exceed the capacity of the finery process. Accelerating the conversion of pig iron to malleable iron was attempted by a number of inventors, but the most successful was the Englishman Henry Cort, who patented his puddling furnace in 1784. Cort used a coal-fired reverberatory furnace to melt a charge of pig iron to which iron oxide was added to make a slag. As a result, the melting point of the metal rose so that it became semisolid, although the slag remained quite fluid. The metal was then formed into balls and freed from as much slag as possible before being removed from the furnace and

squeezed in a hammer. The eventual decline in the use of wrought iron was brought about by a series of inventions that allowed furnaces to operate at temperatures high enough to melt iron. It was then possible to produce steel, which is a superior material. First, in 1856, Henry Bessemer patented his converter process for blowing air through molten pig iron, and in 1857 William Siemens took out a patent for his regenerative open-hearth furnace. In 1878 Sidney Gilchrist Thomas and Percy Gilchrist adapted the Bessemer converter for use with phosphoric pig iron; as a result, the basic Bessemer, or Thomas, process was widely adopted on the continent of Europe, where high-phosphorus iron ores were abundant. For about 20 years, the open-hearth and Bessemer-based processes were jointly responsible for most of the steel that was made, before they were replaced by the basic oxygen and electric-arc furnaces. Apart from the injection of part of the fuel through tuyeres, the blast furnace has employed the same operating principles since the early 19th century. Furnace size has increased markedly, however, and one large modern furnace can supply a steelmaking plant with up to 10,000 tons of liquid iron per day. Throughout the 20th century, many new iron-making processes were proposed, but it was not until the 1950s that potential substitutes for the blast furnace emerged. Few of these techniques survived, and those that did were extensively modified. Another alternative iron-making method, smelting reduction, had its forerunners in the electric furnaces used to make liquid iron in Sweden and Norway in the 18th century. The technique grew to include methods based on oxygen steelmaking converters using coal as a source of additional energy, and in the 1960s it became the focus of extensive research and development activity in Europe, Japan, and the United States. Iron ores occur in igneous, metamorphic transformed, or sedimentary rocks in a variety of geologic environments. Most are sedimentary, but many have been changed by weathering, and so their precise origin is difficult to determine. Hematite and magnetite are by far the most common types of ore. Pure magnetite contains 72.4 percent iron. Deposits with less than 30 percent iron are commercially unattractive, and, although some ores contain as much as 66 percent iron, there are many in the 50–60 percent range. Silica (SiO₂) and phosphorus-bearing compounds usually reported as P₂O₅ are especially important because they affect the composition of the metal and pose extra problems in steelmaking. China, Brazil, Australia, Russia, and Ukraine are the five biggest producers of iron ore, but significant amounts are also mined in India, the United States, Canada, and Kazakhstan. Japan, the European Union, and the United States are the major importers. Most iron ores are extracted by surface mining. Some underground mines do exist, but, wherever possible, surface mining is preferred because it is cheaper. Lumps and fines As-mined iron ore contains lumps of varying size, the biggest being more than 1 metre (40 inches) across and the smallest about 1 millimetre (0.04 inch). The blast furnace, however, requires lumps between 7 and 25 millimetres, so the ore must be crushed to reduce the maximum particle size. Crushed ore is divided into various fractions by passing it over sieves through which undersized material falls. In this way, lump or rubble ore 7 to 25 millimetres in size is separated from the fines less than 7 millimetres. If the lump ore is of the appropriate quality, it can be charged to the blast furnace without any further processing. Fines, however, must first be agglomerated, which means reforming them into lumps of suitable size by a process called sintering. Sintering Iron ore sintering consists of heating a layer of fines until partial melting occurs and individual ore particles fuse together. For this purpose, a traveling-grate machine is used, and the burning of fine coke known as coke breeze within the ore generates the necessary heat. Before being delivered to the sinter machine, the ore mixture is moistened to cause fine particles to stick to larger ones, and then the appropriate amount of coke is added. Initially, coke on the upper surface of the bed is ignited when the mixture passes under burners in an ignition hood, but thereafter its combustion is maintained by air drawn through the bed of materials by a suction fan, so that by the time the sinter reaches the end of the machine it has completely fused. The grate on which the sinter mix rests consists of a series of cast-iron bars with narrow spaces between them to allow the air through. After cooling, the sinter is broken up and screened to yield blast-furnace feed and an undersize fraction that is recycled. Modern sinter plants are capable of producing up to 25,000 tons per day. Sintering machines are usually measured by hearth area; the biggest machines are 5 metres (16 feet) wide by 6 metres (20 feet) long, and the effective hearth area is 30 square metres (330 square feet). Concentration refers to the methods of producing ore fractions richer in iron and lower in silica than the original material. Most processes rely on density differences to separate light minerals from heavier ones, so the ore is crushed and ground to release the ore

