IRON AND STEEL

Its general history in brief

Earliest methods of iron-making used the bloomery furnace. Even though a forced blast was often used, even from the 10th century, the mass in the furnace never got hot enough for the iron to liquefy; it was always a spongy mass of iron and slag, needing to be hammered into form. It was, nevertheless, a low-carbon iron, suitable as wrought-iron, and all early iron products were wrought or forged.

The blast-furnace, although apparently known in China from about 300 B.C, was not developed in Europe until the 15th century. First was probably near Liége, in what is now Belgium, around 1400. The blast-furnace is still the basis of the iron and steel industry, producing an iron with 3 - 4% carbon which can be cast into moulds, forming pig-iron. This cast-iron is brittle and lacks tensile strength, but can be used for making some things; and cast-iron cannon were made in Sussex in 1543; machine frames, household ironmongery, even bridges, were made from C.I. over a long period.

But for most purposes, wrought iron was required; it could be hammered into shape when hot, welded by hammering; it was strong in tension. So cast iron was converted into wrought iron by heating and stirring under a blast of air over a charcoal-fired hearth. The oxygen in the air oxidized the carbon. The hearth was called a finery and the whole set-up and its building was called a forge.

Blast furnaces in the early days required charcoal as fuel, to mix with the iron ore and flux (limestone). So they were to be found in wooded areas, notably the Sussex Weald, where water power was also available for blowing and for the hammering required when the wrought-iron was formed. Later the Forest of Dean and Furness became more important areas as the Sussex woodland all got used up.

The reduction of iron-ore (or smelting) using coke made from coal was a most important step forward. It is often said that Dud Dudley invented this process in the early 1600's. Certainly he had a patent for it in 1638, and an earlier one in the name of his father Lord Dudley dated 1621. But it is thought unlikely that he actually succeeded in making iron this way. He used small coal, not coke. The real originator of the coke-smelting of iron was almost certainly Abraham Darby (1676-1717) of Coalbrookdale. Coke was knownto him, and he used it in a blast-furnace successfully in 1709.

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As there was little charcoal available in Shropshire, this was important; but it was several decades before the process became widespread. It also happened that Darby was an ironfounder and wanted high-carbon iron - which was fortunate, for his cast iron was not suitable for conversion to wrought iron.

As long as charcoal was used in blast furnaces their height was limited to about 20 ft because the charcoal was soft and could not support a great weight without collapsing into a solid mass. Coke permitted greater heights to be used, and the furnaces could therefore be more efficient. But greater heights needed stronger blast, and so steam-blowing began to replace water-blowing. The advent of steam power changed the geography of the iron industry, for it could now operate where there were no streams - e.g. in the Black Country-provided the ore and coal and flux were available.

In 1784 Henry Cort (1740-1800) found a way of <u>using coal in the finery.</u> Hitherto the sulphur content of coal had prevented its use, but Cort adopted the reverberatory furnace (already in use in other metal industries, e.g. lead) for the purpose. Here the fire and melting are done in two almost separate compartments. Hot flame is caused to heat the latter compartment by "reverberation"from a sloping roof.

The making of rods and bars was originally a lengthy and difficult task, since hammering them out of a lump of wrought iron was required. The process was revolutionized by the introduction of the <u>rolling mill</u> and <u>slitting mill</u> in the early 1600's whereby iron could then be rolled by water power into long plates which could then be cut by rotary shears (also driven by water power) into bars.

<u>Later improvements to the blast furnace.</u>

Nielson's hot blast, in 1828, preheated the air intake and so increased efficiency. It reduced coal consulption from 8 to 5 tons per ton of iron.

In 1857 Cowper's regenerative hot-blast system made a large further increase in efficiency. Two preheating stoves were used in which furnace gas was burnt to heat the brickwork of the stoves. The air intake was passed through one hot stove, which thereby cooled down, Meanwhile the gas was heating up the other. When the first was cool and the second hot, they were changed over, and so on. This got fuel consumption down to one ton of <u>coke</u> per ton of iron.

<u>Steel</u>

So far we have discussed only cast iron with 3 - 4% of carbon, and wrought iron with perhaps only 0.05% carbon. While steel is a term covering a wide range of material, it certainly contains less carbon than C.I. and more than W.I. Mild steel has up to about 0.25% carbon, medium-carbon steel 0.25 - 0.5%, and high-carbon steel 0.5 - 1.4%, If carbon is diffused only into the skin of the iron, it is said to be case-hardened. Manganese makes steel tough and resistant to abrasion; nickel and chromium make it corrosion-resisting. Stainless steel may contain 18% Ni and 8% Cr.

Steel was made in small quantities in the East since 1500 B.C. "Wootz" steel was made in India by sealing a mixture of iron granules and dry wood in a clay crucible and heating strongly in a charcoal furnace. This steel-making was also practical in Damascus and Toledo (Spain) into the 19th century.. The cakes of steel were re-heated on a charcoal fire, forged into shape, and hardened by quenching in water..

