The Jernkontoret 250th anniversary conference

Tim Smith

Introduction

The Swedish Steel Producers Association, Jernkontoret (literally translated as Iron Office) is Europe's oldest steel association and celebrated its 250th anniversary on December 29th 1997. To mark this occasion, Jernkontoret organised a conference in June 1997, *Iron and Steel — Today, Yesterday and Tomorrow*. A complete morning was given over to historical aspects of the Swedish iron industry and its trading and technological relationships with the rest of Europe. This day attracted a number of prominent industrial historians in the audience, including the veteran Swedish historian, Professor Karl-Gustof Hildebrand, author of one of the most comprehensive thesis on the Swedish steel industry, *Swedish Iron in the 17th and 18th Centuries. Export Industry before Industrialisation*. The following account [with notes by the reviewer in square parentheses] summarises the six historical papers presented which are published in full by Jernkontoret as Volume 3 of the conference proceedings.

The Swedish iron industry

Professor Marie Nisser of the Royal Institute of Technology, Stockholm, presented a comprehensive view of the Swedish iron industry from its beginnings over 2500 years ago to the present day 'specialised' steel industry. Professor Nisser explained the dominance of 'greater' Sweden in iron trade in the 17th century, the country then including present day Norway and Finland as well as part of Russia. Some 50% of bar iron exports (made from forged pigs) were to England, the remainder being to the Baltic countries and Portugal; a third of the world's iron was then made in Sweden. The threat from Russia to these markets was largely controlled by Sweden imposing customs tariffs on their export from Baltic ports until 1709 when the defeat of the Swedish army by Peter the Great freed the Baltic to Russian exports.

Iron was first made in Sweden at least 2500 years ago by smelting bog iron [found as 'red ochre' on the edge of former lakes], or lake iron scooped as soft nodules [looking very much like small 'cow pats'] from the bottom of lakes [a task facilitated in winter by cutting holes in the frozen lake surface]. Smelting took place in small bloomery furnaces; over 5000 such sites have been recorded so far [sometimes being found at the present day ground level, so undisturbed are some of the locations]. The first blast furnace dates from the late 12th-early 13th century, 200 years before the technique was used in the rest of Europe, with the exception of Kierspe in Jubachstal, Germany [there is some evidence to suggest a link by marriage between the two sites]. This furnace, located at Lapphyttan, probably came into existence because of local low phosphorus ore which otherwise would have resulted in a brittle cast iron. Output was probably 2-3t a year over a short campaign lasting only a month or so. Prof Nisser traced the development of ironmaking into the early 17th

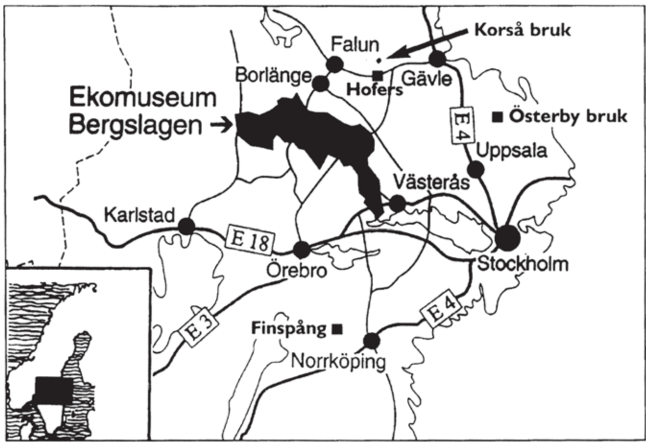

Fig 1: The regions of Uppland, Vastmanland and Bergslagen in central Sweden are particularly rich in industrial heritage sites preserved in situ.

