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The Steel Industry in England: An Historical Overview

By Mike Williams

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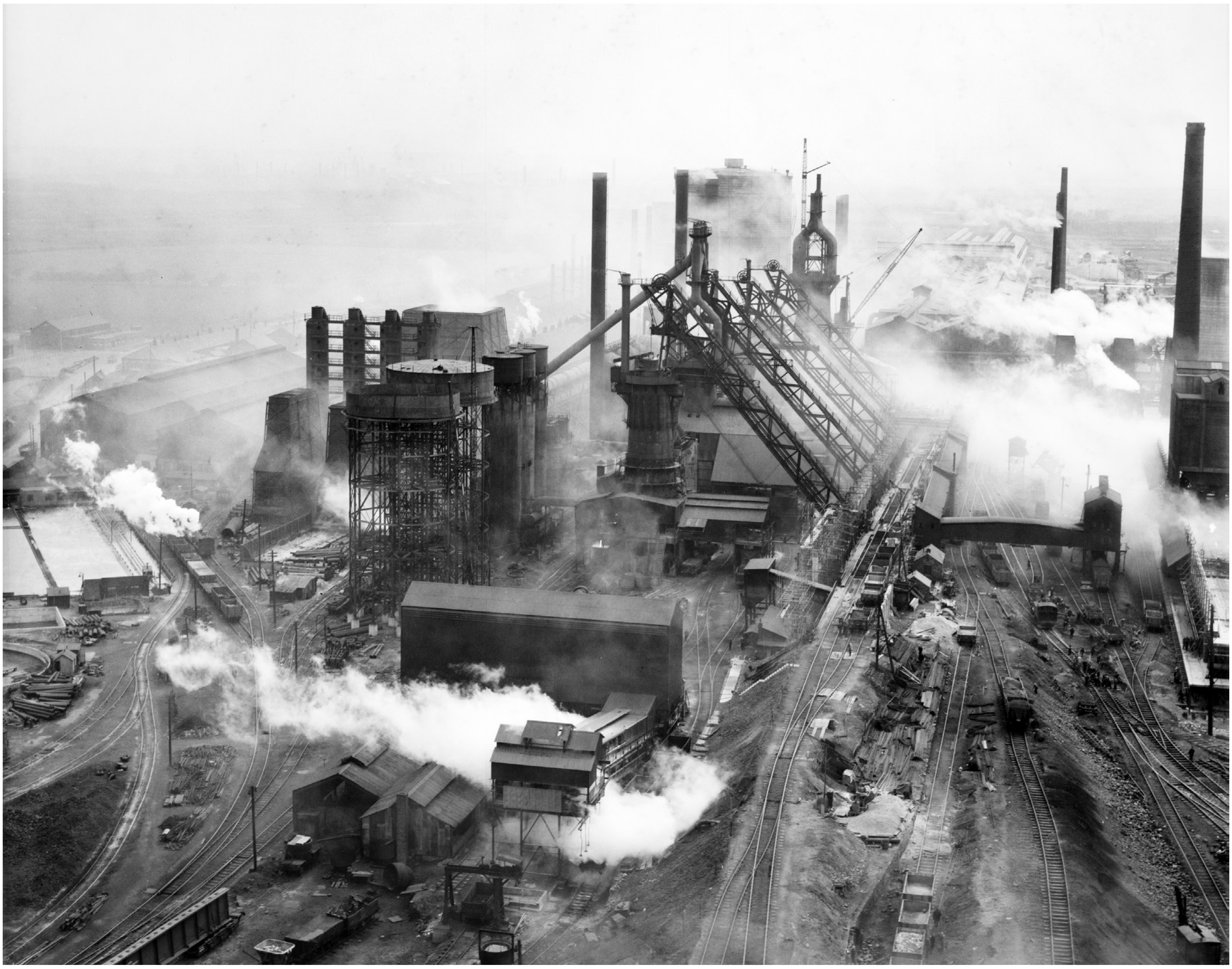

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SUMMARY

Steel has been of unparalleled importance in industrial history, having developed from a specialised trade in the mid-18th century into a global industry which continues to have a huge impact on of all branches of engineering, construction, transportation and architecture. Earlier forms of iron and steel making have been well researched, leading to the protection of historic sites and the regeneration of post-industrial areas. The distinctive sites of the later steel industry have seen little research or recording, however, and have largely been demolished. This overview of the later steel industry was prompted by the recession of late 2015, which resulted in further closures and the reorganisation of an industry that had already contracted dramatically in the second half of the 20th century.

CONTRIBUTORS

This report was compiled by Mike Williams. Ground photography at Sheerness was completed by James Davies and most of the recent aerial photography was by David MacLeod.

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INTRODUCTION: THE HERITAGE OF THE MODERN STEEL INDUSTRY

Steel is iron which has been precisely refined to have a carbon content of well under 1%. A small variation in the amount of carbon has a marked effect on the attributes of steel. Harder but brittle steels contain slightly more carbon, while more ductile steels typically have less carbon.[1] Other elements or alloys, such as chromium or tungsten, can be added to produce a wide range of steels with particular qualities.

Steel has been made in small quantities for millennia, usually for cutting tools or weapons, using a variety of techniques in different cultures. It was more widely produced in Europe by the early 18th century. From the mid-18th to the mid-19th century a distinctive form of steelmaking in Sheffield was combined with the manufacture of a wide range of steel goods and dominated world production, establishing Sheffield's unique position in the history of the industry. In this period, however, steel remained a specialized but high-value industry, and its output was far smaller than either wrought or cast-iron. Later in the 19th century new methods were developed for making steel in much larger quantities. From the late 1880s steel began to replace the use of iron and became the main product of former iron-producing firms outside Sheffield, leading to a transformation of the traditional iron-making districts and establishing the geography of the 20th century steel industry.

By the end of the 19th century steel had become the standard material for large scale construction and a wide range of engineering applications, and wrought iron production rapidly declined. Of particular importance were the use of steel in new types of buildings and other structures, the essential role of steel in the expansion of railways, particularly in North America, and the complete replacement of iron with steel in shipbuilding. The production and innovative use of steel continued to increase throughout the 20th century. Its importance in both World Wars led to government support, paving the way for later nationalisation (Figure 1). In contrast to its specialist origins, by the late 20th century steel had become an almost ubiquitous material around the world. The successes and failures of the industry were often directly linked to the progress of national economies. Its development has continued since the 1980s, as new types of steel have enabled the construction of a new generation of innovative buildings and structures.

Figure 1. Blast furnaces at the former Normanby Park steelworks, Scunthorpe, 1950, illustrate the scale, complexity and environmental impact of the later integrated steelworks (EAW028583, Historic England Archive).

HISTORICAL DEVELOPMENT OF THE STEEL INDUSTRY: KEY STAGES

Pre 18th century

Steel made using the cementation and crucible processes was produced commercially from the mid-18th century, but it was made in smaller quantities much earlier. Examples of rudimentary steel include an Egyptian axe dating from 900 BC. Complex procedures for making steel swords and knives were developed in Japan by the 15th century. Steel making using the cementation method was well established in Europe by the early 18th century, and in the Sheffield area. Such artisan or craft steelmaking involved modifying contemporary iron-making techniques.[2]

Mid-18th to mid-19th century, Sheffield steelmaking

Before the development of bulk steelmaking, the innovations of Benjamin Huntsman in the Sheffield area combined the cementation and crucible techniques to make good-quality steel in larger quantities than were previously possible, and established Sheffield as a historic centre of the steel industry (Figure 2). The compact nature of the process was of great importance to the local trade, ensuring steelmaking could be combined with manufacturing in an urban setting. By the 1850s, crucible steel production was still only about 2.5% of that of wrought iron[3], but Sheffield continued to dominate national production until the late 19th century. In 1881 a national trade directory listed 159 crucible steel firms, of which 146 were in Sheffield.[4] By the end of the 1880s, however, the output of the bulk steel industry had eclipsed both crucible steel and the much larger wrought iron industry.

Figure 2. Restored workshop for crucible steel making, Abbeydale Industrial Hamlet, Sheffield (AA022448, Historic England Archive).

Early 18th to mid-19th century, developments in the iron industry

The development of iron-making and related trades had a major impact on the later history of the steel industry.[5] In this period the British iron industry was the largest in the world and was central to the progress of the Industrial Revolution. The range of innovation was arguably greater than that required for steel in that period, including replacing charcoal with coke as fuel for blast furnaces, improvements to blast furnace design, the preparation of iron ore, the puddling furnace for converting pig iron to wrought iron and the development of the rolling mill for large scale production (Figure 3).

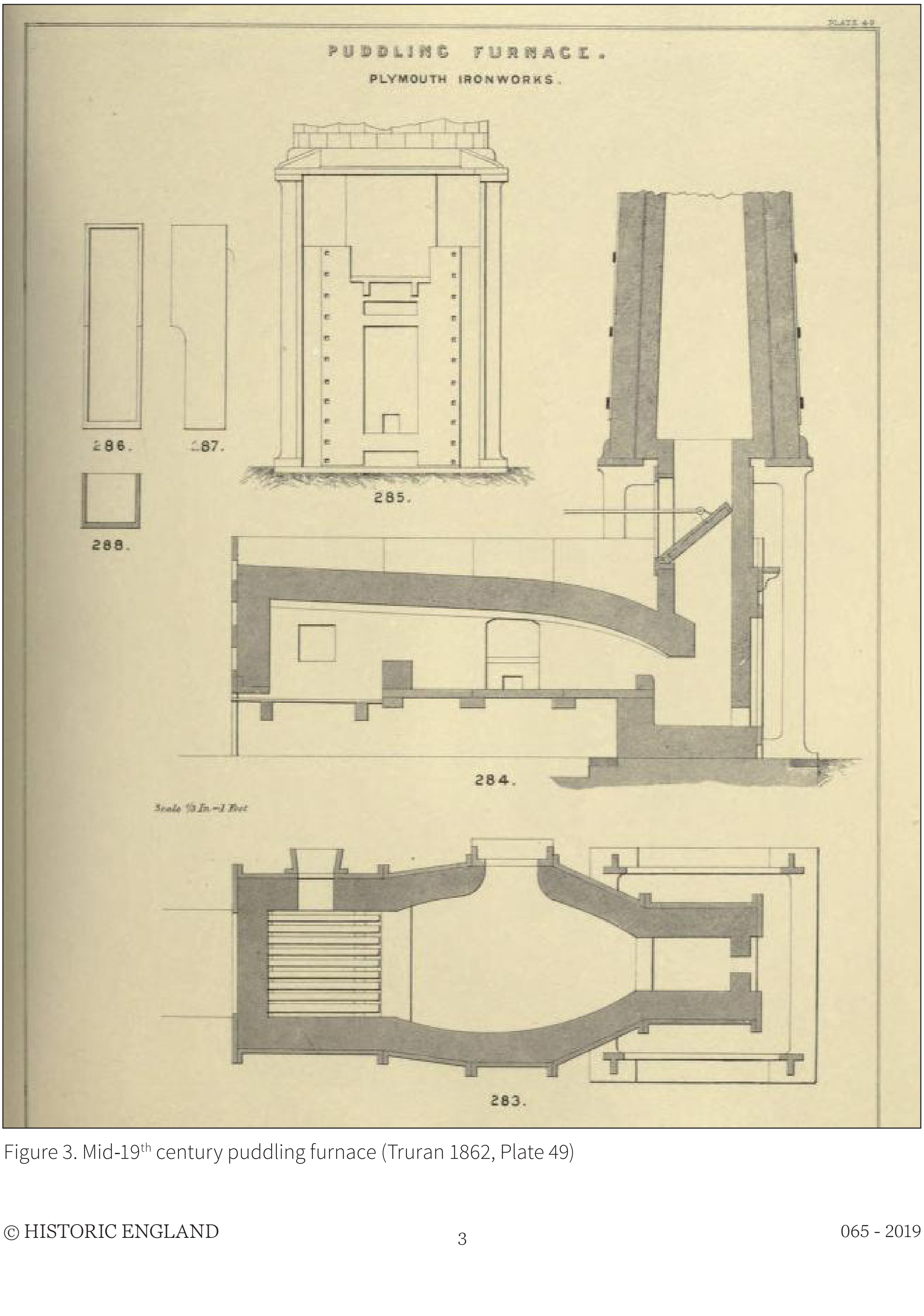


Figure 3. Mid-19th century puddling furnace (Truran 1862, Plate 49)