minerals from the gangue. Magnetic techniques also are used. The upgraded ore, or concentrate, is in the form of a very fine powder that is physically unsuitable for blast furnace use. It has a much smaller particle size than ore fines and cannot be agglomerated by sintering. Instead, concentrates must be agglomerated by pelletizing, a process that originated in Sweden and Germany about 1913 but was adapted in the 1950s to deal with low-grade taconite ores found in the Mesabi Range of Minnesota, U.S. Pelletizing First, moistened concentrates are fed to a rotating drum or an inclined disc, the tumbling action of which produces soft, spherical agglomerates. Finally, they are slowly cooled. Finished pellets are round and have diameters of 10 to 15 millimetres, making them almost the ideal shape for the blast furnace. The earliest kind of firing equipment was the shaft furnace. This was followed by the grate-kiln and the traveling grate, which together account for more than 90 percent of world pellet output. In shaft furnaces the charge moves down by gravity and is heated by a counterflow of hot combustion gases, but the grate-kiln system combines a horizontal traveling grate with a rotating kiln and a cooler so that drying, firing, and cooling are performed separately. In the traveling-grate process, pellets are charged at one end and dried, preheated, fired, and cooled as they are carried through successive sections of the equipment before exiting at the other end. Traveling grates and grate-kilns have similar capacities, and up to five million tons of pellets can be made in one unit annually. Iron making The primary objective of iron making is to release iron from chemical combination with oxygen, and, since the blast furnace is much the most efficient process, it receives the most attention here. Alternative methods known as direct reduction are used in over a score of countries, but less than 5 percent of iron is made this way. A third group of iron-making techniques classed as smelting-reduction is still in its infancy. Process control and productivity improvements all follow from a consideration of these fundamental features. For example, the most important advance of the 20th century has been a switch from the use of randomly sized ore to evenly sized sinter and pellet charges. The main benefit is that the charge descends regularly, without sticking, because the narrowing of the range of particle sizes makes the gas flow more evenly, enhancing contact with the descending solids. Even so, it is impossible to eliminate size variations completely; at the very least, some breakdown occurs between the sinter plant or coke ovens and the furnace. Structure The furnace itself is a tall, vertical shaft that consists of a steel shell with a refractory lining of firebrick and graphite. Five sections can be identified. At the bottom is a parallel-sided hearth where liquid metal and slag collect, and this is surmounted by an inverted truncated cone known as the bosh. Air is blown into the furnace through tuyeres, water-cooled nozzles made of copper and mounted at the top of the hearth close to its junction with the bosh. A short vertical section called the bosh parallel, or the barrel, connects the bosh to the truncated upright cone that is the stack. Finally, the fifth and topmost section, through which the charge enters the furnace, is the throat. The lining in the bosh and hearth, where the highest temperatures occur, is usually made of carbon bricks, which are manufactured by pressing and baking a mixture of coke, anthracite, and pitch. Carbon is more resistant to the corrosive action of molten iron and slag than are the aluminosilicate firebricks used for the remainder of the lining. Firebrick quality is measured by the alumina Al content, so that bricks containing 63 percent alumina are used in the bosh parallel, while 45 percent alumina is adequate for the stack. Schematic diagram of modern blast furnace right and hot-blast stove left. Until recently, all blast furnaces used the double-bell system to introduce the charge into the stack.

8: Basic oxygen steelmaking - Wikipedia

Oxidation of iron is the most important since it controls (i) FeO content of the slag and oxygen content in the steel, (ii) loss of iron in the slag and hence affects the productivity of the steelmaking process, (iii) oxidation potential of the slag, and (iv) FeO helps in the dissolution of lime in the slag.

