# British saw blades: the revolutionary transition from iron to steel in the 18th century

**Simon Barley**

*ABSTRACT: Saws for woodwork are a very ancient tool form, and the materials of their blades have been very little studied. This paper shows that although melted steels were known in London from about 1721, the introduction of Huntsman's crucible cast steel in Sheffield in the mid-18th century was a major factor in effecting a rapid and permanent change of saw-blade material from iron to steel. Using original business documents it is shown that Sheffield saw makers were closely tied to the new steel industry, the growth of which depended on the increasing number of firms. Many of them supervised the making of their own steel, thus enabling quality control. It seems likely that the early combination of these industries was a powerful factor in establishing Sheffield's long dominance of both.*

## Introduction

The saw is one of humankind's oldest tool forms. The earliest users, when faced with the need to cut materials of many kinds, realised that a jagged cutting edge was superior to a straight or smooth one. By the 17th century in Britain, the saw was a regular part of the tool kit of sawyers converting timber (often in a saw pit), carpenters (for heavy work, much of it outdoors), joiners (lighter work) and cabinet makers; the blades for all these workers' saws were normally wrought iron, and much less often steel. The difference in performance of the two metals was very marked, with steel blades more effective, but more expensive (Montgomery 1970). A change in the first choice of metal for all saw blades from iron to steel took place around the mid-18th century, a change that was rapid, comprehensive and permanent. This paper, using new evidence, examines the way the change happened, and some of the reasons for it. As the output of saws from British firms reached hundreds of thousands annually a century later, there can be no question of the importance of the material from which they were made.

The study of tools and their manufacture has attracted little attention from historians, mainly because there is so little primary evidence; most firms were small, often short-lived, their owners leaving few if any business records – if indeed they made any in the first place (Iles 1993, 62). This paper concentrates on one aspect of the manufacture of one tool, saws used by hand, and the material of the blades. Other tools, such as planes, hammers and wrenches, have been treated in detail by writers whose main interest has been in dating, describing and collecting; the most useful have paid some attention to other aspects, including materials. Files in their many forms are an exception to this paucity of notice; of all tools, they were those made in the largest numbers in the 19th century, the quantity reflecting their use in so many trades. Sheffield was the home of more than half of the nation's file makers (Lloyd 1913, appx 3); of the tool-making trades there, files always employed at least half of all those making tools – in 1787 30 out of 50, and in 1871 5,567 of 9,410 (Tweedale 2018,17). Files are also the only tools to have been given more detailed treatment, in Ashton's (1939) classic



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monograph; this work was made possible because the Warrington firm of Stubs left a large archive, an 18th century source not matched in connection with any other single tool. Positioned in the heart of the local Lancashire clock-making industry Peter Stubs and his descendants also made very large numbers of three-sided files (called '3-square' in the trade) for sharpening saws. This linkage of the saw and the file, along with the steel from which they were made, became in Sheffield the vital feature of all three industries.

Other tools have not been studied in Ashton's terms; the nearest approach being an unpublished thesis based around saw making (Barley 2008), which used documents left by the Sheffield saw manufacturer Joseph Wilson (1723-1796). This entrepreneur's purchases show the use of steel in saws in the second half of the 18th century, and are the main original source used in the section on steel-bladed saws below. Another important tool was the plantation hoe, an example used by Evans (2012) to consider its place in the Caribbean economy, and its links to the ferrous metal industries of Britain. As far as the manufacturing of tools in general is concerned, only Tweedale has improved the quality of analysis beyond the many firms' histories that are listed in the RCHM's list (1994), although his monumental Directory of Sheffield Tool Manufacturers 1740-2018 (Tweedale 2018) does not include the detail about materials which is found in his other works (Tweedale 1987; 1995). Systematic metallurgical study of tools and their materials during the last two or three centuries appears to be almost completely absent from the pages of Historical Metallurgy. Much has been written about the production of iron in Britain, but pigs and bars of iron were not generally consumer products; as King remarked, 'Far less has been written about the more elusive secondary trades, the manufacturing of iron and steel into useful artefacts' (King 2007, 124).

A good summary of the historiography of tools and their manufacture has to go back to Ashton's words: 'No systematic study… has yet been made of the trades which supplied the new race of artisans and factory workers with the tools without which the machine age could not have come into being' (1939, 1). His suggestion, not taken up, had to be repeated in almost the same words half a century later by Harris (1985, 27). There is still a place for answers to Ashton and Harris, some of which this paper aims to provide; only the material of a critically important tool, the saw blade, will be considered, and the reasons for the change from iron for making it to the new steels of the 18th century, made chiefly in Sheffield.