The pioneering structural uses of cast- and wrought-iron paved the way for the later demand for steel. Cast-iron was first used for bridges from the 1770s and for framed buildings from the late1790s.[6] Wrought iron was also central to early developments in infrastructure and engineering, notably for railways and shipbuilding, and was replacing the structural use of cast-iron by the mid-19th century. The potential demand for bulk steel had been recognised by the early 19th century; various iron firms tried new experimental methods of steelmaking but none were commercially successful.[7]

1850s to 1880s, innovations in bulk steelmaking

The modern steel industry originated in a series of historic innovations during a period of remarkable technical progress (see section 3). Most of these developments took place in Britain but resulted in the rapid expansion of steel industries in other countries, some of which exceeded the size of the British iron and steel industry by the end of the 19th century. The first two innovations, the Bessemer converter and the Open Hearth furnace, were more efficient methods for converting molten pig iron from a blast furnace into steel. Early modifications to these processes, based on an improved understanding of the chemistry of steelmaking, allowed phosphorous-rich iron ores to be used for the first time. This resulted in the growth of ironstone mining and steel production in other countries, particularly the USA. Many other innovations also contributed to the development of steel in this period, notably the complex development of the hot blast system for blast furnaces, which greatly reduced the cost of pig-iron production.

c. 1860 to c1900, the transition to bulk steelmaking

The introduction of bulk steelmaking led to a transitional period in the British iron and steel industry, in which the larger firms in most of the traditional iron districts added steel-making equipment, establishing the distribution of the 20th century steel industry, and the smaller firms closed. During the transition the steel industry suffered from over capacity, with many small and uncompetitive firms and the continued use of out-of-date equipment. Closures and mergers became the norm, with frequent changes of ownership and alterations to sites as they were adapted to form part of a larger business. In most cases steelmaking was added to an existing integrated iron works, but steel gradually became the dominant product and eventually replaced wrought iron completely. By the early 20th century most of the industry was dominated by a small number of very large steel firms, each controlling many sites; closure of a single firm could therefore result in widespread demolition.

In Sheffield, crucible steelmaking also saw important changes but remained an important branch of the industry until the end of the 19th century. Some of the larger firms added bulk steelmaking for a few decades, but other areas eventually dominated the bulk industry. Instead, the Sheffield industry was increasingly concerned with the production and engineering of steel alloys, known as ***special steels,*** which has continued to be an important branch of the industry in the 20th century. These ***steel engineering*** firms might have originated in the iron or steel industry but later became steel users rather than steel makers, and buildings associated with engineering trades replaced those associated with steelmaking. Such firms are commonplace in former steel-producing areas, including well-known firms in Sheffield and the Black Country, often occupying the sites of former iron or steelworks.

Early to mid-20th century

By 1900 the output of Britain's steel-making industry had fallen behind those of the USA and Germany[8], and most of the later technical developments took place overseas. The British industry produced a wide range of products, reflecting the importance of trade with the colonies. Steel makers in other countries benefitted from more up-to-date steelworks and greater specialisation, such as meeting the demand for the expanding infrastructure in the USA. The relative inefficiency of the British industry led to a shortage of steel in First World War. The problem was rectified by government-funded investment, but this emphasised tried-and-tested methods rather than innovation, exacerbating the problems of over capacity.[9] The rapid expansion of existing steelworks included some state of the art new buildings, however, for example in Rotherham (Templeborough Steel Works; Steel, Peach and Tozer) and Redcar (Redcar Iron and Steel Works; Dorman Long). Electric arc furnaces began to be used for recycling scrap steel and for making special steels (alloys). In the 1920s and 30s the further consolidation of the British industry resulted in a small number of huge multi-regional businesses, most of which were heavily integrated with other industries. The steel industry was nationalised briefly in the 1950s and again in the late 1960s, by which time just fourteen large firms controlled most of its surviving capacity, including thirty nine sites that were still making steel.[10]

Mid-20th to early 21st century

Nationalisation dominated the development of the British steel industry in the second half of the 20th century, although some firms were not nationalised. The long-term plans for the industry, published in the early 1970s, emphasised concentrating investment in a small number of efficient steel-making sites, while the legacy of older plant and increasing foreign competition meant that demolition was widespread.[11] In this period a wave of technical innovation, most of it taking place abroad, resulted in new designs for larger blast furnaces, new methods of steel making, continuous casting and rolling equipment. The efficiency of steelmaking was greatly improved, so the few remaining sites were associated with a significant increase in national output. The new additions to steel works from the 1950s reflected both the development of processes and also current fashions in the design of concrete, steel-framed and clad industrial buildings (eg the extension to Lackenby Steelworks by Dorman Long, early 1950s). Mini mills were built from the 1970s, an American concept in which a relatively compact site was built to utilise electric arc furnaces, continuous casting and rolling mills set up for a specific range of products. A further round of losses in the 1980s and 90s resulted in steel making by the nationalised industry being concentrated in just three locations, Port Talbot, Scunthorpe and Redcar, although the sites of other former steelworks were used for a wide variety of steel engineering and manufacturing. In 2019 Scunthorpe is the last fully integrated steelworks in England, although as this report was being prepared for publication it faced an uncertain future.

PROCESSES IN THE STEEL INDUSTRY: MAIN DEVELOPMENTS

The earlier crucible steel industry involved processes that were completely different to those in bulk steel making, and have been described in detail in several publications, most concentrating on the Sheffield industry.[12] In summary, high-quality wrought iron was imported, mainly from Scandinavia, and converted into blister steel using the cementation process and then further refined into high-quality cast steel using the crucible process. Each clay crucible contained about forty pounds of steel, and the whole process might take up to two weeks. Crucible steelmaking was normally combined with a range of engineering or manufacturing activities, requiring additional buildings such as forges, rolling mills and workshops or powered factories.

In the bulk steel industry, much larger quantities were produced using processes that could take from around 30 minutes to several hours. The overall range of processes is represented by the main stages at an integrated steel works: iron ore was smelted into pig iron; pig iron was converted into steel; the steel was cast into ingots or billets; ingots or billets were rolled or forged into products which were sold to other industries.[13] The full range of processes could be concentrated at one large site or dispersed across several sites. Bulk steelmaking was not combined with the manufacturing of finished goods at the same site, as was common in the crucible industry, although by the early 20th century the larger steel firms had integrated with related industries at other sites, such as shipbuilding and structural engineering.

Smelting pig iron from iron ore

Blast furnaces have remained the principal method of smelting iron ore but their size and complexity continued to increase up to the late 20th century. Their early form and operation was greatly improved in the iron industry from the early 18th century, and later developments were an important aspect of the bulk steel industry from the late 19th century. The aim was to reduce the cost of fuel while increasing the quantity and quality of the iron. In the 1880s a hundred and fifty iron- and steel-making sites in England were using blast furnaces; by the mid-1970s they were in use at just 10 sites owned by the nationalised British Steel. In its simplest form (up to the mid-19th century) a blast furnace comprises an upright, substantially-built shaft which is open at the top and has a funnel-shaped interior which narrows above a hearth at the base (Figure 4). Iron ore, fuel (charcoal or coke) and limestone are ***charged*** into the top of the furnace. Most of the height of the furnace contains burning material which slowly descends as combustion progresses and the waste products exit upwards in the form of highly-toxic smoke. A continuous air blast, provided by water-, steam- or electrically-powered pumps, is directed into the narrow section of the furnace, creating sufficiently high temperatures to finally separate the molten iron from the other materials. Iron and slag accumulate in the hearth and are periodically tapped from separate openings in the sides. The molten iron is either poured into a casting bed of rectangular moulds, known as pigs, or in a later steelworks transferred directly to the steel-making plant. Slag is processed as a valuable by-product.

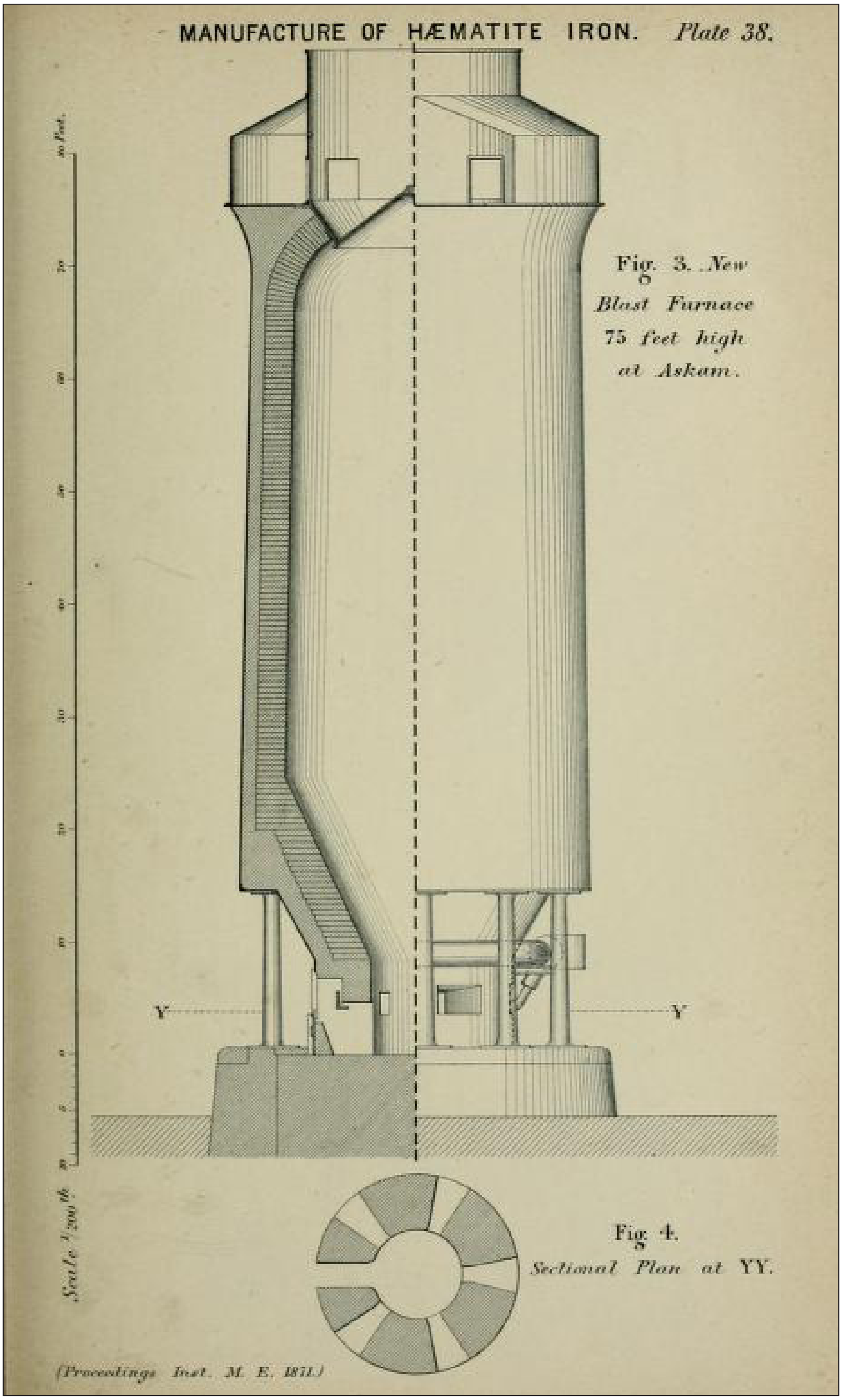


Figure 4. Typical late 19th century blast furnace, with a charging gallery, bell hopper and five tuyere openings above the hearth (Proceedings of the Institute of Mechanical Engineers, 1871).