Steel was also made by incomplete decarburization of iron from a blast-furnace on a finery hearth, but this was possible only when the ores were rich in manganese and low in phosphorus.

The cementation process was used from the early 17th century until 1951. Wrought iron bars were embedded in charcoal and maintained at red heat for many hours. This produced "blister" steel. The bars of blister steel were then bunched together and forged into "shear" steel.

Crucible steel was introduced by Benjamin Huntsman in 1740. He remelted blister steel bars in closed crucibles of refractory clay to produce steel of more uniform carbon content, and free of slag and cinder. The process is still used on a small scale for making cast steel from selected scrap.

The Bessemer process was invented by Sir Henry Bessemer (knighted in 1879) in a series of experiments starting in 1854 and getting into commercial production in 1860 or thereabouts. Basically the invention was this. Molten iron is put in a vessel (called the "convertor") and air is blown through it from the bottom. This oxidizes the carbon and enables the percentage of carbon to be reduced to a suitable level for the desired grade of steel. The heat of the reaction keeps the metal molten, so that no fuel is needed for the process. Bessemer had a lot of ups and downs with his invention; it took some time to discover why it would work with some iron and not with another. This was actually because it worked only with low-phosphorus iron, and most British iron had high phosphorus. Then it was found that too much oxygen was absorbed by the steel, and it needed "spiegeleisen" (a compound of manganese, iron and carbon) to remove it. But it was eventually a great success and introduced a new era in engineering. By 1863 there were Bessemer steelworks in Sheffield, Manchester, Penistone, Barrow-in-Furness.

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The open-hearth process was invented almost concurrently by C.W. Siemens (of the famour Siemens family of Germany) who lived 1823 - 1883, was knighted in 1882, and lived largely in England after 1843. He applied the regenerative principle to an open-hearth furnace in rather the same was as Cowper, already mentioned, had applied it to blast-furnace preheating. Decarburization involved the use of a suitable material to form a slag, so the chemical processes were evidently less simple than in the Bessemer converter. Moreover the process was much slower - 6 to 12 hours as opposed to ½ hr; this enabled control of the steel to be much more exact. It could handle cold metal, e.g. scrap, while the Bessemer converter required molten metal. These last two points were big advantages, and the open-hearth process has consequently been more widely used than the Bessemer, although both have survived to the present time. Only very recently have new processes been introduced. Oxygen steel-making (the "LD" process) is coming into general use.

References

1 W.K.V. Gale, "The British Iron and Steel Industry", David and Charles, Newton Abbot, 1967.

2 Science Museum collections, London, are very good on this topic.

THE PRESENT-DAY IRON INDUSTRY

Over 500 m tons of iron ore are extracted each year over the world.

Estimated iron ore reserves in world - 250,000 m tons.

Ore travels vast distances to blast furnaces: average distance, British furnaces 2100 miles; Japanese furnaces, 5000m. Therefore low freight charges essential, and the important world ore fields are those near the sea.

Sources 1966 figures)	Production (millions of tons)	Average iron content %
USSR	160	60
USA	82	65
France	55	35
China	around 30 or 40	?
Canada	37	70
Sweden	28	65
India	26	70
Venezuela	17	70
U.K.	13	30
Rest of world	59	-

Movement of the smelting industry. First where the forests (for charcoal) and ores were found together (+ limestone).

Then it moved to the coalfields (for coke)

Then to the orefields, because transport of coal cheaper than that of ore (modern blast furnaces use 1 part coal to 2 of ore).

A modern single blast furnace produces 400,000 tons of pig iron a year. It consumes each year

1 m tons ore
0.4 m tons coke & limestone
2 m tons air
2000 m gallons water for cooling

It also produces 200,000 tons of slag
and 2.5 m tons of low-grade gas.

With all the railway yards, dumps, etc., an ironworks with 3 or 4 blast furnaces requires 300 acres or so of level land. With steel production as well, 1 - 2 sq.miles may be occupied.

Fuel. Coke used for smelting. Only certain coalfields give suitable coal. In Britain the only good coking coal comes from quite limited areas in Durham and South Wales. The major suitable coalfields are in the Ruhr and in the Appalachians.

The British Iron Industry

3 - main centres - Scunthorpe, based on Frodingham orefield uses mainly British ore. Production 2.3 m tons pig iron (per annum).

Stoke-on-Trent and Bilston, based on coalfields, uses mainly British ore, production 0.4 m tons p.a.

South Wales & Mons., based on coast, uses mainly imported ore, mostly from Sweden production 3.6 m tons p.a.

The British Steel Industry

Nowadays 10% of steel works exceed 3 m tons p.a.
35% of steel works are below 1 m tons p.a.
(20 years ago, 93% were below 1 m tons p.a.)

Reference: E.H. Cooper, "Introduction to Economic Geography", Univ. Tut.Press, 1968.