Extra Special Best Best: Black Country iron puddling and wrought iron manufacture in the nineteenth century

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ABSTRACT: This paper examines a unique document, the pocket book of a worker at Noah Hingley and Sons' ironworks at Netherton, near Dudley. This book (in a private collection) records the ingredients for the different types of puddled iron produced by the firm during the years 1891–1893. Hingleys were famous for their chains and anchors, and prided themselves on the superior tensile strength and anti-corrosion properties of their wrought-iron chains and cables. The notebook makes it clear that differentiation between 'best', 'best best' and other grades took place at the puddling stage rather than during subsequent forging; many of the mixtures described can be associated with different grades advertised by Hingleys at the time.

Introduction

Benjamin Westwood (Fig 1) was born in 1860, the son of Francis and Mary Westwood of 97 New Street, Netherton. Francis Westwood worked as a shingler in one of the local forges. The Westwood family were originally from Brierley Hill, and Francis' grandfather Thomas had also been a blacksmith. The tradition passed to young Benjamin, who was apprenticed to the Netherton wrought ironmakers Noah Hingley and Sons. He was an active member of the Netherton Ironworks Social Club from 1882 to 1884; after that he joined the Foresters Society, and became involved with the emerging trade union movement. He taught himself to read and write by copying newspaper articles and other items of ephemera. In 1885 he married Harriet Loach, and shortly afterwards they set up house in St. Andrews Street, Netherton. By 1891 Benjamin Westwood had been given responsibility for supervising the puddling process.

With his self-taught writing skills he recorded the different mixtures he used, in a new notebook he probably bought for that purpose. For whatever reason, he discontinued recording this work in 1893 – perhaps he moved on to a more senior position; perhaps he had

Figure 1: Benjamin Westwood. A photograph taken in his later years, probably c *1914.*

Figure 2: Advertisement of 1893, from Ryland's Directory, *although the engraving of the works may have been made some years earlier (courtesy Ironbridge Gorge Museum Trust).*

developed enough knowledge to dispense with his written account. In 1901 Benjamin Westwood built a new house on Baptist End Road, and he and Harriet lived there for the rest of their lives. Benjamin died in 1942, after a lifetime of work at Hingleys; work valued by the firm, for they paid a pension to him and his wife in their years of retirement. His notes on puddling mixtures from 1891–1893 somehow survived, and were passed down through the family. This paper is based on those accounts.

Noah Hingley and Sons

The firm of Noah Hingley and Sons was established at Netherton in 1838. Netherton was administratively a detached part of Worcestershire within South Staffordshire. Geologically, metallurgically and culturally it belongs in the 'Black Country', which has a long tradition of ironmaking, specifically wrought iron, chains and cables. Noah Hingley himself had previously worked for his father as a journeyman ironworker (Mallin 1997, 1/1). The business grew rapidly, and by 1844 employed 3,000 men (Godden 1987, 24–30). Its main product was 'Netherton' wrought iron, a term which in later years was often applied generically to wrought iron from the Black Country, much to the firm's annoyance (Fig 2) (Mallin 1997, 6/9). Following the development of the Bessemer process in the 1860s, mild steel was increasingly seen in applications which had formerly used wrought iron; however Hingleys persisted with the manufacture of wrought iron chains and cables until well into the twentieth century. Indeed, the Hingley concern has been described as 'an industrial anachronism harnessed to a paradox'—for its determination to continue the manufacture of high quality wrought iron at a time when mild steel was in the ascendancy, yet managing to find, exploit and expand a niche market for wrought iron (Mallin 1997,1/7).

By the time Noah Hingley had passed the works on to his youngest son Benjamin in 1877, the role of wrought iron was being seriously questioned. Many rival producers went out of business in the last quarter of the nineteenth century (Mallin 1997, 6/8–9). Hingleys' marketing emphasized two main points. The first of these was their control over all aspects of production, from 'the ores and fuel that go into the blast furnaces to the finished bars leaving the works'. The second was the expertise of their workforce, who possessed that 'inherited skill without which the perfection of craftsmanship cannot be attained' (Hingley and Son 1910, 10).

It was certainly true that Hingleys was a classic vertically integrated business. Their Old Hill mine produced Staffordshire thick-coal or 'ten-yard coal' which contained around 0.58% sulphur; when coked the average sulphur content was only 0.51% (Percy 1861, 102–3; Percy 1864, 546). Fireclay was also extracted from the Old Hill mine. Contemporary analysis of comparable fireclay from Brierley Hill suggests silica and alumina contents of around 50% and 30% respectively (Percy 1861, 214). Ironstone from the same source was very low in phosphorus, and contained between 37% and 41% iron (Percy 1864, 212–3). During the 1870s the firm acquired the Dudley Wood coal and ironstone mine at Netherton. In the 1890s the Old Hill and Dudley Wood mines employed around 250 workers between them, under the management of William Davies (Scott 1896). The Old Hill and Dudley Wood pits were supplemented in 1891, when Benjamin Hingley purchased the Coombs Hill estate from Samuel Weston, with rights to extract minerals.