A range of ancillary processes were built with blast furnaces from the later 19th century, sometimes while the furnace itself was being rebuilt. These included engine houses and boilers to generate the air blast, roadways, tramways, galleries and mechanical hoists for charging material into the furnace and improved facilities for handling slag and casting pig iron. Furnaces with closed tops were built in some areas from the 1850s, requiring a new design of loading hopper to allow charging without releasing furnace gas. Engine houses with air pumps, known as Blast Houses, were associated with both blast furnaces and Bessemer converters and survive in some areas. Steam boilers were of different types to those used in other industries, some being partly heated by waste gas from a blast furnace.[14] Of particular importance was the development of the hot blast system, with early examples patented by Thomas Botfield and, independently, James B. Neilson, both in 1828. The concept was greatly improved by Edward Alfred Cowper in 1857.[15] Initially the waste gas from the furnace was used to directly heat the hot blast, but in Cowper's more efficient system the blast was heated by gas burners in a series of large vertical tanks located next to the furnace. The burners used the processed waste gas from blast furnaces.[16] Similar tanks are a common feature of modern blast furnaces.

The blast furnaces associated with the 20th century steel industry generally have little in common with the historic 18th century furnaces that have been investigated and protected. The furnace itself is a huge structure but is often dwarfed by the adjoining complex of ancillary buildings and equipment, including the hot blast system, the waste gas plant and the facilities for handling raw materials, iron and slag. The increasing size and complexity of blast furnaces is illustrated by the quantities of iron produced. In the early 18th century blast furnaces might produce 50 tons of pig iron per year; by c1800 the larger furnaces, such as those at Coalbrookdale or Blaenavon, were making around 50 tons of pig iron per week; in the 1950s the new blast furnaces at Scunthorpe or Bilston were making around 1,000 tons per day; in the late 1980s the daily output of the Redcar blast furnace was 11,000 tons of pig iron, over 3,000 tons of slag and 21,000 tons of furnace gas.[17]

Making steel from pig iron

Pig iron (also known as cast iron) has high carbon content, usually above 5%, which needs to be reduced to less than 1% to make steel. Bulk steelmaking in the late 19th century was in part based on experience of the earlier puddling furnaces, which were used to convert pig iron into wrought iron, and involved exposing the molten pig iron to an air flow. At high temperatures oxygen in the air naturally combines with carbon in the pig iron to form carbon monoxide, thus decarbonising the iron. The new techniques involved novel ways of generating the air flow and the high temperatures. From the mid-20th century more precise methods were developed in which pure oxygen was directed onto the molten iron.

Three key innovations in the late 19th century enabled bulk steelmaking to develop as a separate industry. The first was the Bessemer converter, patented by Henry Bessemer in 1856 but was not made commercially viable until the early 1860s. It was initially developed in London, after which Bessemer set up a business in Sheffield and undertook further trials. It was licensed to several major iron and crucible steel firms, notably those of John Brown and Charles Cammell in Sheffield, who were both making rails from Bessemer steel by 1861.[18] It comprised a pivoting vessel with a perforated base, but without a heat source. Pig iron was poured in and air forced through the base, starting a dramatic reaction which generated high temperatures while converting the iron into steel. The process took about thirty minutes, the operatives judging when the conversion was finished by the colour of flame produced in the reaction. Bessemer converters were widely used in the late 19th century but were gradually replaced by other methods in the 20th century. The last one in Britain ceased work at Workington in 1974, and is now on display outside Kelham Island Museum in Sheffield (Figure 5).

Figure 5. Restored Bessemer converter at Kelham Island Museum, Sheffield (AA022440, Historic England Archive).

The second method was the Open Hearth furnace, invented by Carl Wilhelm Siemens and partners in Birmingham and patented in 1868. Siemens had earlier developed similar furnaces for other industries, in which ***regenerator chambers*** in the flues absorbed waste heat which was used to greatly increase the working temperature in the hearth. The technique was partly developed by Pierre-Emile

Martin in 1865, and is sometimes referred to as the Siemens-Martin process. The Open Hearth process took longer that the Bessemer converter but produced higher quality steel, and also allowed a proportion of scrap to be melted with the steel, reducing costs.[19] The Open Hearth technique was continually improved and became the most widespread method of steelmaking in the early and mid-20th century.

The third innovation was by S.G. Thomas and P.C. Gilchrist, the latter a chemist working for Blaenavon Iron Works, who introduced their concept of ***basic steelmaking*** and patented modifications to the Bessemer converter in 1878. In the Gilchrist-Thomas process ***basic*** refers to the need to reduce acidity, which was in part achieved by lining furnaces with refractory material made from dolomitic limestone instead of traditional fire brick.[20] The modifications enabled widespread phosphorous-rich iron ores to be used for steelmaking for the first time, resulting in the great expansion of steel industries overseas.

Relatively few major innovations in steelmaking took place in the first half of the 20th century, although existing techniques were refined and there was continual development of the wide range of ancillary equipment. Larger types of Bessemer converters were introduced and Open Hearth furnaces were further improved, including the introduction of tilting designs, and became the most widely-used method. Open Hearth furnaces were still being installed in new steelworks in the early 1950s.[21] Additional functions at an integrated steelworks might include water-cooling systems, ventilation systems, railway and road transportation, warehousing, testing facilities and accommodation for the workforce and management.

New processes to replace Open Hearth steelmaking were introduced from the 1950s, but were not widely used in Britain until the early 1960s. Most were based on oxygen-blown steelmaking, in which pure oxygen was directed onto molten pig iron using a water-cooled lance. Basic Oxygen Steel became the most widely-used process in the second half of the 20th century. A common variation was the LD system, which was developed in the Austrian steelmaking towns of Linz and Donawitz in the 1950s. These techniques enabled more precise control of the quality of the steel, which could be made much faster and in larger quantities than with the Open Hearth process.[22] The 1960s saw further innovations such as the Kaldo process, which involved rotating the steel converter, and the injection of inert gas to promote mixing of the steel. Electric arc furnaces also became more widespread. A notable example was the Templeborough Steel works in Rotherham, which built the largest electrically-powered melt house in the world in the 1960s, now preserved as the Magna museum. From the 1970s secondary steelmaking was added to many works, in which the newly-made steel was analysed and adjusted to produce alloys.

Steel casting

In an integrated steelworks the steel was normally cast into ingots or billets which were stored on site before reheating and rolling. Up to the 1950s ingot casting was the normal method; ingots were typically around 30.4cm (12 inches) square and 152cm (5 feet) long, with the size depending on the final product, and were cast individually in upright moulds (Figure 6). Prior to rolling they were reheated and conditioned in a high-temperature ***soaking pit***. After the 1950s steelworks were increasingly converted to utilise continuous casting of billets or slabs instead of ingot casting. Billets were typically 15cm (6 inches) square and up to 10 metres (32.8 feet) long. A similar process was first suggested in the mid-19th century but continuous casting was not introduced until a century later, initially by American firms. Molten steel was poured into a tundish and extruded through water-cooled moulds. The parallel strands of steel were then cooled in a spray chamber and rolled, producing steel in a form that required fewer stages of rolling than the earlier ingots.[23]

Figure 6. Casting steel ingots at Port Talbot, c1970 (FF98_00246, Historic England Archive).

The rolling of long, flat or round steel products

The use of powered rolls instead of forging was patented by Henry Cort, inventor of the puddling furnace, in 1784. The internal layout of the process had a marked influence on the size and plan of rolling mills. Early rolling was arranged transversely, with the rows of side-by-side rolling stands driven from either the end or the centre of the building, but from the late 19th century the sequence of rolling was arranged longitudinally, usually referred to as continuous rolling, which required a long rectangular building. By the mid-20th century this was the normal arrangement, with very large buildings containing an in-line sequence of stands, each with two or more rolls of the required shape. The sequence of machinery included mechanical shears for cutting or the longitudinal slitting of the product. The process was typically divided into a roughing, intermediate and finishing stage; steel ingots also required an earlier stage of heavy-duty rolling, known as a cogging mill. The steel was elongated greatly during rolling, which was achieved by varying the speeds of the rolls. The rolls themselves could be changed to make products of different sections. After rolling the products were fed directly onto a cooling bed which was dimensioned according to the length of products required, sometimes over a hundred metres long. Cooling beds comprised a grid of transverse ribs with a saw-tooth upper edge, which cooled the products without distortion.

STEEL INDUSTRY SITES AND BUILDINGS

The most distinctive feature of an integrated steelworks is the scale of the site and its main buildings. The largest of the sites that were still functioning in the late 20th century cover an area comparable with a small town (Scunthorpe, Port Talbot and Redcar, where the blast furnace site alone covers an area of 4.5 square kilometres). Most of the buildings and structures are utilitarian designs with little or no fenestration, although some reflect architectural trends of the 1950s and 60s. The vast plain exteriors of the main buildings contrast with the visual complexity of the blast furnaces and other engineering structures which dominate much of the site. Most of the external details are functional, such as those associated with the ventilation systems attached to melt shops and rolling mills. Very few steelworks buildings survive from before 1950. At some sites, including former iron works, smaller buildings and boundary walls may date from the late 19th century.

The overall layout of an integrated steelworks is also dictated by function. Blast furnaces are detached and located close to infrastructure for delivery and processing of the raw materials, including stockyards, and are connected to the steelmaking plant by railway. A late 20th century blast furnace is in effect a complex within a complex, with a wide range of distinctive ancillary structures (see below). The steelmaking plant is located in a building adjoining the rolling mill, in some cases with an intervening billet store. Electric arc furnaces are sited in a melt shop, also with good access to a rolling mill. In some of the larger sites the main processes are located under the same roof, but separated by internal divisions.

Steelworks buildings are usually steel framed with various types of external cladding, containing substantial concrete foundations and platforms for the main processes. Steelmaking furnaces and electric arc furnaces are often located on a mezzanine or gallery, with facilities for transferring the molten steel to secondary steelmaking equipment and the continuous casting plant. The latter is typically arranged on three levels, with steel billets delivered onto an adjoining cooling bed.

The main buildings are notable for their huge internal volume, only a small proportion of which is occupied by the equipment. The empty space is in part dictated by the nature of the processes, such as the need to avoid close contact with molten steel or steel-handling equipment and the large size of the ventilation systems. The rolling mill at Sheerness Steel Works, for example, was 324 metres long (1063 feet) and 21.4 metres wide (70 feet). An important aspect of building design is the provision of facilities for the movement of iron and steel, either molten or in the form of billets. The most frequent method used ladles carried by overhead gantry cranes, with the building frame including massive supports for the crane tracks. In other cases ladles were moved by trolleys on tracks at ground level.