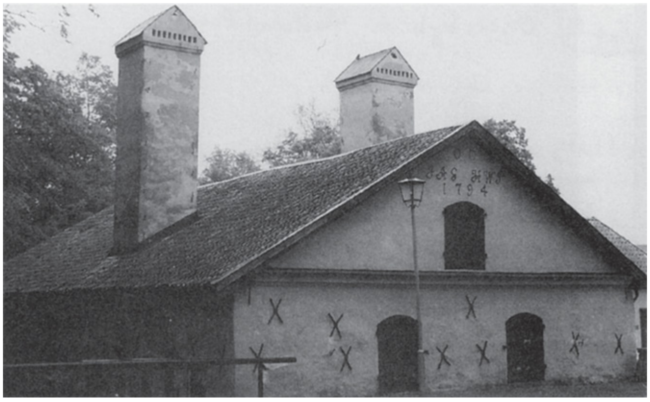

Fig 2: Österbybruk has the only remaining in situ Walloon forge in the world. Established in the 16th century, the surviving building dates from the late 18th century and closed in 1906.

Fig 3: Walloon pigs were about 5m long, much larger than those from the German process, and were fed to the finery hearth through a hole in its back wall so that iron could be melted off bit by bit from the end. The forged bloom was then reheated in a second hearth (chafery) for further consolidation by hammer forging.

century when immigrant workers arrived from the Walloon district of present day Belgium and Holland, first, in 1595, at the invitation of the future king of Sweden to cast cannon at Finspöng, 200km south-west of Stockholm, but later in the 1620s and 1630s, to settle in greater numbers to the north of Stockholm in Uppland [where the low phosphorus ore also contained manganese, making it particularly suitable for the production of bar iron for subsequent conversion to steel by the cementation process, then being adopted rapidly in England].

At first, the cast iron was refined in forges using large open hearths, and forged by tilt hammers powered by water wheels, but these were extravagant consumers of charcoal — to the extent that a decree was passed preventing new forges being built near blast furnaces so as to spread the demand for charcoal. In 1831 the Lancashire hearth arrived in Sweden which, being enclosed, was more energy efficient and also accelerated the output of iron. [The Lancashire forge in Sweden used charcoal for fuel and employed the wet puddling process in which an iron-oxide-rich slag and air blown from two tuyeres were used to decarburise the pig iron]. With the adoption of the Lancashire hearth, rolling mills were also introduced, offering greater productivity and less fuel consumption over the finishing hammer. [Initial forging of the puddled ball to bloom was still by hammer, followed by reheating of the bloom for rolling].

Attempts by the crown to gain greater value from Sweden's iron exports were less successful. The export of iron ore was banned from the 17th century, as was pig iron until 1856. Osmund iron — small pieces of forged iron typically weighing 280g made by rural smiths for domestic and export consumption since Viking times — was stopped in 1604 in favour of bar iron [measuring 2-3m by approx 50x10mm] which was made on an industrial scale. Attempts to make cementation iron [in which the wrought iron bar was recarburised to make steel] met with only limited success [probably due to the lack of coal to fuel the lengthy process, which could take a week to complete].

Swedish chemists were setting the scene for modern metallurgy, Scheele recognised oxygen (independent of Priestley in England), laying the foundations for smelting and decarburisation. He also realised the free carbon in cast iron was the form of graphite, and that phosphorus was the cause of cold brittleness. He discovered wolfram too [called tungsten in England due to a misunderstanding in language; it was referred to as 'heavy steel' (tung stål) in Swedish]. Swedish chemists discovered other elements important in steelmaking; manganese by Gahn in 1774, nickel by Cronstedt in 1751; and silicon by Berzelius in 1823, who also showed that oxygen was not a property-determining factor of pig iron. Sven Rinman's book, *Bergwerks lexikon*, published in 1734 can be considered the first scientific record of ironmaking (Agricola in 1563 recorded events without explanation and made no reference to the blast furnace as it was unknown to him).

Sweden saw its predominant position in ironmaking eroded during the 18th century, first by increased exports from Russia, and in 1709 by the successful smelting of iron with coke by Abraham Darby in England (Sweden had only one coal mine). In 1784, the puddling process was developed in England, which provided a method of mass producing wrought iron. Swedish 'Walloon' iron was still sought after for special steel production, ['double hoop' (OO) iron from Österbybruk — the letter Ö being absent from the French and English alphabets, it was replaced by OO — was the most prized in Sheffield], but Sweden could not compete for the mass produced market with its traditional techniques. Erik Svedenstierna was sent to England by Jernkontoret to assess the challenge; he concluded that Sweden should continue to exploit its raw resources of charcoal and low phosphorus ore to concentrate on special steel manufacture, but in a more efficient manner.