What follows is in four parts. The first describes ferrous-metal saw blades up to the late 17th century, and what is known of their manufacture and performance in use. The second selects some extant examples of iron and steel blades to consider in greater detail where and how they were made, and the third describes the inception of the Sheffield saw trade and its influence on the development of the early crucible-steel industry. The conclusion suggests that saw manufacture was a decisive factor driving Sheffield's long and world-wide domination of that branch of the steel industry.

## Early iron-bladed saw making

The study of surviving saw blades is always difficult because the material was thin to begin with, wears away with use and sharpening, and when no longer useful as a saw the metal might be repurposed to make, for instance, a scraper or some other tool. It must also have been the case that when a better tool came along the first was simply scrapped. Museums world-wide contain examples, albeit usually fragmentary, of ferrous-metal saw blades from the Iron Age onwards; metallurgical analysis of some of them is in Tylecote and Gilmour's work (1986). The three Roman-period saw blades they analysed from Wanborough (Wiltshire) showed one to be a steel edge welded to iron, another iron hardened with phosphorus, and the third homogenous high carbon steel lightly tempered; they concluded that 'It would seem that the smiths took their saw blades seriously and tried to produce good blades within the limits of their technology' (*ibid*, 89). Similar analysis of later saw blades has not been found in the literature. Descriptions of the appearance of blades and handles are well treated in histories of woodworking tools (Goodman 1964; Mercer 2000) and of saws (Jones and Simons 1961); although these works are over half a century old, in descriptive terms they have not been superseded. A useful conspectus of English saws before the Industrial Revolution is by Ingraham (2014), which describes the form and variations of several kinds of saw, large and small. The material of his examples is not always specified and in most it must be assumed to be wrought iron, some of them case- or hammer-hardened, a few of some form of steel. Although Ingraham cites evidence of steel-bladed saws surviving in small numbers from the 17th and the first half of the 18th centuries, he could say little about the nature and provenance of their steels.

Saws over 200 years old that have survived in good condition (many useable) are almost entirely in the hands of private collectors, with a few in museums, apart from the very large number (over 2000 of all dates, most for the


This saw is iron (spark tested), and if tapped sharply gives a dull thud. The surface shows some rust pitting, and also the inherent roughness of iron, compared to steel. The blade is 560mm (22 inches) long, the tip being broken, and the struck mark is 19mm (0.76 inches) long. The timber of the handle is not known. Photographs courtesy of Edward Ingraham.

*Figure 1: Iron hand saw by R Jones c1720.*

woodworking trades) in the Ken Hawley Tool Collection at Kelham Island Industrial Museum, Sheffield (https://www.hawleytoolcollection.com/). The Science Museum in London has only one 18th century saw for woodwork, and from private information (mainly from correspondence) and from the website www.backsaw.net it is safe to say that world-wide, there are now probably no more than a few hundred that date from before 1800. Almost all of these early known saws were made in Sheffield, with a handful from London and Birmingham. Figures 1 and 2 show typical examples.