Blast furnaces

Blast furnaces are an iconic feature of the iron and steel industries. The later, taller examples dominate the landscape of a steel works and are often featured in media coverage. Early blast furnaces, up to the mid-19th century, were built into embankments allowing an upper roadway to be used for charging. Later free-standing designs with charging galleries were built in masonry and then steel (see Figure 4, above). Blast furnaces operate continuously with internal temperatures in excess of 1,200 degrees centigrade and frequently needed re-lining, so well-preserved examples are understandably rare. The early masonry types might last several decades before a rebuild, but later steel-built furnaces needed overhauling more frequently. In the second half of the 20th century blast furnace design advanced considerably leading to several generations of ever-larger furnaces (Figure 7). The largest to be built, such as Redcar (1978), occupied a comparable area to an early 20th century steelworks.

Figure 7. Blast furnaces at the former Consett Steel Works, c1960s (FF98_00252, Historic England Archive).

Typical features of a late 20th century blast furnace:

The furnace stack

Older stone and/or brick types were replaced with steel shells with water-cooling by the end of the 19th century. The larger more-recent designs use external columns to support galleries and attached equipment.

Hot blast system

The blast is heated to over 1,000 degrees centigrade, which greatly improves smelting efficiency. Hot blast is produced in a series of Cowper stoves, heated by gas burners, at least three of which are need for each blast furnace. By the late 20th century each hot blast stove comprised a pair of upright tanks, one being an external combustion chamber. Air is supplied to the stoves from a separate blast house, originally containing steam engines with reciprocal pumps but by the mid-20th century electric or steam-driven turbo pumps were widespread. The hot blast is delivered to the furnace by a hot blast main pipe feeding an array of water-cooled nozzles, or tuyeres.

The furnace gas system

Blast furnaces have been sealed with caps from the late 19th century, the charge being delivered via an air-tight hopper. Furnace waste gas is extracted by large-diameter pipework which forms a distinctive feature on top of the furnace. The angled “downcomer” pipe delivers waste gas to an adjoining processing plant, which removes the solids and extracts combustible gas. The latter is used in the gas burners of the hot blast system, reducing energy costs.

Preparation of the charge

Facilities comprise stock yards for iron ores, limestone, sinter and coal; a coke-making plant; a stock building to prepare the recipe of ingredients for delivery to the furnace. These were substantial features at a large site, occupying far more area than the blast furnace itself (Figure 8). Sintering comprises the roasting of ground iron ore, limestone and coke to produce a clinker that is more efficiently smelted than the low-grade ores commonly used from the mid-20th century. Up to the mid-20th century banks of calcining kilns were often sited close to a blast furnace, in which the ore was roasted to remove moisture and chemical impurities.

Tapping and removal of iron and slag

Takes place at intervals of several hours, using an upper tapping hole for the slag and a lower hole for the pig iron. Slag is a valuable by-product, used for building materials, road surfacing etc., and in the 19th century was also used for land reclamation in coastal areas. Molten pig iron is tapped from a lower hole and fed into insulated railway wagons, commonly known as torpedoes, for delivery to the steelmaking plant.

Figure 8. The disused Redcar Blast Furnace, built in the late 1970s on the site of the former Redcar Steel Works, 2015 (28836_058, Historic England Archive).

Cooling system

Water cooling is used throughout, such as for the furnace shell, the tuyeres and hot blast system, requiring ponds and a pump house. The Redcar blast furnace had four separate cooling systems.[24]

Infrastructure

Includes shipping wharves with unloading equipment. Conveyor systems are used for transporting raw materials. The prepared charge is delivered to the top of the furnace by trucks or an angled conveyor. Pig iron is removed by railway. In some areas rail tracks used for delivering iron ore and limestone were raised above storage bunkers on long structures known as gantries, often sited close to the blast furnaces.

Steelmaking and casting: melt shops and related plant

Bessemer converters and Open Hearth furnaces were located at the heart of an integrated steel works, with access to both the blast furnaces and the storage area for the cast steel. They were housed in large single-storeyed structures with ample ventilation, sometimes referred to as melt shops, which often adjoined a rolling mill. A distinctive feature was the row of tall chimneys along a side wall, serving a bank of furnaces. Bessemer converters needed a dedicated air supply, provided by an adjoining engine and blast house, with an associated boiler house. Open Hearth furnaces were fired by gas burners, usually supplied from a nearby Gas Producer comprising a bank of retorts with a row of chimneys. Equipment for casting the molten steel was located in a dedicated area in the melt shop, known as a casting bay or teeming bay.

By the mid-20th century steelmaking was often located in an annex of a large rolling mill, with separate melt shops used for the electric arc furnaces and related processes (Figure 9). Later melt shops typically comprise a tall steel-framed clad building with prominent louvres and external ducting for the ventilation systems but little or no fenestration. They lack the rows of chimneys seen attached to earlier melt shops. The steel frame incorporates the massive supports for overhead gantry cranes used for moving baskets of scrap or ladles of molten steel. The furnaces are arranged longitudinally on a substantially-built concrete gallery or mezzanine, alongside which is the lower casting bay, where the molten steel or slag is discharged into ladles. Melt shops were usually sited to facilitate the arrangement of processes around the site. In the late 20th century the continuous casting plant was located inside or adjoining the melt shop, with related equipment for handling ladles and secondary steelmaking. Other adjoining structures included buildings for preparing the scrap steel, facilities for processing the waste furnace gas and the water-cooling system for the furnaces.

Figure 9. Enclosure of an electric arc furnace at Sheerness Steel Works, prior to the demolition of the site in 2017 (DP181934, Historic England Archive).

Rolling and Rod Mills

The largest building at an integrated steelworks was the rolling mill, built to a rectangular plan which by the late 20th century could be over a kilometre long (Figure 10). Late 19th century examples were built in brick but from the mid-20th century rolling mills were steel-framed, clad enclosures, distinguished by their huge size and plain utilitarian design. Interiors are open but may include longitudinal divisions and raised walkways. In some cases two or more buildings were built side by side and internally open except for the columns of the intervening wall frames.

The gabled or mansard wide-span roofs have steel trusses which are heavily built to support the ducting, hoods and louvres of the ventilation system. The wall framing serves the dual purpose of supporting the tracks of the massive gantry cranes, with paired steel columns below the tracks and a lighter frame of single columns above.

Functional details are similar to other buildings used for other steelmaking processes. Fenestration might be completely absent or consist of skylights or long glazed panels below the eaves. Ventilation comprises a combination of opening louvres in the walls, raised structures on the roof apex and ducting suspended from the roof and powered from an external fan house. A distinctive feature of the interiors is the large amount of space around the main processes, contrasting with other industries where most of the space was filled by machinery.

Figure 10. Cooling bed in the rolling mill of Sheerness Steel Works, prior to demolition in 2017 (DP181849, Historic England Archive).

19th century rolling mills were steam-powered from external engine houses, sometimes with separate engines for the different stages of rolling. Engine houses sometimes had similar embellishment to those built for textile mills, contrasting with its near absence in other steelworks buildings. The drive shafts and gearing were located at or below ground level, contemporary illustrations indicating that they were substantial features which significantly influenced building design. From the late 20th century rolling stands were individually powered by overhead electric motors and gearboxes. Processes were controlled from an elevated room or cabin, often known as a control pulpit, reached by metal stairs and walkways. With the increased use of digital monitoring and control these were often rebuilt to suit computers and control panels.

Other features

Integrated steelworks also included a wide range of additional buildings to support steelmaking and the needs of the substantial workforce and its management. These included warehousing, maintenance and engineering facilities, laboratories, medical facilities, canteens and offices. When offices were sited close to the site entrance they often showed a greater concern for architectural appearance, reflecting contemporary fashions. The road and rail infrastructure used for moving materials, products and people was usually a major influence on site layout. Related structures included the coke ovens, sintering plant, stock yards for different materials and access to facilities for docking and unloading ships, which were sometimes located within the boundaries of the larger steelworks.

CONSERVATION / LEGACY ASPECTS

The rich heritage of the steel industry is often mentioned in media coverage, but the history of the bulk-steel industry, including its meteoric rise followed by the widespread loss of its sites, has received little attention. The historic importance of the later steel industry has yet to be revealed to a public audience. The earlier iron and crucible steel industries were of great significance during the Industrial Revolution, as is widely recognised in publications and reflected in designations, including extensive listing in Sheffield and two World Heritage Sites (Ironbridge Gorge and Blaenavon Industrial Landscape). The late 19th century innovations which gave rise to the bulk steel industry are perhaps less well-known but were arguably of equal significance. The processes of bulk steelmaking that originated in Britain were quickly adopted by the emerging iron and steel industries in other countries, laying the foundations for the global expansion of the steel industry in the 20th century. In contrast to the numerous publications on the early industry, however, very little research has been carried out on the impact or the structures of the later steel industry.

Steelmaking was of fundamental importance to the national economy from the mid-19th to the mid-20th century, and related industries are still a major employer in the manufacturing regions. The historical significance of the steel industry is enhanced by its extensive connections with other industries, notably shipbuilding and a wide range of engineering and manufacturing, and its direct relevance to many aspects of industrial history. In some cases steelworks supplied the essential raw materials for an industry, while in others steel firms directly controlled other industries through mergers and integration. For over a century steel was recognised as an indicator of the wellbeing of the national economy; a decline in the fortunes of the industry often presaged a national recession, while increasing demand for steel was one of the first signs of a general economic recovery.[25]

Significance of sites, buildings and structures

Buildings used for steel production are essentially large metal-clad enclosures, distinguished from earlier forms of industrial architecture by their scale, utilitarian exteriors and functional details that are specific to the steel industry. They exhibit little concern for architectural appearance, and have a strongly functional aesthetic. Buildings of this type have seen little study or protection but are representative of industrial architecture in the late 20th century. Like earlier industrial buildings they show a connection between external form and internal processes, and comprise a number of well-defined building types. A full appraisal of the architectural context of steelmaking would benefit greatly from comparative studies of other late 20th century industries.

Steelworks also included other building types, such as offices, laboratories and associated housing, which were of more conventional brick and concrete construction and reflected current architectural fashions. Suitability for protection could be considered using similar criteria to those used for other commercial, suburban and domestic buildings of the mid- to late 20th century.

In contrast to the late 19th century industry the machinery and equipment of late 20th century steelworks was generally not manufactured in Britain. From the early 20th century most of the new innovations, and the production of steelmaking machinery, took place in other countries, notably the USA and Germany. The more progressive (and long lasting) British firms continued to implement the latest techniques, however, so their sites represented the international development of the industry, including the increased use of electric arc furnaces and the construction of mini mills from the 1960s. Under nationalisation (1969-89) production was concentrated at a small number of very large sites, where the scale of integration and the adoption of new technology represented the state of the art of steelmaking in the 1970s and 80s (Scunthorpe, Redcar, Port Talbot). In the last decade further rationalising and new investment has maintained the competitiveness of the working sites.

The steel industry always had a significant impact on the local landscape and economy. It was widely distributed and developed in most of the former iron-making areas. It was usually associated with environmental problems which would not be acceptable today. Its visual impact was dramatic, often dominating urban, rural and coastal landscapes. The blast furnaces and other distinctive structures have become iconic symbols of late 20th century industry. External related features often survive after a steelworks has been demolished, including workers' housing, rail, road and coastal infrastructure and ancillary buildings such as offices at the steelworks itself. In some cases engineering industries that were formerly dependent on locally-made steel have survived by using imports, thus preserving industrial sites after the steelworks has closed.

Threats

Surviving features have a high rarity value because demolition of the later steel industry has been unusually extensive; more survives of the earlier crucible steel industry in Sheffield (Figure 11). No typical examples survive of the integrated steelworks that characterised the bulk steel industry from the late 19th to the late 20th century, and many of the well-known sites were demolished during the period of nationalisation. Scunthorpe is the last integrated steelworks still working in England, and is therefore of interest, but its exceptional size is not typical (it originated as five separate iron works). The twenty or so non-integrated sites that are still involved with steel making comprise buildings dating from the mid-20th century or later, in some cases with fragmentary survival of earlier features. Demolition of some of the remaining sites has continued since the crisis in the industry in 2015.