In the early 1890s, when Benjamin Westwood compiled his record of puddling mixtures, the firm had two blast furnaces at Old Hill which produced low phosphorus pig (Table 6). Westwood's book shows that wrought iron production also used pig from Corngreaves. The New British Iron Company had six furnaces here in 1890, producing pig with the 'NB LION' and 'NBIC CORNGREAVES' brands (Ryland 1890, 280). Hingleys appear to have taken over this works by 1896, for the New British Iron Company is no longer listed in Ryland's *Directory* and the Corngreaves brands appear under the entry for Hingleys (Ryland 1896, 197). By the early years of the 20th century Hingleys stated that 'the pig iron which forms the basis of the mixtures…is the well-known "NB LION" brand', suggesting that the Old Hill furnaces were no longer in use (Hingley and Son 1910, 10).

Figure 3: Exterior view of No.3 Forge, N. Hingley and Sons Ltd., Netherton, taken on 3rd March 1951. This photograph, together with others reproduced below (Figs 5, 6 and 7), is from the Keith Gale Library at the Black Country Living Museum and has been reproduced here with the kind permission of Mrs Gale. BCLM Keith Gale Library, 1994/013/1247 (Gale 1951a).

The pig iron was converted to wrought iron at the Netherton works (Fig. 3). In 1893 this site contained '130 Puddling, Heating, Ball, Mill and Forging Furnaces, with the necessary Helves, Steam Hammers, Trains of Rolls &c. &c.' (Ryland 1893, 412). At this time the firm produced a wide range of different qualities of iron, from common or merchant bar to 'Best Best Best' grades.

Figure 4 is a detail of the entry from Ryland's *Directory* of 1893 which lists the brands used in that year; these are discussed further below. As well as producing rounds for chainmaking the firm also rolled squares, flats, thick flats and various angles, together with a bewildering array of more complex sections for specialist purposes (Hingley and Son 1916). Hingleys also made their own chains and chain cables, which were used in mines, railways and ships. Netherton wrought iron was claimed to offer superior resistance to 'shock and vibration [and] corrosion' over steel and other brands of wrought iron (Hingley and Son 1910, 15-7). By the turn of the

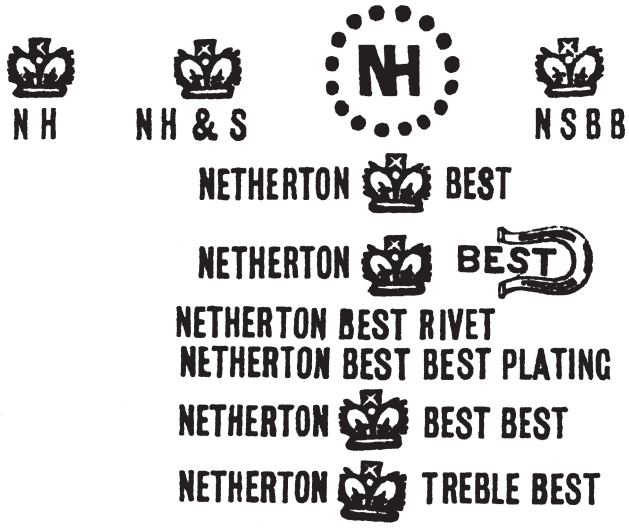

Figure 4: Brands listed in the Ryland's Directory *entry for N. Hingley and Sons in 1893 (courtesy Ironbridge Gorge Museum Trust).*

twentieth century the firm was producing approximately 1000 tonnes of wrought iron every week (Mallin 1997, 6/10).

The twentieth century saw increasing specialisation in marine chains and anchors, and Hingleys were the sole suppliers of Hall's Patent Anchor from 1903 (Mallin 1997, 6/12; Hingley and Sons 1912). Perhaps their most famous wrought iron anchors were made in 1911 for the *Titanic*. Weighing 16 tonnes apiece, they were the largest anchors ever made at that time and were proudly paraded through the streets of Dudley en route to Harland and Wolff's shipyard in Belfast. The niche market for anchors sustained the firm through the first part of the twentieth century, but advances in steel-making technology and the increasing expense of the labour-intensive puddling process meant that the firm ceased rolling at Netherton in March 1966 (handwritten note appended to Gale 1951b, 1).

The process

The processes involved in the manufacture of the different grades of iron referred to in the notebook were puddling, shingling, reheating and rolling. The invention of the puddling process is usually attributed to Henry Cort, who registered a patent in 1784. The origins of the process are still unclear, and it is evident that there were a number of attempts earlier in the eighteenth century to produce malleable iron in a coal-fired reverberatory furnace (Mott 1983, 1–15; Schubert 1957, 282–84). There is not space to detail these developments here, suffice it to say that earlier processes such as 'stamping and potting' were rendered commercially unviable by Cort's patent, and although still in use in Shropshire early in the 19th century were effectively superseded elsewhere (Mott 1983, 48–60).

Several contemporary descriptions exist of the puddling process, which, once established, changed little from the mid-19th century onwards. It is extremely fortunate that the late Keith Gale made a tour of Hingleys' Netherton works in the early 1950s (Gale 1951b). Despite the passing of almost a century, the similarities between Gale's account and that of John Percy, describing puddling at Bromford in 1859, are striking (Percy 1864, 640–58). The process was also described in a textbook of 1895, contemporary with Benjamin Westwood's notebook (Rhead 1895, 169–173). These three sources form the basis of the following description of the process.