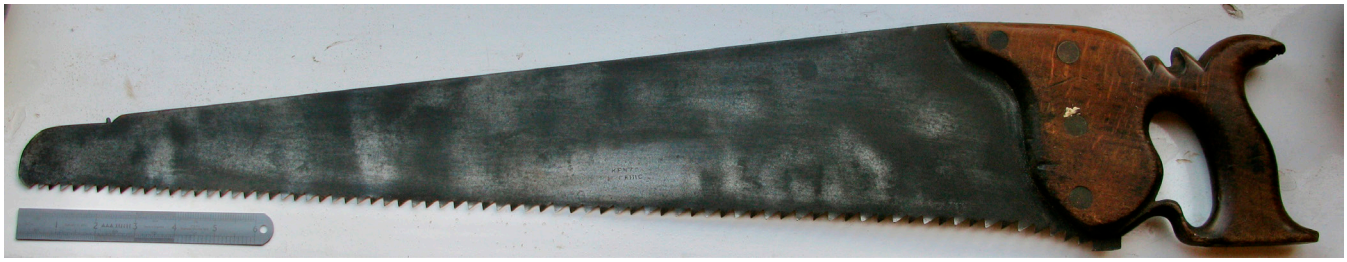
The growth of a saw-making industry in Britain can be traced from the 16th century, when saws as well as raw materials were coming into London from Europe (Dietz 1972), although again their materials are not known. Local smiths may have been producing saw blades at that time, and by the middle of the 17th century London contained the first recorded specialists; the provinces also were home to smiths whose trade had become sufficiently specialised for them to be known as saw makers (Riden 1985; Barley 2015). In his Mechanick Exercises, issued in parts from 1678 onwards, Joseph Moxon distinguished iron from steel saws, although the amount of steel available, and its price, made it a less common choice (Montgomery 1970). The iron-master George Sitwell employed a number of named saw makers in north Nottinghamshire; his letter books (Riden 1985) list large numbers of saws of several kinds being sent to London ironmongers and thence to the Caribbean. It seems very likely, chiefly from Sitwell's other output, that these saws were all iron-bladed. Without evidence to the contrary, it is also assumed that his saw makers were using the techniques of the time for the first stages of blade making: individual smiths, sometimes working in teams of up to four forgers together, flattened the iron or steel on an anvil, after which the teeth were punched out one at a time with dies of different sizes for various sizes of saw. This method is described by 18th century foreign observers of British industry such as Angerstein (Borg and Borg 2001) and Jars (1774). Part of the method was superseded by rolling the plate. In the West Midlands some rolling was done, but there is insufficient evidence to know how much was of iron or steel. When the industry began to be concentrated in Sheffield, the rolling of plate, which was soon all steel, became the norm, with some of the technology and skills for this process being transferred from the developing silver-plate industry. Earlier rolling for saws not far from Sheffield is mentioned in Sitwell's letters: in a lengthy agreement dated 1656 between himself and Thomas Tibbatts, a whitesmith of West Bromwich, to erect and operate a mill for slitting iron at Renishaw; a final sentence adds that Tibbatts would 'have liberty …to roll a ton of his own iron for saws in the rod mill and to convert and dispose of the same for his own proper use' (Riden

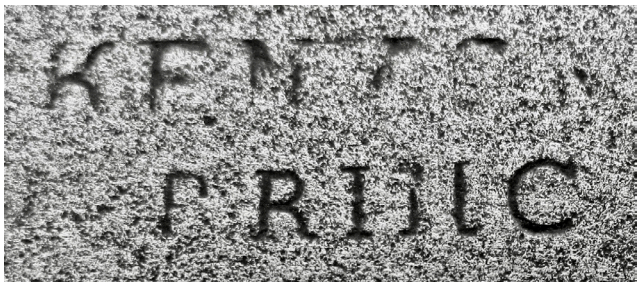
David La Touche, the purchaser of this saw and its donor to the Ken Hawley Collection Trust (Sheffield), thinks it probably came from a 'hard-luck farm' somewhere in the USA, where it had stayed for many years, used up, but not maintained; he has provided the following note, edited for publication:

… an unprepossessing saw with an owner-made handle, a lumpy mistreated blade, and something like a false nib filed in the centre of the top edge. Only 500mm (22 inches) of the original blade remains, with 43mm of it covered by the handle; it is 50mm wide at the toe and 130mm at the heel … The crude handle, of unknown timber, is secured to the blade by two fasteners. The top one is a castellated nut and bolt, which fell out of use around 1760, while the bottom one is simply a square headed nail hammered to function as a rivet … the single castellated fastener stayed together with this much abused saw for over 250 years. The dinged, poorly hammered and likely shortened blade provides little evidence of its original appearance. As far as measurements can determine from such a mistreated tool, the blade seems to have been taper ground, thicker at the tooth line and thinner at the back edge. The top edge is approximately 0.50mm thick at the handle and 0.44mm at the toe, while the tooth line is approximately 0.55mm at the handle and 0.48-0.50mm at the toe. A spark test on a part of the blade under the handle determined that the blade was of iron, not steel. The makers' mark is 35mm long; it is more deeply struck into the relatively softer iron than would be usual for a mark struck into a steel blade (cf Fig 3).

Photographs courtesy of David La Touche.

*Figure 2: Iron hand saw by Kenyons & Jones c1757.*





This saw has a steel blade 660mm (26 inches) long; the wording of the struck marks (probably made with two separate punches) is Kenyon and Spring (20mm long). The surface of the steel has retained much more polish than the iron saws would ever have had (photograph: Author).

*Figure 3: Steel hand saw by Kenyon c1790.*

1985, 277-8). There is no record that Tibbatts took up the offer. The word 'convert' is the term used to make steel from wrought iron, and its use here is a tantalising glimpse of a possible development: was Sitwell on the brink of starting to make his own steel at Renishaw?

In the end, the strongest evidence in favour of steel's superiority lies in the rapid and complete change from iron which was enabled by the virtues of the crucible cast material.