The survival of early or historic features is unlikely because of the frequent replacement of equipment in steelworks. This was partly due to the nature of the work (steelmaking equipment is itself generally made of steel) and partly because the continued emphasis on technical development meant out-of-date machinery was replaced.

In contrast with other industries, such as textiles, steel industry sites were rapidly demolished after closure, probably reflecting a number of factors including environmental impact, nationalised ownership and the perceived lack of adaptability of the buildings. In other industries disused sites might retain extant but empty buildings for decades.

Figure 11. The casting bay of Sheerness Steel Works, prior to demolition in 2017. Steel industry structures and equipment were often built on a dramatic scale, conveying a powerful illustration of functional design (DP181929, Historic England Archive).

The number of sites associated with Sheffield industry was much larger than the later steel industry, and consequently a larger number survive, greatly helped by the EH/RCHME work in the 1990s.[26] The early Sheffield steel industry (mid-18th to later 19th century) was not representative of the later bulk steel industry but was of international historic importance and has been well-researched, but there was little recording of its buildings until the late 1990s.

Current protection / criteria

The Sheffield industry has seen good protection of the surviving sites following the EH/RCHME project, but there appears to have been no listing of the 20th century bulk steel industry in other areas. In Sheffield 72 sites are listed or scheduled, the majority being workshops and factories associated with the metalworking trades (exact number is subject to definition of function; several sites have more than one designation. Grade I: 2; Grade II*: 14; Grade II: 64; SM: 6). The Sheffield list includes the few remaining examples of crucible or cementation furnaces and represents a good cross section of local buildings types, including early forges and a small number of early 20th century buildings.

The earlier iron industry is also well represented in both listing and scheduling in historically significant areas, reflecting the extent of previous research and archaeological investigation. Few of the early sites retain extant buildings so scheduling is the main form of statutory protection. Scheduled archaeological sites include the Dark Hill Ironworks and Titanic Steelworks in the Forest of Dean, the Derby Ironworks at Coalbrookdale and parts of the recently-recorded Butterley Iron Works in Derbyshire.[27]

The scale of later steel industry sites, and their dissimilarity with other types of listed buildings, raises wider issues related to protection and conservation. These include the location of steel sites in areas where economic regeneration is currently a priority, the relatively few studies of later industry in general and difficulties in identifying new uses for the distinctive types of buildings and structures at steelworks, following any designations. The potential for late but significant steel industry structures to contribute to regeneration would merit further assessment. Physical conservation of the steel industry may also require a different approach to other industries, including dealing with very large steel structures such as blast furnaces.

Research / recording / publication

In comparison with other industries surprisingly little has been published on the physical heritage of the bulk steel industry, in spite of the widespread loss of its historic sites and the dramatic transformation of former steel-making districts. There is great potential to reveal the British contribution to the origins of the modern industry, and to further promote the heritage of the present-day steel industry. The heritage aspects of the later steel industry are largely a new subject, however, which requires original research and investigation. The buildings and structures differ considerably from earlier periods, and much of the terminology is specialised and unfamiliar to a public audience. Previous work has understandably concentrated on the formative crucible steel industry in Sheffield, and historical publications are biased towards the technical and economic aspects. English Heritage's Monuments Protection Programme assessments and other archaeological work has also focussed on the earlier stages of the iron industry.

Given the extensive demolition of the steel industry, further research will emphasise documentary evidence, but with potential for on-site investigation. Relevant collections, including photographs, exist in several libraries and archives, including Sheffield Library and the British Steel Collection (which is focussed on companies in the north east). Existing plans and drawings may be used in place of new measured surveys. Recently developed 3D scanning techniques could also be usefully employed in some cases, although it should be noted that steel industry structures are more complex and challenging for these techniques than other types of historic buildings. At intact sites emphasis would be given to photographic recording, with resourcing appropriate to large, hazardous and poorly-lit buildings (for reasons of health and safety this needs more than one photographer). At working sites the potential of video recording of steelmaking processes should also be considered. Air photography has been of great value for this report and provides the best way of illustrating the huge structures of the industry and their impact on the landscape.

Any further fieldwork should prioritise areas which retain extant sites. A useful extension of previous EH/RCHME work, for example, might be to assess a wider area to the north, east and south of Sheffield, while adding later periods to the previous recording. This study area would give good coverage of the late 19th century transition from iron- to steel-making, and include working sites in Rotherham and Scunthorpe. The North East also merits further urgent recording, with Teesside in particular retaining important working sites including Lackenby, Skinningrove and the recently closed Redcar Blast Furnace.

Related subjects are of considerable interest and overlap with other Historic England priorities. Steel sites were associated with extensive infrastructure, such as railways and shipping terminals. Some had purpose-built housing, including garden suburbs such as Dormanstown on Teesside, while others had significant influence on the development of townscapes, for example at Sheffield, Barrow-in-Furness, Scunthorpe and Corby. Steel communities still retain strong connections with the industry. Oral history has already been undertaken in some areas but could shed further light on the human story and provide useful information about processes and equipment.

Archaeological potential

Steelworks buildings were often quickly demolished after closure but in some cases landscape evidence survives of both plant and buildings and is visible in aerial photography. The extent of archaeological survival is varied, however, and is less likely in urban areas which prioritise decontamination and regeneration. In areas such as the Black Country only the boundaries of the former steelworks are visible following redevelopment. In coastal and rural areas archaeological evidence can survive for decades after the buildings have been removed, good examples being the Workington steelworks, the original Redcar Iron Works (which is discernible alongside the later blast furnace site) and parts of the Skinningrove Steelworks.

Visible evidence at these sites includes the foundations of blast furnaces, gantries, stock buildings, rolling mills and railway infrastructure, all of which would have seen considerable alteration while the sites were in use. In view of the extensive demolition of the later steel industry, and its transition from the earlier iron industry, archaeological investigation may be a better way of recording site development than studies limited to extant buildings, most of which date from after 1950.

Archaeological investigation has made a major contribution to the understanding of the iron and crucible steel industries during the Industrial Revolution, complementing the documentary studies, including many publications on blast furnace sites, iron works and crucible steel works.[28] In addition, the Monuments Protection Programme (MPP) in the 1990s identified 467 sites of archaeological interest in the iron and steel industries, which was estimated to be about 5% of the total.[29] The MPP studies were mostly concerned with earlier periods.

Wider perceptions of the steel industry

In the 18th century the early iron industry was perceived as both dramatic and awe-inspiring, as was reflected in literature and painting, but the impact of the late 19th century steel industry seems to have been less immediate, possibly because it was perceived as a development of the iron industry. The new techniques were frequently reported in technical publications, however, and engravings of the well-publicised demonstrations featured in newspapers and magazines. From the early 20th century the steel industry was covered by a wide variety of media which adds greatly to the range of research material. Company literature and publicity included books, leaflets, films, photography and in some cases paintings, provide a useful insight into the functioning of steelworks which is lacking in academic studies. Notable examples, which exude confidence in the industry, include the Dorman-Long film ***Steel Strides Ahead*** (1960), about the Lackenby steelworks, along with other restored steel industry films at the British Film Institute, and an article in ***New Scientist*** (1964) about the innovative use of computers to control steelmaking at a site in Rotherham. In the last two decades digital media have become a major source on both the decline of the industry and the latest technical developments. This includes websites and blogs created by former steel workers, which are often the main source of images of demolished steelworks (see attached list). Perceptions in the mainstream media have changed notably in recent years, often referring to the historic nature of the industry. News coverage is largely empathic, using images of blast furnaces and other iconic structures to promote concern for the future of a historic industry and its workforce.

International recognition of steel industry heritage

The later iron and steel industries have received more attention abroad than in Britain, with a variety of conservation schemes making effective use of the dramatic structures and large interior spaces. In Germany the Thyssen company's blast furnaces and related buildings, which were connected to a nearby steelworks, have been preserved and converted into Landshaftspark Duisberg-Nord, a visitor attraction and venues for art and music. In Mexico parts of two blast furnaces, a hot blast system, casting shops and other steelmaking equipment have been creatively displayed at Fundidora Park, the site of the former Monterrey Steel Foundry Company (Figure 12). In The USA the historic Carrie Blast Furnaces in Pennsylvania were recorded in the late 1980s, included in the Rivers of Steel National Heritage Area in 1996 and designated a National Historic Landmark in 2006; a programme for their interpretation and conservation is being developed. In England, most of the designation and conservation has focussed on listing the buildings of the Sheffield crucible industry and scheduling the archaeological evidence of the early iron industry. In both cases conservation and interpretation has directly resulted from designation. In contrast, in Britain the later bulk steel industry has seen extensive losses, but little recording or designation.

Figure 12. Restored blast furnaces and hot blast stoves at Fundidora Park, Mexico, site of the former Monterray Steel Foundry Company (www.parquefundidora.org)

REGIONAL DEVELOPMENT IN THE STEEL INDUSTRY

Steelmaking and related industries were found in most of the industrial regions but with concentrations around the West Midlands, the Sheffield area, the North East and the North West, although some well-known sites were located outside these areas. Steel had a similar overall distribution to the 19th century iron industry. Iron was established in areas with access to coal, iron ore and water power, expanding into new areas from the late 18th century as steam replaced water power. Steam power also enabled the iron industry to be more closely associated with urban development. The formative cementation and crucible steel industry largely remained in the Sheffield area. Areas associated with bulk steel often retained strong historical connections with the earlier iron industry, but in general only the larger iron firms survived the conversion to steelmaking.

The North East

In the mid- to late 19th century the North East developed an extensive iron industry, mostly located around Teesside, Wearside, Tyneside and adjoining areas, which was closely related to the iron ore mining, heavy engineering and shipbuilding industries. The industry was converting to bulk steel by the early 1890s, when the region accounted for 41% of the world's new shipbuilding. Steel production was mainly concentrated in Teesside and Tyneside. The region had strong historical continuity with the earlier iron industry, including a medieval industry in the Cleveland Hills south of Teesside. In addition, by the 18th century much of the Scandinavian wrought iron used in the Sheffield industry was imported via the North East ports.

The dramatic industrial development of Teesside began with the construction of the new harbour and planned town of Middlesbrough in 1830, with an iron works and shipyard added about a decade later. By the late 1840s the discovery of iron ore deposits led to a dramatic expansion of iron and related industries, as about 80 new mines opened to the south of Teesside.[30] Iron and later steel industries completely dominated the area, notably in the Iron Master's District adjoining Middlesbrough. Hartlepool also developed important iron, steel and shipbuilding industries, with iron steel and mining in Stockton. By the end of the century Teesside was one of the main iron-producing areas in the world, including around one hundred blast furnaces. From the mid-20th century the industry used imported ore and consolidated into a small number of large firms, most located closer to Redcar to the east. In the Newcastle area, Tyneside's shipbuilding industry was the largest in the region, including some yards which combined shipbuilding with iron and steelmaking, but without the very large integrated iron and steel works that developed on Teesside.

The North East has seen extensive demolition of steel and related industries but the few survivors include some of the best-preserved, and rarest, mid- and late 20th century sites in the country. The impact of the industry is still clearly visible in the Teesside landscape. As in other regions, sites have only survived because they are in use or closed recently. The Redcar Blast Furnace, commissioned in 1978 on the site previously occupied by a former Dorman Long steelworks (c1920) and the

Redcar Iron Works (c1878), survives completely intact with its ancillary buildings and infrastructure; survival of disused steel industry features on this scale is highly unusual.[31] It remains a dramatic monument to the Teesside steel industry and was the largest blast furnace in Europe when built. The nearby Lackenby steelworks, still in use under the current British Steel, dates from the early 1950s when it represented a confident expansion of Dorman Long with Open Hearth steelmaking, rolling mills and shipping facilities. Its buildings and technology were clearly distinguished from those associated with the steel industry just a decade later.