The product sinter is shown in Fig. Super-fluxed sinter brings extra CaO to the blast furnace. For self-fluxing and super-fluxed sinter, the lime reduces the melting temperature of the blend and at relatively low temperature. In case of self-fluxing and super-fluxed sinter, the lime reduces the melting temperature of the blend and at relatively low temperatures deg C to deg C strong bonds are formed in the presence of FeO. The Process The process of sintering begins with the preparation of the raw materials consisting of iron ore fines, fluxes, in-plant metallurgical waste materials, fuel and return fines of the sinter plant. These materials are mixed in a rotating drum and water is added in order to reach proper agglomeration of the raw materials mix. This agglomeration is in the form of micro-pellets. These micro pellets assist in obtaining optimum permeability during the sintering process. These micro pellets are then conveyed to the sintering machine and charged. A layer of controlled size sinter bedding is fed to the bottom of the sinter machine grates for the protection of the grates. After this the moistened micro pellets of the raw materials mix is fed and leveled. After the material is leveled on the sinter machine, the surface of the charged material on the sinter machine is ignited using gas or oil burners. Air is drawn through the moving bed causing the fuel to burn. During the machine movement the sintering of the material bed on the grate proceeds downward. Waste gas circuit is to be fully leak proof, not allowing air from atmosphere to be sucked by the system. This results into saving of power in the waste gas circuit. At the end of the machine the sintered material in the form of cake is discharged into the hot sinter crusher. Here the hot sinter cake is crushed to a pre-determined maximum particle size. From here the sinter is discharged onto sinter cooler which can be either straight line or circular cooler. After cooler the sinter is transferred to the screening section. In the screening section the product sinter, bedding and return fines are separated. Return fines, not suitable for downstream processing, are conveyed to a bin for recycling in the sintering process. Waste gases are treated for dust removal in a cyclone, electrostatic precipitator, wet scrubber or fabric filter. The material flow of the sinter plant is shown in Fig 2. Fig 2 Material flow in a sinter plant The flexibility of the sintering process permits conversion of a variety of materials, including iron ore fines, captured dusts, ore concentrates, and other iron-bearing materials of small particle size e. Sinter machines Sinter machines are of two types i circular and ii Straight line. Straight line Machines are also being known as Dwight and Lloyd machines. Circular sinter machines are normally suitable for blast furnaces having useful volumes of Cu m and less.

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Steel - Primary steelmaking: In principle, steelmaking is a melting, purifying, and alloying process carried out at approximately 1,600 °C (2,900 °F) in molten conditions. Various chemical reactions are initiated, either in sequence or simultaneously, in order to arrive at specified chemical compositions and temperatures.