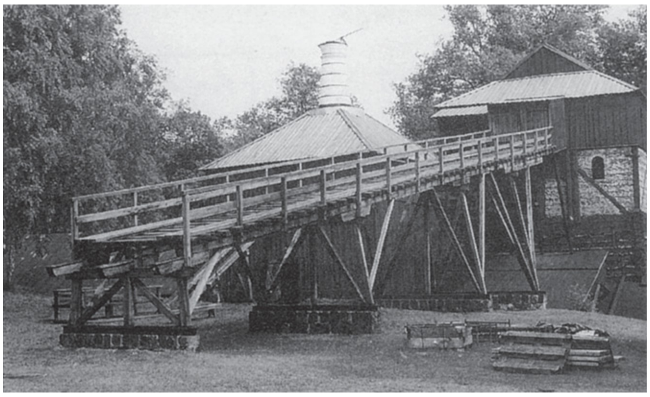

Fig 4: Engelsberg Bruk charcoal blast furnace (right) and ore roasting furnace (left) were built in 1779 on the site of an older furnace and worked until 1919 following an extensive rebuild in the 1870s.

In 1833, pre-heating of the blast furnace air, an invention of the Scotsman James Neilson, was introduced in a number of Swedish blast furnaces, cutting fuel consumption and increasing productivity. The hot blast necessitated the replacement of bellows [even the timber Steffen bellows introduced in the 1630s, which consisted of two close fitting timber chests] by the three-cylinder blowing engine developed in the UK by Bagge in 1835. 1859 saw the installation of the first free standing blast furnace in which the stack was no longer surrounded by a wall infilled with earth to provide insulation. This new [Ljusne] furnace at Långshyttan in Dalarna, owed its design to developments in UK, and was taller and slimmer than earlier furnaces [and generally used four tuyeres instead of the earlier single one]. Between 1861 and 1885, 47 of the 226 older blast furnaces were closed but annual production increased from 170,000 to 465,000t. At the same time, charcoal consumption fell by 800 litres per ton of pig iron. The arrival of the railways in the 1860s meant charcoal could be brought in from outside the immediate locality, allowing increased production, and iron could be shipped out.

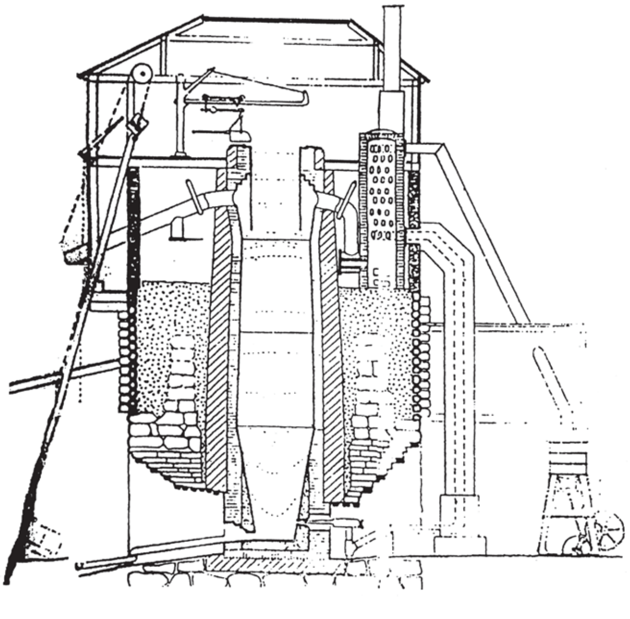

Fig 5: Section of a typical timber-clad earth-insulated blast furnace.