The Sheffield area

From the mid-18th to the mid-19th century the formative cementation and crucible steel industry, with associated manufacturing, was concentrated in Sheffield, but the late 19th century expansion of the bulk steel industry mainly took place in the adjoining areas to the north, east and south. This "greater Sheffield" region, which included Stocksbridge, Penistone and Rotherham, now retains the largest number of intact features of the later steel industry, complementing the well-preserved evidence of the earlier industry in Sheffield itself. Several sites are producing recycled steel or concentrating on special steel alloys, with associated rolling mills, notably at Stocksbridge, Aldwarke and the Brinsworth Strip Mill at Rotherham. The latter is located close to the Magna Centre, the preserved electric-arc melt shop of the former Templeborough Works. The Sheffield steel industry is well covered by a range of academic studies, most concentrating on its origins and early development.[32]

The Black Country

The Black Country, comprising the districts of Dudley, Sandwell, Walsall and Wolverhampton, included several major functioning steelworks up to the late 20th century. None are extant, but the area also includes a large number of former steel and iron sites that are still occupied by engineering firms. The Black Country's extensive iron industry expanded from the late 18th century with the introduction of steam power. It contained far fewer water power sites than earlier iron districts, such as adjoining Shropshire. The local industry was associated with a number of the innovative early iron masters and developed strong connections with iron industries in other regions.[33] All the later bulk steel sites were extensions of earlier ironworks. Most of the engineering sites were rebuilt in the mid- to late 20th century, typically with late 20th century wide-span metal-clad structures and only partial survival of earlier features; this is similar to the later development of many sites in Sheffield. A search of the combined HER and archives database suggested just over 100 sites in the area were formerly related to the steel industry.[34] The later integrated steelworks were nationalised under the British Steel Corporation until demolition in the 1980s, including the famous Bilston and Round Oak Works. Other notable steelworks in adjoining parts of the Midlands included Shelton near Stoke on Trent, finally demolished in the 1990s. From the 1970s BSC emphasised investment in steelmaking in other regions, eventually leading to the closure of the industry in the West Midlands.

The North West

The steel industry in the North West was more dispersed than in other regions but included some of the most significant early bulk steelmaking sites and was strongly connected with other industries, notably iron ore mining, railways and shipbuilding. The earlier iron industry, from which it developed, was widespread and was associated with the development of successful engineering industries in the main towns, and with the important formative iron industry in South Lakeland. It is unlikely that any of the region's bulk steelmaking sites retain extant buildings. The iron industry has seen similar extensive demolition, but has been the subject of more archaeological investigation. The largest and best known steelmaking site was the Barrow Haematite Steel Company, built as an extension to an adjoining ironworks in 1864 to concentrate on the production of steel rails from locally-mined ore.[35] By 1871 it was claimed to be the largest steelworks in the world, with fourteen blast furnaces and eighteen Bessemer converters, but it later suffered from competition from the expanding steel industry in the USA. The steelworks, and nearby shipyard, were closely associated with the dramatic growth of Barrow in Furness in the late 19th century. Three other steelworks were located in the Workington area but only one, the former ironworks at Distington, retains extant buildings.

Liverpool and Birkenhead both had iron and steel works associated with shipbuilding by the late 19th century. The Birkenhead site was established by the firm of William Laird in the 1820s, which merged with the Sheffield steelmaker Johnson Cammell in c1900 to form the integrated steelmaking and shipbuilding business Cammell Laird. The shipyard is still in use. The Manchester area included a steel engineering works at Ardwick and two rare examples of purpose-built early 20th century integrated steelworks, at Trafford Park and Patricroft, all demolished.

Steelworks in other areas

A number of significant steelworks were established outside the main areas described above. In North Lincolnshire the Scunthorpe steelworks originated as an open cast ore mine in the mid-19th century which was occupied by five ironworks by the 1870s.[36] These were later consolidated into the Appleby-Frodingham Steel Company which was nationalised under the British Steel Corporation in 1969. The huge site now has two owners and remains the last working integrated steelworks in England. The Corby steelworks in Lincolnshire was an early 1930s expansion of an earlier iron works, also located close to an iron ore mine.[37] Its blast furnaces have been removed but most of the other parts of the extensive site remain in use for the manufacture of steel tubes. In Kent, the Sheerness Steel Works, built c1972 as Britain's first mini mill, was demolished in 2016 following rapid recording by Historic England.[38]

ENDNOTES

1 Gale 1969, 3-7
2 Barraclough 1990 2-5
3 In 1850 national steel production was about 50,000 tons pa and wrought iron about 2million tons; Barraclough 1990, 16
4 *Ryland's Iron, Steel and Tin-Plate Trades' Directory*, 1881, reproduced in www.gracesguide.co.uk
5 Developments in wrought iron summarised from Gale 1969, chapter 4
6 Early structural uses of cast-iron summarised in Giles and Williams, 2015
7 Barraclough 1990, 3-5
8 Vaizey 1974, 8
9 9 Vaizey 1974, 11: Kenyon 2015, 61
10 Vaizey 1974, 181
11 Vaizey 1974, 51; a government committee in 1929 recommended that the industry be consolidated into just six integrated firms.
12 Wray, Hawkins and Giles, 2001; Barraclough 1976, *Sheffield Steel...*
13 This brief summary of steel processes is based on the detailed accounts in Gale 1969, chapters 2-7, and Barraclough 1990, chapter 2.
14 One example was at Lackenby Iron Works, Teesside: Hill, Alfred C., 1872, On the working of the improved compound-cylinder blowing engines and Howard Boilers at the Lackenby Iron Works, Middlesbrough, *Proceedings of the Institute of Mechanical Engineers*, 1872, p279
15 Belford 2012, 33-5
16 Gale 1969, 75
17 Wakelin 2011, 44; Williams 1983, 38
18 Barraclough 1990, 67
19 Gale 1969, 76-77
20 The development of the process is described in detail in Barraclough 1990, 206-212
21 A notable example was the new Dorman Long Steelworks built at Lackenby c1954
22 Gale 1969, 99-101
23 Henderson and Royall 2015, 86-87
24 Williams 1983, 36
25 Vaizey 1974, 1, 14
26 Wray, Hawkins and Giles 2001
27 Pullen 2010
28 Examples include Bowden 2000; Belford 2007; Hart 1971; Crossley 1990; Cleere and Crossley 1995
29 Chitty and Edwards 2005, 65
30 North 1975, 17-19; Heggie 2013, 3-6
31 Morris 2012, 2, 8-23
32 Examples include Barraclough 1976; Wray, Hawkins and Giles, 2001
33 Gale 1969, Chapter 4 "Wrought Iron Ascendant 1800-1860" includes numerous examples
34 Database searched at http://blackcountryhistory.org/
35 On Barrow steelworks see Henderson and Royall, 2015
36 Vaizey 1974, 42; Scunthorpe Museum and Art Gallery, 1974, *The Heavens Reflect Our Labours...*
37 Vaizey 1974, 72-5
38 Williams 2016

SELECTED SITES

Steel industry site types

Steel is associated with a wide range of manufacturing, engineering and construction industries, and this is reflected in the diversity of steelmaking sites. From the end of the 19th century most bulk steelmaking was associated with distinctive integrated complexes, many developed from former ironworks. No typical examples remain intact, but documentary evidence indicates that they contained specific types of buildings and structures in which external form strongly reflected internal function. By the mid-20th century, however, steelmaking was often combined with other industries. Shipbuilding and heavy engineering included rolling, forging and other processes that were previously associated with iron or steelworks. Steelmaking became associated with a wider range of processes and was increasingly housed in very large metal-clad buildings, similar to those used in other industries. The definition of a steelmaking site became less clear, and firms that combined steelmaking with other activities eventually outnumbered those that concentrated on steelmaking alone.

For the purpose of an overview, and any further research, the fifty seven selected sites in this list could be placed in five general types based on function and the degree of integration. With the exception of type 3, very few sites remained in a single type throughout their history.

> Fully-integrated steel making (all stages from raw materials to industrial products: the main form of bulk steelmaking from the late 19th to the late 20th century).
>
> Part-integrated steel making (where stages are separated, or some are omitted; includes making special steels from the late 19th century and sites built specifically for recycling scrap, mostly from the mid- 20th century)
>
> Crucible and cementation steel making / manufacturing (covered in the Sheffield project so mostly excluded from this overview)
>
> Steel engineering (ie using steel, not making it; includes firms involved with rolling, forging or making special steels. Includes former steelmaking sites.)
>
> Steel manufacturing / engineering (a large number of firms use steel for manufacturing. Excluded from the overview unless the buildings were formerly used for steelmaking.

NORTH EAST:

Redcar Blast Furnace, Redcar and Cleveland, NZ 56595 25809. Extant

HE 28836_058, 19-11-2015

HE 28836_010, 19-11-2015

Lackenby Steelworks, Redcar and Cleveland, NZ 55781 22024. Extant

HE 28931_059, 23-9-2016

HE 28931_095, 23-9-2016

Skinningrove Steelworks, Redcar and Cleveland, NZ 70802 19642. Extant

HE 28931_017, 23-9-16

Britain From Above EAW033936, 1950

Hartlepool north tube works, Hartlepool, NZ 50746 28969. Extant

HE 28932_039, 23-9-2016

Hartlepool south tube works, Hartlepool, NZ 50506 27895. Extant

HE 28932_022, 23-9-2014

Palmers Shipbuilding and Iron Works, Jarrow, South Tyneside, NZ 32743 65728

HE 28947_069, 4-8-2017

Britain From Above EAW047887, 1952

Consett Iron Works County Durham, NZ 10034 50489

(Left) Britain From Above EPW026588, 1929

See Figure 7: HE ff98_00252 Eric de Mare collection, nd

Derwentcote Steel Furnace, County Durham, NZ 13045 56504. Extant

(Above) HE 28950_001, 4-8-2017

(Right) HE j910335, 30-8-2005

Seaton Carew Iron Works, Hartlepool, NZ 51625 30861

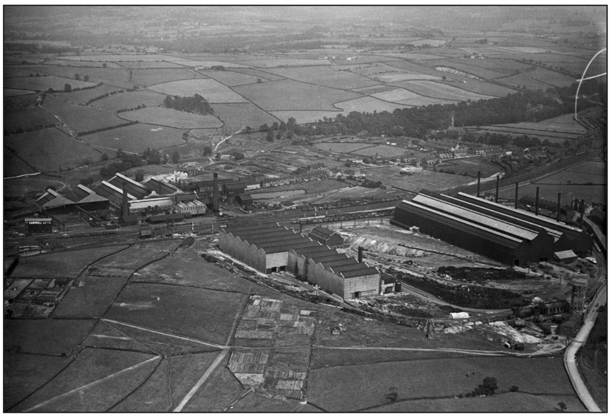
Britain From Above EPW049489, 1935

Newburn Steel Works, Newcastle upon Tyne, NZ 17049 65251

No image available

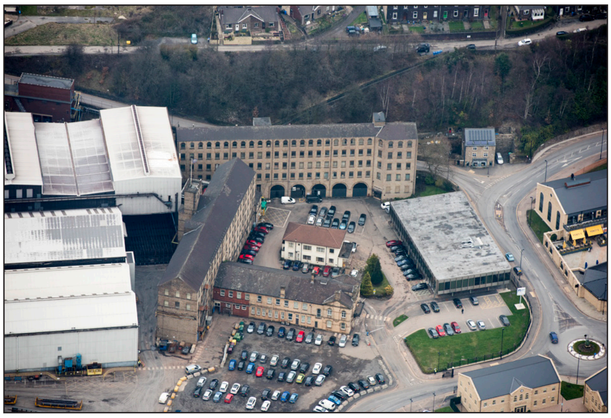
SHEFFIELD AREA:

Yorkshire Steel and Iron Works, Penistone, Barnsley, SE 25308 03194



Britain From Above EPW016280, 1926

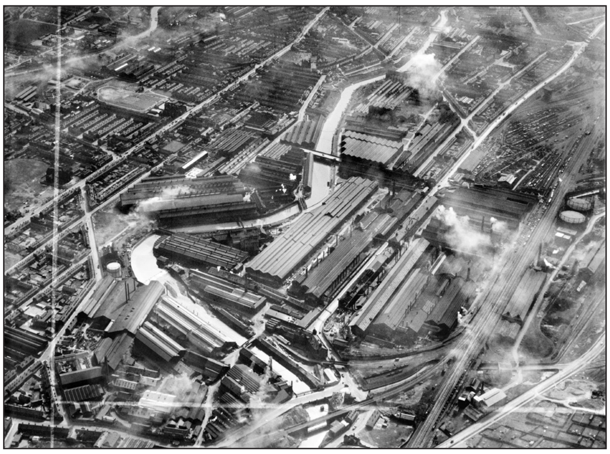
Stocksbridge Works, Stocksbridge, Sheffield, SK 27048 98676. Extant



HE 28987_006, 22-3-2018

HE 28987_009, 22-3-2018

River Don Works, Sheffield, SK 38350 90107



Britain From Above EAW022027, 1949

Insignia Works, Sheffield, SK 34756 88550

No image available

Templeborough Works, Magna Science Centre, Rotherham, SK 40800 91547. Extant

HE 28941_023, 5-5-2017

Britain From Above, EPW041704, 1933

Brinsworth Strip Mill, Rotherham, SK 40952 91280. Extant

HE 28941_019, 5-5-2017

Thrybergh main works, Rotherham, SK 44873 95080. Extant

HE 28936_030, 31-3-2017

Thrybergh Bar Mill, Rotherham, SK 45698 95049. Extant

HE 28936_019, 31-3-2017

Cyclops Works, Sheffield, SK 36430 88492. Extant

No image available (for similar sites see Wray, Hawkins and Giles, 2001)

SMACC Melting Shop, Sheffield, SK 40369 89162. Extant

No image available

Roundwood Processing Centre, Rotherham, SK 44968 96137. Extant

HE 28936_021, 31-3-2017 (top)

THE BLACK COUNTRY AREA

Staffordshire Steel and Iron Works, Bilston, Wolverhampton, SO 93893 95832

Britain From Above EPW015207, 1926

Round Oak Works, Brierley Hill, Dudley, SO 92311 87559

Britain From Above EAW008343, 1947

Shelton Iron and Steel Works, Stoke-On-Trent, SJ 87557 47771

No image available

Osier Bed Iron and Steel Works, Wolverhampton, SO 92448 98722. Extant

No image available

Etruria Steel Works, Stoke-On-Trent, SJ 86729 47578

Britain From Above EPW020019, 1927

Corngreaves Iron Works, Cradley Heath, Sandwell, SO 94742 85361. Extant (part)

HE 29974_061, 15-8-2016

Albion Strip Mill, Sandwell, SO 98884 90826. Extant

HE 29975_016, 15-8-2016

Phoenix Steel Tube Works, West Bromwich, Sandwell, SO 98764 92101. Extant

HE 29976_026, 15-8-2016

Birchills Iron Works, Walsall, SP 00616 99501

No image available

Brunswick Works, Wednesbury, Sandwell, SO 98001 94813

Britain From Above EPW011876, 1924. Brunswick Wks centre, Monway Wks top

Monway Iron and Steel Works, Wednesbury, Sandwell, SO 97676 95015

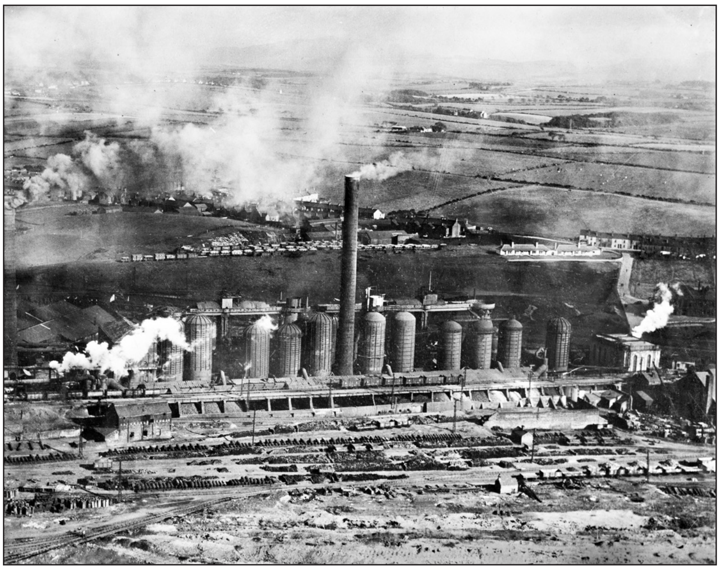
No image available

Monmer Lane Iron Works, Walsall, SO 96645 99473

No image available

THE NORTH WEST:

Mossbay / Derwent Iron and Steel Works, Workington, Cumbria, NX 98783 27219



Britain From Above, EPW052115, 1936

Oldside Iron and Steel Works, Workington, Cumbria, NX 99515 29789

No image available

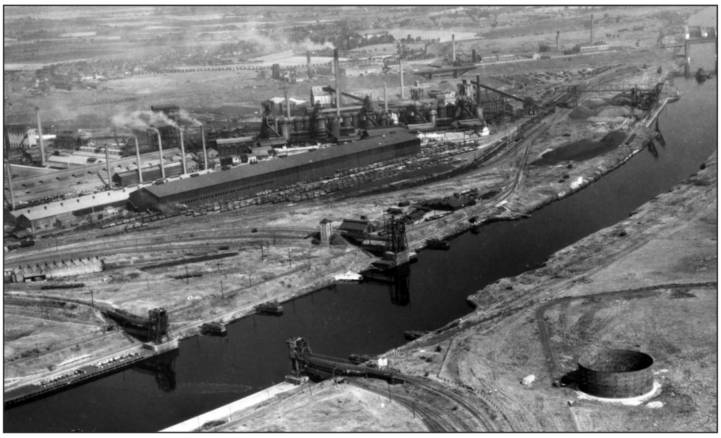
Barrow Haematite Iron and Steel Works, Barrow-in-Furness, Cumbria, SD 18936 69954

Britain From Above EPW004059, 1920

Mersey Steel and Ironworks, Toxteth, Liverpool, SJ 35311 87831

No image available

Partington Steel and Iron Works, Irlam, Salford, Greater Manchester, SJ 71867 92747



Britain From Above EAW009437, 1947

Trafford Park Steel Works, Trafford, Greater Manchester, SJ 78042 97015

Britain From Above EPW027481, 1929

Bolton Iron and Steel Works, Bolton, Greater Manchester, SD 71410 09002

No image available

Pendleton Iron Works, Salford, Greater Manchester, SJ 81568 99528

No image available

Pearson and Knowles, Warrington, SJ 59153 87591

No image available

North Street Works, Openshaw, Manchester, SJ 87977 97911

Britain From Above EAW022088, 1949

STEELWORKS IN OTHER AREAS:

West Yorkshire

Pressed Steel Works, Hunslet, Leeds, SE 30845 32468

No image available

Leeds Steel Works, Hunslet, Leeds, SE 31339 31114

No image available

Coghlan and Dury, Hunslet Forge, Leeds, SE 32050 31297

No image available

Midlands

Butterley Iron Works, Ripley, Derbyshire, SK 40136 51591

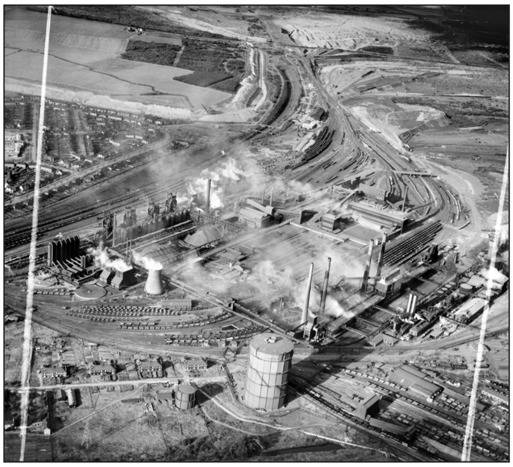
No image available

Crewe Works, Crewe, Cheshire, SJ 69315 55918. Extant

EH 33126_006, 26-5-2017

Corby steel works, Corby, SP 90426 89393. Extant

HE 29982_009, 15-8-2016



Britain From Above EAW034118, 1950

Scunthorpe main works, North Lincolnshire, SE 92201 09923. Extant

HE 28843_067, 13-1-2016

HE 28843_047, 13-1-2016

Scunthorpe bar mill, North Lincolnshire, SE 91179 10401. Extant

HE 28842_027, 13-1-2016

Scunthorpe, Normanby Park works, North Lincolnshire SE 88956 13434

Britain From Above EAW028583, 1950

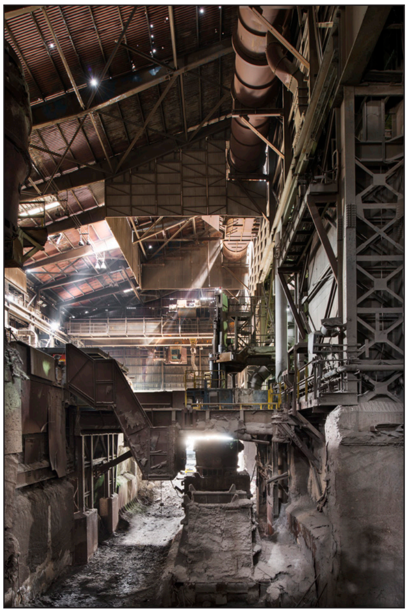
Britain From Above EAW028564, 1950

South of England

Sheerness Steel Works, Sheerness, Kent, TQ 91390 74772

HE 29841_008, 20-4-2016

HE DP181826, 20-7-2016



HE DP181929, 21-7-2016

HE DP181928, 21-7-2016

Darkhill Iron Works, Coleford, Forest of Dean, SO 59019 08838

No image available

Titanic Steelworks Coleford, Forest of Dean, SO 58780 08898

No image available

Bristol Rolling Works, Bristol, ST 60438 72537

No image available

Mells Steel and Iron Works, Frome, Somerset, ST 73896 48880

No image available

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GLOSSARY OF TECHNICAL TERMS

Bag House	External structure for processing the waste gases from a furnace, and extracting solid by-products, using a system of hanging textile tubes, fans and hoppers
Bar iron	Widely-used term for wrought iron, pre-dating the bulk steel industry but still used
Bar Mill	a: The sequence of rolling stands (typically roughing, intermediate, finishing), cutting shears and cooling bed, often arranged in-line, for making long products from steel billets or ingots. b: A building containing rolling machinery for long products. Also known as a Rolling Mill.
Basic steelmaking	Part of the Gilchrist-Thomas innovation in bulk steelmaking in the late 19th century: Bessemer converters were lined with limestone material (which is chemically *basic*) to enable steelmaking with iron made from phosphorous-rich ores.
Basic Oxygen Steel	Mid-20th century development of basic steelmaking, in which manufactured oxygen is blown onto pig iron through a water-cooled lance.
Basket	Large steel buckets with a “clam shell” opening base, for transferring sorted scrap to a furnace using overhead cranes (term in use at Sheerness steelworks)
Bessemer process	The first bulk-steel process, patented by Henry Bessemer in 1856. Air and steam were pumped into molten pig iron in a Bessemer converter, causing a reaction which decarburised the iron.
Billet	Long, straight steel bars produced in the continuous-casting process; typically 127 or 150mm square and 12m long. Used for making long products or rod.
Blast furnace	The most widely-used and economic method of producing pig-iron from iron ore
Blast main	Heavily-constructed pipe for delivering the hot blast to a blast furnace.
Bloom (in steel industry)	The first stage of rolling cast-steel ingots into long products, carried out in a heavy rolling stand sometimes referred to as a primary mill or cogging mill.
Bloom (in early iron industry)	Partially-smelted iron produced in bloomery furnaces in the early iron industry. Converted to wrought iron by forging.