## The transition from iron to steel for saw blades

Seventeenth-century documentary evidence for the material of saw blades, much of it connected with the Atlantic trade, is found in invoices, letterbooks and inventories; Ingraham describes the stock of imported English manufactured goods maintained by Boston merchants of that time as 'formidable' (2014, 73). Instances of imports can be found in the probate inventory of 1677 of Edward Warton, a merchant of Salem, which includes six steel handsaws along with 12 others (presumably iron), the steel being three times as expensive as the iron (Dow 1988). Other inventories of the last decades of the 17th century from Port Royal, Jamaica, include saws of iron and steel, the last of them, dating to 1700, is notable for listing 'London' handsaws (Custer 2004). The use of the word London is ambiguous, and may refer to the quality of the saw, or to its geographical origin: this difficulty is discussed below in considering different qualities of steel used in saws. Nevertheless, by the late 17th century there were numerous named London saw makers, some known from the parish registers of St Giles, Cripplegate (Barley 2008). One firm, the White family, made at least some, perhaps most of its saws in steel, and is considered further below.

Something about the performance of these early saws can be learned from Moxon. In the late 17th century, steels of several sorts were available from different countries, and were evidently inconsistent and had differing applications. His conclusion (Montgomery 1970, 57) was that '…each Country produces almost indifferently good and bad [steel]; yet each Country doth not equally produce such Steel, as is fit for every particular purpose…' Having said that, he gave unequivocal advice (*ibid*, 96) about saw blades: 'Chuse those that are made of Steel'. He described the difference between iron and steel blades, emphasising the poorer performance of the former: being softer, and only hammer-hardened, the blade was more likely to bend and break, whereas the steel was generally harder, and ground bright and smooth. Figures 1-3, showing some of the difference in quality between iron and steel in saws of about the same period, partly confirm Moxon's opinion.

Although by the late 18th century Sheffield became the home of the British saw trade, its dominance was preceded by important developments in first London and then Birmingham. The most famous London firm was the Whites, whose earliest known member was working probably in the 1660s; from him descended generations of saw makers in the parish of St Giles, Cripplegate (Barley 2015). Their reputation stretched across the Atlantic, where both of the two surviving saws with their name were found: the blade material is unknown but is probably steel. White saws, which in documents are

usually the only ones singled out by brand, were named in advertisements (Gilliam 1997, 62) and in invoices, for instance to Colonel George Washington in 1759 and 1760 (Papers of George Washington 8, 299). The family's fame survived even after the last of them died in the 1750s, their saws appearing in the 1765 edition of Hoppus' *Practical Measuring* (1765), which incidentally also continued to list iron saws: an indication of their quality is given by the prices of 24 inch (610mm) hand saws per dozen – iron 16 shillings, steel 28 shillings and White's, available only singly, 78 shillings per dozen for the same size. It may well be, however, that Hoppus' information was a simple reprint and not up to date: the White family was by 1765 extinct, and steel was on the verge of becoming the material of choice for most saw blades.

Part of the reason for the high price of White's saws is known from the diary of a visiting Swedish industrial investigator in 1749 (Schröder 1748-1751; the translated text of part is given in Barley 2015). White used steel, made from iron sourced from Abraham Crowley's Newcastle establishments (Flinn 1962). The steel was 'welded or hardened two or three times … [until] it was all melted to one lump', then the pieces were hot forged 'to length, width and thickness', then 'cold forged to make them smooth and even'. Next, the teeth were cut and filed to shape, hardened and tempered and then 'in great secret, the master makes the same work himself in a large hearth in his cellar, and during which no-one else can be present'. Schröder emphasised that the superiority of White's saws over others he examined in Birmingham was found mainly in the steel being 'totally smelted again … before it is turned into a new piece' and because 'the blades are [re-]hardened and tempered'. This description seems consonant with the production of a remelted, *ie* crucible cast, steel such as Benjamin Huntsman was learning to make in Sheffield at about the same date. Other sources, such as Horne (1773), show that melted steel was well known in 18th century London where it was also being made in the St Giles, Cripplegate area; some reasons for the rapid failure of this steel manufacturing in the capital are discussed below.

Given the higher price in London of materials such as coal, and probably transport, labour and rents, the Whites' high prices were justified also by the amount of extra work put in – including, presumably, a premium for decades of reputation. The same pattern of price increases was applied in the 19th century by Sheffield saw makers, whose catalogues show that the more work put into the making of the steel of the blade, the higher the price. From the above description of White's saw production it appears that no rolling or grinding of the blades was done, although it is possible that the saw blades had been taken off site for grinding with horse, donkey or water power, without Schröder recording the fact. Spatial separation of manufacturing processes was common in both the West Midlands and Sheffield, and saws were not made at any time in Sheffield without grinding at one or more stages.