Methods of forging also improved; not only was the Lancashire hearth widely adopted from 1831, but also in 1845 the shaft welding furnace, which used a charcoal-fired gas generator, was invented by the Swede Gustaf Ekman. This enabled bundles of wrought bar to be reheated to a sufficiently high temperature to be fused together, so improving homogeneity and enabling further shaping by rolling rather than hammering. Production of hearth-refined iron peaked in 1887 when 221,000t were produced.

Bessemer steelmaking

In 1858 came the dawn of modern steelmaking with the construction of the world's first commercial Bessemer converter at Edsken in Uppland, a process brought to commercial success by the Swede, Göran Fredrik Göransson. [The low phosphorus Swedish pig iron enabled the process to succeed, while in other areas using high phosphorus iron, good steel could not be made until the vessel was modified by Sydney Gilchrist Thomas who added a rammed dolomite lining in 1879, 23 years after Bessemer's original patent]. The arrival of the Basic Thomas converter removed the advantage of the low phosphorus ores of central Sweden, but steel from the Swedish Acid Bessemer was still considered superior for special grades, a tradition continued to the present day, although not with Bessemer converters. Between 1870 and 1885, output of Bessemer ingots rose from 7700t to 52000t. The Thomas converter made its appearance in Sweden in 1890 at Domnarvet [present day SSAB Tunnplåt at Borlänge], along with the basic Siemens Martin furnace, to exploit the country's phosphorus-containing ores, first from the Grångesberg mines of Bergslagen and, at the turn of the century, from the vast quantities discovered in the far north around Kiruna [western Europe's only remaining significant iron ore mine today].

Siemens Martin Open Hearth steelmaking, adopted in the UK in 1865 after development work there by the German emigrant Siemens, and first put into practical operation in France by Martins, did not appear in Sweden until the mid 1880s due to the dominance of the Bessemer process which remained predominant in such markets as bearing steels, saw blades, rock drills and razor blade steel. However, Swedish acid open hearth steel developed a high reputation, with production peaking at 470,000t in 1970.

20th century production

Only 177 of the former Bergslagen estates, which consisted of self-supporting units with farms and forests to supply the ironworks, remained in 1913, compared with 381 estates with 213 blast furnaces in 1870; blast furnace numbers had fallen to 140. Sweden's share of world steel output had dropped to 2% by 1890. Swedish metallurgists continued to make significant contributions to the steel industry into modern times. Brinell (1849-1925) for example, developed the hardness test which still bears his name to-day and remains in common use.

Iron output remained constant during the First World War but in the 1920s, with a post war fall in demand, many of the surviving Bergslagens combined, while others such as Stora Kopparbergs, with a 700-year history of metal smelting, commencing with copper mining at Falun, diversified into forestry products using the timber of the estates formerly destined for charcoal production. [Today, Stora is Sweden's largest pulp manufacturer and no longer holds any steel interests but still owns the Falun copper mine, now open as a tourist attraction].

In the 1930s, production of steel by the electric arc furnace, but also by induction furnaces [and even an electric smelting blast furnace] commenced. By 1939, using Sweden's abundant hydro-electricity, 25% of all steel was made in electric furnaces. The production of stainless steel was one result of electric steelmaking [despite no reserves of chromium or nickel, although molybdenum ore was exploited].

Imported coke was rapidly replacing charcoal in the blast furnaces, although the last charcoal blast furnace survived until 1966 at Svartå in Bergslagen, making Sweden the last country in Europe to smelt with charcoal [Brazil remains the only country still producing iron with charcoal].

In the 1950s, at the dawn of modern oxygen steelmaking, the Kaldo converter was devised at Domnarvet, Borlänge. [A vessel still proudly stands at the gates of SSAB Tunnplåt Borlänge, although liquid metal is no longer made at the plant].

Ore mining came to an end in Bergslagen in the 1970s, followed by the closure of the last blast furnace (at Domnarvet, Borlänge in 1981), Lancashire hearths (at Ramnås in 1964), Bessemer converters (at Fagersta in 1961) and acid open hearth furnaces (1981). Prof Nisser concluded her presentation by reminding the audience that Sweden is still a major producer of special steels [some 4Mt being made in 1996].