Burden	The ratio of coke to ore used in charging a blast furnace (Gale, 27); also a general term for the ore component of a blast furnace charge.
Bustle pipe	Annular external pipe enclosing the lower part of a blast furnace, delivering hot blast from the blast main to the tuyeres
Bosh (blast furnace)	The tapered part of a blast furnace interior, in which the diameter reduces from its widest point to its narrowest at the level of the tuyeres
Bosh (forging)	Water trough, eg for cooling tools used at a puddling furnace or forge
Calcining kiln	1. Kiln used for preparation of iron ore by roasting, thus removing moisture and impurities, prior to smelting in a blast furnace. 2. Vertical kiln for conversion of limestone into lime.
Carbon steel	Types of steel in which carbon is the main alloy; other types of steel are alloyed with additional metals or elements
Casting Bay	Area within a Melt Shop or steelmaking plant where steel was tapped into ladles or teemed into ingot moulds (eg at Sheerness Steel Works)
Charge	The combination of prepared raw materials that are fed into a blast furnace; also a general term for the insertion of raw materials into any type of furnace.
Charging (a furnace)	Filling a furnace with iron, scrap, flux and other additives prior to smelting
Cogging Mill	Heavy rolling machine, the first stage in the rolling of steel ingots. Introduced in the 1860s, replacing the steam hammers used previously
Coke	Fuel used in blast furnaces from the early 18th century. By the mid-20th century specific types of coke were made with properties suited for use in large blast furnaces, including high strength and permeability
Cold blast	Air supplied to the hot blast system, pumped by steam or electric power
Cold short iron	Wrought iron which is brittle and cannot be worked when cold, typically because it contains phosphorous
Concast	The trade name of a manufacturer of continuous casting equipment
Continuous casting	Technique for producing continuous strands of steel, replacing casting into ingot moulds, introduced from the late 1940s. Liquid steel is passed through copper

	moulds, water-cooled in a spray chamber and rolled into billets or slabs.
Cooling bed	Large grid of transverse steel beams with a saw-tooth upper edge for cooling long products without distortion. Can be 100 m long, usually sited at the end of a continuous rolling mill. Most common type is the walking-beam bed, where the product is moved across the bed as it cools by the movement of the transverse beams.
Cowper stove / tank	A widely-used system for generating hot blast, comprising vertical tanks heated by gas burners, which utilises gas obtained from the exhaust of a blast furnace. Patented by Edward Cowper in 1857.
Crucible steelworks	A compact site in which the cementation and crucible steelmaking processes were combined with workshops or factory buildings, often for the production of consumer goods. The characteristic steelworks of the Sheffield cutlery and metalworking trades.
Downcomer	Long, angled pipe for furnace gas (waste gases), running from the top of a blast furnace to a gas-processing plant
Electric Arc Furnace	Cylindrical furnace with a steel shell and refractory lining, in which an electric arc emitted from carbon electrodes passes through the charge, causing it to melt. Developed in the 1880s and 90s, notably by Paul Heroult in France. Increasingly used for scrap and special steels from the mid-20th century.
Finer’s metal	Type of cast iron produced in an intermediate stage in puddling process, introduced c1790. Prior to puddling, the pig iron was melted in an oxidising environment and then quenched. This greatly improved the quantity and quality of the wrought iron which was produced by puddling.
Gantry	Long rectangular structure to support elevated rail tracks above a series of bunkers for ironstone, coke, limestone etc. Materials were dropped directly into bunkers from wagons. Usually located close to blast furnaces and calcining kilns.
Gooseneck	Jointed air pipe connecting the hot blast main to the tuyeres of a blast furnace
Hot blast	The pre-heated air supply fed into a blast furnace. Large-scale plant, often including Cowper stoves, heated the blast up to around 1000 degrees C.
Hot short iron	Wrought iron which breaks up and cannot be worked when red hot, typically because it contains sulphur

Induction furnace	A furnace in which the charge is melted by electromagnetic induction. The most common type is the coreless furnace, in which a crucible containing the charge is enclosed by a copper coil. High voltage alternating current induces a voltage in the charge, producing both heat and a magnetic field which stirs the melt. Used for steelmaking from the first decade of the 20^{th} century.
Ingot	Rectangular block of cast steel, the initial output of a steelmaking plant shop before the introduction of continuous casting
Integrated steelworks	A large complex carrying out the full range of steelmaking processes from the raw materials to a wide range of long, flat or round products. Includes blast furnaces, steelmaking plant, rolling mills and extensive support infrastructure.
Iron ore	The main raw material for iron and steel making. Varies greatly in chemistry and in the proportion of iron present. Low-grade ores, with around 50% iron content, were more widely used by the mid-20^{th} century, requiring preparation as pellets or sinter prior to use in a blast furnace.
Ladle	Circular tub for moving or hoisting large quantities of molten iron or steel, using trolleys on tracks or gantry cranes.
Ladle furnace	A heated ladle in which steel is analysed and adjusted prior to casting
Laying head	Alternative term for loop layer
LD process	Linz-Donawitz steel making, a development of the Basic Oxygen Steel process, named after the Austrian towns where it was made commercially viable in 1952-3
Long products	L-, U-, I-, H-, or flat-section bars, beams and other products made from rolled steel
Loop layer	Machine for converting straight rod into coiled rod
Melt Shop	Building containing furnaces for melting iron, steel or scrap, usually including related equipment for charging, handling hot metal and casting.
Merchant steel (or iron)	General-purpose steel or iron products, of flat, round or angled section, made to standard dimensions for sale to engineering or manufacturing firms.
Mini mill	A relatively compact type of steelworks, developed in the USA in the 1960s, using electric arc furnaces to melt scrap for rolling a narrower range of products than an integrated steelworks.

Open Hearth process	Developed by C.W. Siemens in the 1850s and 60s, and patented in 1867. A large reverberatory furnace using gas or oil as fuel, which utilised regeneration chambers containing a brick honeycomb to absorb exhaust heat. This was used to pre-heat the air flow from the burners, producing very high temperatures. Gradually replaced the Bessemer process in the early to mid-20th century.
Pellets	A preparation of iron ore prior to its use in a blast furnace, common by the late 20th century but less widely used than sinter. Used for low grade iron ores, with approximately 50% iron content, which are ground, separated and compressed into small marble-sized pellets. The burden might include both pellets and sinter.
Pickling	Application of hydrochloric acid to steel products to remove surface rust
Pig boiling	Development of the puddling process of making wrought iron, widespread from the 1820s; furnace slag containing iron oxide was incorporated into the molten iron, causing a reaction which removed carbon and impurities. Also known as wet puddling.
Pig iron	Iron produced in a blast furnace, the first stage of iron and steel making. High carbon content, typically above 4%.
Puddling process	Technique for converting pig iron into wrought iron using a reverberatory furnace, patented by Henry Cort in 1783-4.
Pulpit	Control room overlooking any part of a steelworks
Rebar construction	Reinforcing bar or rod, as used in concrete
Refining / Refinery	Term used for the re-heating and preparation of pig iron for the puddling process, from c1790. Involved melting in an oxidising environment, followed by quenching, to make ***white iron***. Used coke as a fuel instead of the charcoal used in the earlier finery.
Re-heat furnace	Gas or oil-powered furnace used for heating billets prior to rolling; usually sited between a billet store and a rolling mill
Roasting	Preparation of iron ore to remove moisture and impurities before smelting in a blast furnace; in a calcining kiln
Rod	Round steel products that are rolled from billets and finished in a rod mill, working at up to 94 metres per minute. Typically used for rebar, bolts, or drawn into wire.

Rod Mill	1: A building or wing dedicated to rod production 2: A train of machinery for rod finishing and coiling
Rolls	The pairs of steel rollers used in a Bar Mill, with flat or shaped surfaces to suit the products being rolled
Rolling Mill	Building containing equipment for making long products or sheet products. Sometimes given a more specific term, such as Bar Mill.
Rolling stand	Individual machine containing a set of horizontal or vertical rolls, electrically-driven. Arranged in groups along a Bar Mill or Rod Mill to carry out the roughing, intermediate and finishing stages.
Secondary steel making	The analysis and adjustment of molten steel, including alloying, to produce special steels. An intermediate stage between the steel furnace and casting plant.
Shear	Machinery used for the cutting (cross cut) or slitting (longitudinal cut) of rolled products, located at various stages in a Bar Mill, sheet mill, plate mill or rod mill.
Siemens-Martin process	A variation of the open-hearth process in which scrap was added to the charge, first used by Emile and Pierre Martin in France in 1863.
Sinter	A preparation of iron ore prior to its use in a blast furnace, commonly used by the late 20th century. Ground iron ores are blended with coke dust, fluxes and furnace dust and heated at over 1,000 degrees C in a sinter plant. Forms a clinker-type material which is charged into the furnace with coke and limestones. It reduces the quantity of coke needed and utilises waste materials. Sometimes combined with pellets.
Slab	A nominally rectangular-section billet, used for making sheet products
Soaking pit	Heated chamber or furnace used for conditioning steel ingots prior to rolling, invented by John Gjers at Darlington, c1870.
Spiegel (Spiegeleisen)	Type of manganese-rich pig iron produced in blast furnaces and used as an additive in Bessemer steelmaking. It helped remove phosphorous, sulphur and silica from the steel, while adding manganese. Its use was developed by Robert Mushet.
Strand	The length of semi-molten steel produced during continuous casting, prior to cutting into billets
Strip	Thin, flat steel, less than 0.2” thick and rolled to fine tolerances; when over 18” wide known as *wide strip*

Teeming	Pouring molten steel or iron from the base of a ladle into a mould
Tapping	Releasing the molten slag, steel or iron from the sides or base of a furnace
Torpedo	Heavily-constructed cylindrical railway carriage used for transporting molten iron from a blast furnace to a steel-making plant.
Tundish	Open vat for feeding molten steel into the moulds of a continuous caster. The steel is transferred to the tundish using ladles.
Turret	Massive rotating platform supporting ladles of molten steel at each end. Used to ensure that prepared steel is always available for the continuous casting plant.
Tuyere [***tweer***]	Water-cooled nozzle for directing hot-air blast into a blast furnace. In earlier furnaces tuyeres comprised clay cylinders with a perforated base, and were frequently replaced.
Universal rolling (or beam) mill	A mill or stand which rolls a steel product on the top, bottom and sides.
Uptakes	Prominent upright pipes used for extracting the waste gases from the top of a blast furnace. Connected to the downcomer.
Vacuum melting	Mid- to late 20th century technique for remelting and refining steel, typically using an induction furnace inside a vacuum chamber. Produces very pure steels and alloys for special applications (eg turbine blades), but increasingly used for bulk steel from the 1960s.
White iron	In L18/E19 iron industry, type of iron produced in a refinery prior to melting in a puddling furnace.






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