Early saw making in the Birmingham area is more difficult to describe, as there are few documents to draw on, apart from trade directories and some wills, and the single interview of one prominent maker by the same Swedish diarist Schröder (1748-1751). A few 18th-century steel-bladed saws survive but show no features apart from the maker's name to distinguish them from contemporaneous examples in London or Sheffield. The trade was not confined to the town itself, where about 20 named saw makers are recorded before 1800, a few of them continuing into the new century. To the west, where the amount of water power was usually sufficient only for blade mills, evidence of saw making is known from four sites, in Wednesbury, Kidderminster, Oldbury and the small village of Kinver on the river Stour (Dilworth 1976). Perhaps the area's most significant legacy lies in its exporting skilled saw makers to Sheffield from the 1750s.

It is clear that by mid-century saw-blades made from steel were a feature of the London industry. The White family were only one amongst a small number in their part of the city (Barley 2015), and there were family and doubtless commercial connections that would have been conduits for sharing knowledge and techniques. It is not therefore surprising to read (Evans and Withey 2012) that before Huntsman had begun regular production of his crucible steel, melted steel was being used in London as early as 1721; Schröder's description, which they cite, seems to be firm proof to add to these writers' instances. They directed their study mainly towards investigating the relationship between the development of steel and the Enlightenment, and most of their examples were from the worlds of fashion and consumption and the use of this new metal to make small objects that were 'a significant part of enlightened material culture … alongside objects of desire like Chinese porcelain, mahogany furniture and vibrantly coloured cottons …' (Evans and Withey 2012, 547). They mention the Whites' saw making, as well as the file-making in Warrington studied by Ashton (1939), but these are comments in passing; they aimed to define crucible steel in the context of 'high-end artisans working in steel … increasingly eager to badge

their wares as embodying enlightened ideals … [T]here was an enlightenment in steel, but it manifested itself in the design and marketing of goods rather than their manufacture' (Evans and Withey 2012, 534).

Evans and Withey displaced Benjamin Huntsman and Sheffield from what was for so long the pinnacle of early crucible-steel making. Production in London for well over 20 years before Huntsman even began to experiment may partly explain why he did not claim for himself the towering priority which 19th century writers like Samuel Smiles or metallurgists like Hadfield laid so firmly upon him. This re-positioning of Huntsman and his fellow townsmen can be modified by considering the amounts of steel used in saw making in the decades following the establishment of the Sheffield saw industry. Huntsman's significance can also be viewed by turning the focus of steel production more in the direction of tool manufacture, and away from the world of fashionable consumption.

## Steel saw-blade making in Sheffield

Sheffield's long history of producing metal wares needs no recapitulation here (Tweedale 1995; Pollard 1959; Lloyd 1913). For these writers, the town's industrial reputation rests chiefly on its steel and cutlery, with a third part – tools – being much less well known, although during the 19th century over half of Britain's tool production, and 90% of its files, were made in this one place. Tweedale (2018) has given a corrective steer to this bias with an overall view but the detailed history of the multiple different tool trades, each with its separate skills and traditions, remains largely unwritten, particularly for the early days in the 18th century. In spite of Sheffield City Libraries' archive material on the metal trades being so extensive and detailed, the documents to provide the necessary detailed analysis of making and selling files, hammers, edge tools, joiners' tools, planes, or engineering tools and a myriad of others are not available. The firms were extremely numerous, the great majority of them small, doing much of their business orally (Iles 1992); when they ceased operations, evidence of their existence, apart perhaps from family reminiscences or a name in a trade directory, almost always disappeared. However, one industry, saw making, does provide enough primary documentation to give a reasonably comprehensive account (Barley 2014).

Saw manufacture as a separately defined trade in Sheffield began in 1757 when two prosperous steel- and file-makers formed a partnership with a local businessman to bring a specialist saw maker from the West Midlands (SA: WC1552). The name of this saw maker, brought from Kidderminster, is worth celebrating, as he was the man who actually made the first saws in Sheffield in the first business to be set up for that purpose. Two saws only with his name struck on them survive. One is simply marked R Jones (Fig 1) and is made of iron. Ingraham has tentatively dated it from perhaps the 1720s (pers comm). If this attribution is correct, the saw dates from Jones' Kidderminster days. The second (Fig 2), also iron-bladed, is the only known one which shows the partners' names, adding Jones to the Kenyons. Its material shows that this nascent firm made at least one saw blade from iron, even though Jones had been hired to work in Sheffield, the growing new centre of steel making. The impetus for this development must, in the absence of documentation, be inferred as coming mainly from the influence of the expanding crucible steel industry, and from other factors such as locally abundant water power, a working population with centuries of metal-working skills, and national and international prosperity providing a rising demand for superior tools. We can only speculate about the reasons why an iron saw was made because the business records of the Kenyons have vanished, even though they were used for a bi-centenary celebration published in 1910 (Sheffield City Library).