Transfer of technology and trade

Walloon technology

The influence of the Walloon immigration, which probably numbered just 900 skilled workers, was amplified by Paul Nilles, Executive Director of the Belgian-based research centre, CRM. He defined the Walloons as being the French speaking people of the low countries centred on Liège, but covering an area which includes parts of present day Belgium, Luxembourg and the Netherlands. Huy, Namur, Chimay, Sedan and Habay were all important iron production centres. Emigration commenced following the capture of Liège by the Spanish, the Walloons finding Sweden sympathetic to their calvinist Protestant religion, and the Dannemora ore ideal for their ironmaking techniques. The Walloon blast furnace differed from the German, already established in Sweden, in that it was a taller, all-stone structure (the Swedish had earth-filled timber retaining walls for the top third). The refining forge also differed in that it was a two-stage process — refining followed by reheating to further consolidate the bloom — enabling sounder iron to be produced [but at the cost of greater charcoal consumption]; in later years coal was sometimes used in the second hearth as the temperature was lower so there was no danger of contamination from the fuel. The Walloon forge in Sweden remained largely confined to Östergötland and the Uppland area of Sweden, some 160km north of Stockholm, an area which today has the only remaining in situ Walloon forge, at Österbybruk. One of the most important innovations came later with the introduction of slitting mills in the first half of the 17th century which enabled the forged iron to be cut into narrow bar for production of such commodities as nails; two workers with a mill did as much work as 100 men before.

The English influence

Raymond Douglas, representing the UK Steel Association (formerly BISPA), reviewed technology transfer and trade between Sweden and UK, an occurrence as common in the 17th and 18th centuries as it is today despite the far greater difficulties in travel. He quoted from a petition of 1661 from the Sussex and Kent Weald, [the birthplace of the British blast furnace using Walloon technology], complaining of cheap imports of iron from Sweden, made possible by its abundance of timber for charcoal and high grade hematite ore (a rare commodity in the UK, known then only in the Forest of Dean). In 1614 the first cementation furnace was built in Britain (following the construction of such a furnace in 1601 at Nuremburg), and Swedish bar iron from the Walloon forges in the Dannemora region of Uppland — with its low phosphorus content and the presence of manganese — proved ideal for the process. Demand further increased with the crucible melting of the cemented iron to improve homogeneity in 1740 by Huntsman. Attempts by Swedes to adopt these techniques in their home region were less successful, possibly due to a lack of coal for heating. The Lancashire forge, however, was a technology which transferred successfully in 1831, providing a more fuel-economic method of refining pig iron by using an enclosed hearth.

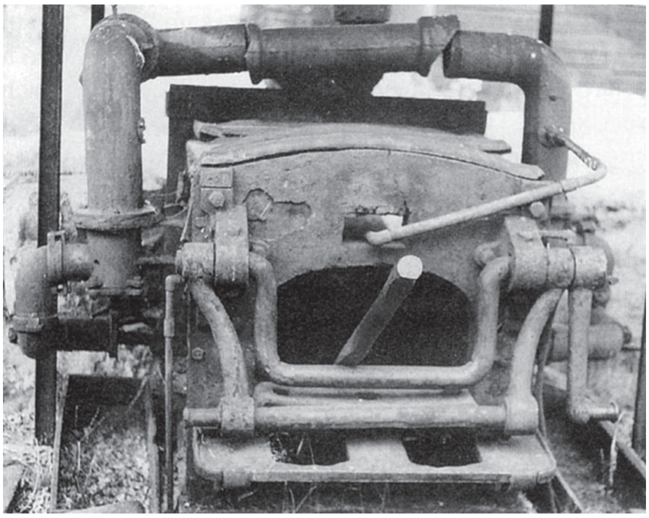

Fig 6: The Lancashire hearth puddling furnace began to replace the Walloon forge from 1831 as it was far more fuel-efficient. Note the powered crank at the furnace mouth to assist in lifting the puddling bars.