History[edit] An illustration of furnace bellows operated by waterwheels , from the Nong Shu, by Wang Zhen , , during the Yuan Dynasty of China Chinese fining and blast furnace, Tiangong Kaiwu , History of ferrous metallurgy Cast iron has been found in China dating to the 5th century BC, but the earliest extant blast furnaces in China date to the 1st century AD and in the West from the High Middle Ages. The fuel used in these was invariably charcoal. The successful substitution of coke for charcoal is widely attributed to English inventor Abraham Darby in The efficiency of the process was further enhanced by the practice of preheating the combustion air hot blast , patented by Scottish inventor James Beaumont Neilson in History of metallurgy in China Archaeological evidence shows that bloomeries appeared in China around BC. In China blast furnaces produced cast iron, which was then either converted into finished implements in a cupola furnace, or turned into wrought iron in a fining hearth. In construction, they are both around the same level of technological sophistication [11] The effectiveness of the Chinese blast furnace was enhanced during this period by the engineer Du Shi c. Usage of the blast and cupola furnace remained widespread during the Song and Tang Dynasties. This may have happened as early as the 4th century AD. By using the blast furnace, it was possible to produce larger quantities of tools such as ploughshares more efficiently than the bloomery. In areas where quality was important, such as warfare, wrought iron and steel were preferred. Nearly all Han period weapons are made of wrought iron or steel, with the exception of axe-heads, of which many are made of cast iron. The Catalan forge was invented in Catalonia , Spain, during the 8th century. Instead of using natural draught, air was pumped in by a trompe , resulting in better quality iron and an increased capacity. This pumping of airstream in with bellows is known as cold blast, and it increases the fuel efficiency of the bloomery and improves yield. The Catalan forges can also be built bigger than natural draught bloomeries. The iron from the Lapphyttan complex was used to produce balls of wrought iron known as osmonds , and these were traded internationally – a possible reference occurs in a treaty with Novgorod from and several certain references in accounts of English customs from the s and s. Other furnaces of the 13th to 15th centuries have been identified in Westphalia. Al-Qazvini in the 13th century and other travellers subsequently noted an iron industry in the Alburz Mountains to the south of the Caspian Sea. This is close to the silk route , so that the use of technology derived from China is conceivable. Much later descriptions record blast furnaces about three metres high. However, since blast furnace has also been invented independently in Africa by the Haya people , it is more likely the process has been invented in Scandinavia independently. The step from bloomery to true blast furnace is not big. Simply just building a bigger furnace and using bigger bellows to increase the volume of the blast and hence the amount of oxygen leads inevitably into higher temperatures, bloom melting into liquid iron and, cast iron flowing from the smelters. Already the Vikings are known to have used double bellows, which greatly increases the volumetric flow of the blast. In this, the molten iron was tapped twice a day into water thereby granulating it. This may have included the blast furnace, as the Cistercians are known to have been skilled metallurgists. The Cistercians became the leading iron producers in Champagne , France, from the mid 11th century to the 17th century, [30] also using the phosphate -rich slag from their furnaces as an agricultural fertilizer. Origin and spread of early modern blast furnaces[edit] Period drawing of an 18th-century blast furnace Due to the casting of cannon, the blast furnace came into widespread use in France in the mid 15th century. From there, they spread first to the Pays de Bray on the eastern boundary of Normandy and from there to the Weald of Sussex , where the first furnace called Queenstock in Buxted was built in about 1460, followed by one at Newbridge in Ashdown Forest in 1470. They remained few in number until about 1550 but many were built in the following decades in the Weald, where the iron industry perhaps reached its peak about 1600. Most of the pig iron from these furnaces was taken to finery forges for the production of bar iron. The output of the industry probably peaked about 1600, and was followed by a slow decline until the early 18th century.

This was apparently because it was more economic to import iron from Sweden and elsewhere than to make it in some more remote British locations. Charcoal that was economically available to the industry was probably being consumed as fast as the wood to make it grew. The blast furnace spread from here to the central Russia and then finally to the Urals. Metallurgical grade coke will bear heavier weight than charcoal, allowing larger furnaces. Limestone ties up sulfur. Manganese may also be added to tie up sulfur. Coke pig iron was by this time cheaper to produce than charcoal pig iron. The use of a coal-derived fuel in the iron industry was a key factor in the British Industrial Revolution. Steam-powered blast[edit] The steam engine was applied to power blast air, overcoming a shortage of water power in areas where coal and iron ore were located. The cast iron blowing cylinder was developed in to replace the leather bellows, which wore out quickly. The steam engine and cast iron blowing cylinder led to a large increase in British iron production in the late 18th century. Within a few years of the introduction, hot blast was developed to the point where fuel consumption was cut by one-third using coke or two-thirds using coal, while furnace capacity was also significantly increased. Within a few decades, the practice was to have a "stove" as large as the furnace next to it into which the waste gas containing CO from the furnace was directed and burnt. The resultant heat was used to preheat the air blown into the furnace. Anthracite was first tried successfully by George Crane at Ynyscedwyn Ironworks in south Wales in Anthracite use declined when very high capacity blast furnaces requiring coke were built in the s. Modern furnaces[edit] Iron blast furnaces[edit] The blast furnace remains an important part of modern iron production. Modern furnaces are highly efficient, including Cowper stoves to pre-heat the blast air and employ recovery systems to extract the heat from the hot gases exiting the furnace. Competition in industry drives higher production rates. Variations of the blast furnace, such as the Swedish electric blast furnace, have been developed in countries which have no native coal resources. Lead blast furnaces[edit] Blast furnaces are currently rarely used in copper smelting, but modern lead smelting blast furnaces are much shorter than iron blast furnaces and are rectangular in shape.

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