In today's eastern states of the USA, examples of that firm's 18th century saws have been more commonly found than those of any other contemporary maker, but there is no information to confirm that their output also was larger than that of their rivals. It may well be that Kenyons and Jones' iron saw is the end of a line, the definable terminus of a disappearing technique, overtaken by the powerful reality of the new: Sheffield's signature steel industry, which was strongly influenced by the parallel development of the saw industry. It is notable that after the mid-18th century, no iron saws appear to have been made, and certainly none is known to have survived. There is always the unprovable possibility that blacksmiths continued to make saws from wrought iron for local use; a narrow blade of poorer quality metal could do excellent service, if held in tension in a frame, or designed to cut on the pull stroke and hence not subject to bending forces.

By the time Sheffield's first trade directory appeared in 1774 there were four firms making saws, all of them men who had already become successful in one or more of the town's metal trades. One was Thomas Boulsover, the wealthy inventor of fused silver plate, who in 1763 built the world's first integrated saw-making establishment on one of Sheffield's small rivers (SA: Fairbank). The

*Figure 4: Swedish wrought iron for conversion to crucible steel c1900. Photograph courtesy of Ken Hawley Tool Collection Trust.*

first founding firm did not last long in its original form: by 1760 the Kenyons had bought out their businessman partner, and by 1763 had removed their saw maker, Robert Jones, who appears in another partnership agreement of men making tools of several kinds, saws not being specified (SA: WC1554). It seems likely that by then the growing saw trade in the town was producing the trained saw makers who in the previous decade had had to be recruited from a distance.

The growth of Sheffield's intertwined steel and saw-making industries can be traced from the papers of Joseph Wilson, one of the four manufacturers listed in 1774. His records, held by Wilson & Co, Sharrow Mills, Sheffield, contain detailed information about his concurrent activities in several trades, including iron and steel processing, snuff grinding, silver plated goods and saw making. Although incomplete, these papers form the only set of 18th century data for a detailed study of early Sheffield saw manufacture (Barley 2008). After Wilson's apprenticeship to a businessman, in 1743 he joined his elder brother in operating a family forge that served a large number of men in the town's many secondary metal trades. In this and all his businesses Wilson was a manager and employer, never a skilled tradesman. His income came to be derived chiefly from snuff-grinding, which the firm continues today, together with selling Sheffield goods of all kinds in Britain, Europe and America. He was an assiduous networker and engaged in multiple business partnerships, being for a time in silver plating with Boulsover, and it may be that his friendship with that pioneer industrialist induced Wilson to set up his own saw-making establishment on the same small river about two miles nearer to the town centre.

The scale and scope of his saw making, which began in 1768, is shown in several books of sales (Wilson & Co, passim). It is unfortunate that his methods were somewhat idiosyncratic and that some documents have been lost. Furthermore, Wilson overlapped his businesses, so that it can sometimes be difficult to tell to which of them a particular transaction related. Nevertheless it is clear that he bought large amounts of iron and steel and used a good deal of it for saw making. The Whites in London had already shown that high quality iron, mainly from Sweden, was necessary for their saws, and Sheffield's crucible-steel makers always followed their example as much as trading conditions permitted (Barraclough 1984); one variety of Swedish wrought iron (Fig 4) became closely specified for crucible-steel making (Mackenzie and Whiteman 2006).

Wilson's purchases began as soon as he started his saw making; in 1768 and 1769 he dealt with the Hull merchants Williamson and Waller (Jackson 1971, 108; Wilson & Co, ledger 4, 15). He bought almost entirely iron, some specified as 'strong Swede', 'strong Bullitt', 'Anchor', or 'Old Sabel' and amounting to over £1300 of bars at prices, depending on quality, between 13s 6d and 23s 6d per cwt. Most entries are itemised in money only, but in 1769 alone, when weights are given, over 17 tons of iron were bought through this one agent alone. In the

same year Wilson also bought over £330 worth of iron, in similarly named varieties from another Hull merchant, Joseph Sykes (Wilson & Co, ledger 4, 6). There are no other invoices to suggest that Wilson continued to buy iron at the same rate: his initial large stock could have been stored, to be used when needed. Nevertheless, these amounts imported by just one of the firms making saws in Sheffield must call for some recalibration of views that the town's steel industry did not amount to much before the end of the 18th century.