The first commercial application of the Bessemer converter also took place in Sweden, at Edsken in northern Uppland, with credit being given to Göransson for its development, as well as financial support from Jernkontoret. The low-phosphorus Swedish ores provided suitable iron for the process.

In more recent times the Kaldo converter was developed by Eketorp and Kalling at the Domnarvet works, Borlänge. It was used at several sites in the UK, but was eventually replaced by the present day BOS converter due to the high refractory wear experienced in the Kaldo, caused by the continuous rotation of the vessel to aid mixing. Other examples of technological co-operation have been martempered saw blades and construction steel sections, while the joint venture companies set up with British Steel for electrical sheet production and for stainless steel have resulted in a two way transfer, not only of technology but also of cultural exchange between schools in Sheffield and in Avesta.

French culture
André Faessel, Chairman of the French steel association, ATS, and President R&D, Usinor [the company recently dropped the Sacilor part of its name], summarised the influence of French education on prominent Swedes and the setting up of Catholic schools in the country. Education and the development of the physical sciences had moved ironmaking from a craft to a science. Bar iron, cannon and arms were exported to France, as well as copper from the Falun mine to roof the Palace of Versailles.

German trade and technology
Friedrich Toussaint, Chairman of the Historical Society of VDEh, pointed out that German blast furnace technology and forges had arrived in Sweden by 1500, well in advance of the Walloon methods, and possibly as early as the 13th century at Lapphyttan. [The 'German' method produced 90% of Sweden's forged iron]. Technology transfer was two way, new engineering techniques were brought from Sweden to Germany in 1694 by Christopher Polhem, who had constructed an elaborate system of water-driven lifting engines, first at the Falun copper mine, and later throughout the Bergslagen district. Also, Swedish technical papers were regularly published in German journals.

Osmund iron and copper were traded from the time of the Vikings. In the second half of 19th century, ore from the north of Sweden became an important source for the German steel industry, ironically because of its phosphorus content, since Germany had widely adopted the Thomas Basic Bessemer converter to exploit phosphorus ores in Lorraine. The difficulty of winning the ore from the hostile arctic region, and the long distance it had to be transported, were compensated for by its high iron content, twice that of the Lorraine ores. At times as much as 60% of German steel was made from Swedish ore, and today some 10% still is.

Trade in cannon

The historical session concluded with a paper from Gustaaf van Ditzhuijsen of Hoogovens Technical Services who spoke on the trade in cannon between Sweden and the Netherlands in the first quarter of the 17th century, which fluctuated and reversed in direction depending on which wars were being fought. The Walloon influence was again noted; Louis De Geer was the main supplier of armaments to the Swedish Crown and first came to Sweden in 1595 to help set up a cannon foundry in Finspöng 200km southwest of Stockholm. In the 1620s he bought into and established a number of ironworks to the north of Stockholm in Uppland making pig iron for forging into bar iron. Österbybruk was one such site taken over by De Geer in 1643 which was later inherited and developed by his son. These ironworks, established around the Dannemora mines, produced a bar iron particularly suitable for the cementation process which was rapidly developing in England.

Further Reading

Iron and steel - Today, yesterday and tomorrow, Vol 3, Yesterday and Tomorrow conference proceedings, 1997. ISBN 91-973072-4-6 SEK200

Karl-Gustaf Hildebrand, *Swedish iron in the 17th and 18th centuries. Export industry before industrialisation.*

Ivar Bohm, *The Swedish blast furnace during the 19th century*.
Available in English or Swedish from Jernkontoret, Box 1721, 111 87, Stockholm, Sweden. Tel: +8 6791 700, Fax: +8 6112 089, e-mail: office@jernkontoret.se
Gert Magnusson (ed), *The Importance of Ironmaking. Technical Innovation and Social Change*. (Two volumes from the proceedings of the 1995 Norberg conference) Also available from Jernkontoret.
HMS News (Winter 1996) 34.
Steel Times (March 1994) 222(3), 123.
Steel Times (May 1996) 224(5), 195.

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