Further information about Wilson's metal trading locally is in his account with the above-mentioned Kenyon brothers (Wilson & Co, ledger 4, 4) between November 1768 and July 1769, also at the beginning of Wilson's saw making. Most entries give weights only, and show he bought in total well over 11 tons of iron and steel from his local rivals. Some purchases indicate what the material would be used for: examples include four cwt of iron to be rolled for saw backs [the strengthening rib along the back of smaller saws], a little over one ton of steel (variety not named) to be rolled for 'long' [pit] saws, 18 cwt for frame saws, and almost 1.5 tons for 'short' [joiners'] saws. The Wilson cash ledger 17 also records transactions in iron and steel with seven other local businesses, as well as with a partnership of himself and two other family members. Apart from the last (over £400 between 1768 and 1772), most are for quite small amounts. Most of these transactions are less specific about what the iron and steel were for so that it cannot be known how much was used in Wilson's saw business and how much in the other businesses he was concurrently operating. These records – one man's day-to-day commerce – are a significant clue to the degree to which the Sheffield of this period was beginning to contain a dynamic and expanding new world of steel making, buying and selling by multiple actors, some at least of them heavily involved in saw making.

Turning to Wilson's productivity, his invoices (ledgers 21, 25 and 51) show that before he was bankrupted in 1775 many thousands of saws were produced by his tradesmen: 4,216 were sold in just three years 1772-1775, and 4,526 unsold were listed in stock-takings in the same period; other documents are inadequate for calculating his early years' production. Putting it another way, in his final three years of trading there were over 200 invoices for saw sales across 11 English counties, London and Ireland.

Only one saw with Wilson's name is known to have survived, whereas at least ten times that number have survived that are known to have been made by the Kenyons in their first four decades. It is unfortunate that there is no way of knowing whether extrapolation to calculate the town's total productivity could be reasonable from the example of Wilson, or of the Kenyons, or any of the other 11 known saw makers in Sheffield before 1800. If Wilson were to be a maker with an assumed average, the total number of steel-bladed saws made by all these firms might in only 40 years have been in the hundreds of thousands. The tonnage of steel to produce this output must have been correspondingly very large by the standards of the day. Even if we cannot say what contribution the early saw industry made to steel production, it should not be dismissed as small: small-scale production should not be equated to overall small output. The tiny number of survivors of this output should not deter this estimate, impossible though it is to verify: if only one of Wilson's over 4,000 saws is known today, we should not therefore conclude that Sheffield's overall production was correspondingly small.

Wilson's saws were all made of steel: his invoices show three grades of it, common, best and cast, and all were used to make different qualities of the 17 different types he sold. These three descriptive terms for steel, apart from cast, defy definition: all that can be said is that they broadly reflect the amount of work done to make them; the first two would have been cementation (blister) steel undergoing greater degrees of further forging and tempering to improve performance. Wilson also used some iron for his saw business (for making the 'back' of some types of smaller saws which needed this stiffening rib, with brass for more expensive varieties), and for some parts of long saws for converting timber, but no iron-bladed saws are mentioned.

In 19th century saw production, steel that was not crucible cast was subsumed into a single term, 'German Steel', used by all Sheffield saw makers, but without any suggestion that one maker's German Steel was exactly the same as another's, nor were they like the German Steel imported to Britain before the home industry was well established. Other tool makers and dealers used the words 'common' and 'best,' with price differentials, on other kinds of tools (Rees and Rees 1997, 59) but it cannot be known if there was any consistency across the industries making them. The term German Steel has not been seen marked on any tools but saws, although 'Cast steel' is commonly seen on edge tools. All the terms in this early period lack the precise specification, the sophistication and the scaling noted by Belford to differentiate types of iron in the late 19th century Staffordshire industry: Best, Best Best Plating, Best Best and Treble Best (Belford 2004, 49). Belford showed that 'the notion

of the forging process as the sole determinant of quality' was to be challenged, but he was able to do so because the source of his research gave detailed ingredients of the grades of iron. No such information is available in relation to early Sheffield steels or anything about their ingredients. In the later Sheffield steel industry, product grading and specificity were used; for instance the catalogue of Sanderson, Brothers and Newbould listed 27 types of steel for different industries, again using undefined terms such as Special, Double Special, Extra Cast and Double Extra Cast (Ken Hawley Collection Trust, c1900). Although there is some evidence of the ingredients for different steel melts, the steels here can only be assumed as internally definable (and probably secret) for this one firm.

Competitive pressures in the British saw industry were always intense: a saw could offer little in the way of innovation in design, so that emphasis on quality was of necessity a manufacturer's criterion of success. Pressures were even greater when in the last decades of the 19th century the American industry began heavy advertising of its products, which were high quality and made in large newly established factories with more mechanisation than Sheffield firms could (or wished to) manage (Tweedale 1987, 144-157). Saws were therefore always quality-graded with undefined appellations: as well as German Steel, terms were used such as common, best, very best, extra, warranted, and London Spring. Additional brand names, probably applied to identical quality saws, stretched the product range – 'badging' by the modern car industry is called to mind. Extra work was put into more ornate wooden handles, sometimes from exotic timbers, but most of the price increase attendant on more expensive items reflected increased work on the steel blade.

Examining the role of the saw industry can throw light on a phase of steel making that has not been closely examined in connection with its products. Many Sheffield saw makers not only made their own steel, but also used it in their products. Steel and saw making were also very often linked with a third industry – file-making – an unsurprising combination given that every saw (until flame-hardening of the teeth became common in the last decades of the 20th century) needed periodic sharpening with a file, and a file had by definition to be harder than the metal on which it was used. Ashton's work on the file-maker Peter Stubs shows large purchases of high-class material from Sheffield steelmakers (Ashton 1939, 37-50). This triple integration was a key feature of the Sheffield saw industry, and one of the main reasons for its long-term success.

In the absence of precise figures, it is difficult to imagine that any other trade (except perhaps file making) used crucible steel in such large amounts, and in such a concentrated form. Saw makers' entire (highest quality) tools were made from it, whereas edge tool or scythe makers used a relatively small amount of steel welded onto an iron back, and the makers of razors or needles were putting fractions of an ounce of steel, rather than pounds, into each of their products. Many hundreds of steel buttons could have been made with the amount of steel in one 7-foot pit saw (about 4kg), and in three years Joseph Wilson sold 40 of them, together with 463 hand saws and 144 back saws with blades made completely from crucible steel. This material, with its unique combination of qualities – hardness, ductility, springiness and ability to take a fine polish – was quickly seized upon by Sheffield's saw makers, who were no doubt familiar with steel saws from London makers such as the Whites.

During the many early years when quality was not consistent (and later, when it was), the user of the steel was often the maker of it, so a consignment of steel of doubtful quality could be at once traced back to its source, a few steps across the yard of the same establishment. There was no need, as a Welsh purchaser of saws from a Sheffield firm in the 1840s did, to write and complain: 'Gentlemen. None of the saw [sic] have yet come to hand – all the others you sent us, are broken to pieces they are much too hard two of them did not last 4 hours' (SA: Marsh 26). Similarly, in Birmingham Matthew Boulton's problems with the quality of Huntsman's steel in 1789-1790 are clear from Boulton's letterbooks – it was either too hard, too soft, or lacked 'good body' to withstand the repeated force of a die striking coinage. Corresponding with Huntsman to correct these faults was slow and unsatisfactory; the lengthy learning process in a new and complicated technique that relied chiefly on word of mouth was always much more likely to be effective in a relatively small industrial community like Sheffield. It is not surprising that by 1850 over 90% of British steel was made there.

## Conclusion

This discussion of the early saw trade in Sheffield suggests that the significance of saw making for steel production may have been underestimated. Evans and Withey (2012) described Sheffield's 18th century industry as 'boutique', like London's, which was small scale and geared to trends in fashionable goods for the newly prosperous. They asserted (*ibid*, 554) that '[T]he centripetal pull of Sheffield wiped out an older landscape' of geographically scattered manufacture,

although they do not list the advantages that allowed such an apparently small industry to pull so hard that it eliminated its first-mover rivals. An alternative view is that the Sheffield steel industry was sufficiently robust, concentrated and extensive, even its early days, to achieve a late 18th century national dominance. The making of saw blades in large numbers from crucible cast steel is seldom considered by historians; Sheffield could not have become the most important player in this new market if its saw makers had not had ideal access to this new steel. Being able to make vital tools from a revolutionary material was a major factor in the town's becoming the world centre of saw manufacture for a century after Huntsman's work came to fruition.

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## The author

Simon Barley worked in various medical jobs until he retired in 1998 and joined the volunteers at the Ken Hawley Collection Trust. Assigned to catalogue the saws, he researched in the Collection and elsewhere in Sheffield to write a thesis, two books and some articles. His own collection of saws has been donated to the KHCT, the total number of saws for woodwork alone now reaching over 2000.
Address: Tanglewood, The Knapp, Besbury, Minchinhampton, Stroud GL6 9EP, United Kingdom
Email: barleys@mac.com