The puddling furnace was a reverberatory furnace, with dampers to produce an oxidising or reducing atmosphere as appropriate. The sides and base of the hearth were of cast iron, and before charging were lined with 'puddling mine' (roasted haematite) or 'bull dog' (roasted tap cinder) or a combination of the two; their refractory and chemical properties assisting in drawing off elements such as silica. With a new furnace lining, and subsequently every twelve hours, a charge of scrap iron ('bustling') was added to the furnace and worked into a ball to line it with Fe_2O_3.

The puddling process comprised four separate stages. The first was charging and melting. With the furnace ready, the charge would be added (Fig 5)—usually between 200 and 220kg of pig iron, with up to 55kg hammer scale (Fe_3O_4) as required. The melting stage would then begin, lasting for around half an hour with the furnace on full heat and the damper fully open; the oxidizing atmosphere would remove silicon, manganese and phosphorus. Once melting was complete, the furnace would be damped down, and the 'smothering' phase would begin. After ten minutes or so the metal would start to 'boil'; it would be kept in this state for about another half an hour. Further hammer scale might be added at this stage, the object being to oxidize any remaining silicon and carbon in the metal. The boiling stage required constant 'rabbling' by the puddler (Fig 6), using a tool (the 'rabble') inserted through a hole in the door to keep the metal constantly moving. Towards the end of the boiling stage the iron 'came to nature', following the removal of most of the rest of the carbon, manganese and phosphorus; this separation of malleable iron was 'beautiful to witness' and resulted in a pasty bloom. The final stage was 'balling up' of the bloom: dividing it into four or six balls which were removed one by one from the furnace (Fig 7).

The balls of puddled iron were then shingled under a hammer. It is perhaps not surprising in this context that Noah Hingley had helped 'a friend' develop a steam hammer which 'can come down with such force as to crush a ton of ore, or so delicately that it will hardly break an egg'; this friend was James Nasmyth and the eponymous hammer was first used at Hingleys in the 1840s (Godden 1987, 55–67). The shingled ball was then reduced on the forge train (a heavy-duty two-high rolling mill) to a rough bar called a 'puddler's bar', approximately 20mm by 150mm in section and 3.66m long. A skilled puddler in South Staffordshire would require approximately 1118kg of pig iron to produce 1016kg of puddled bar; this process would consume approximately 1415kg of the local 'thick-coal'. The bar was allowed to cool before being cropped and made into

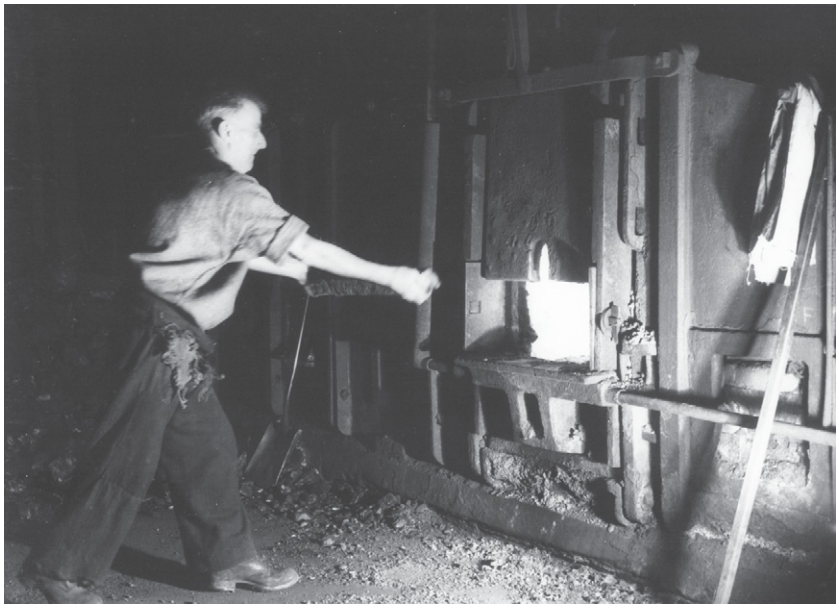

Figure 5: 'Charging the puddling furnace' at Hingleys' ironworks on 3rd March 1951.

Figure 6: The puddler using the 'rabble' to stir the iron during the boiling phase, at Hingleys' ironworks on 3rd March 1951.

Figure 7: 'The first ball comes out' at Hingley's ironworks on 3rd March 1951. The bloom, having been subdivided, is removed from the furnace for shingling and rolling.

piles; these piles were then reheated in a 'mill furnace' or 'ball furnace'. The piles were heated to welding heat, then removed from the furnace, shingled again and passed again through the rolling mill. The result of this process was common or merchant iron. If the process was repeated, this resulted in 'Best' iron; another repetition produced 'Best Best' iron, and yet another 'Best Best Best'.

The mixtures

Benjamin Westwood's notebook lists 44 different mixtures, using 41 different types of iron. Westwood's spelling varied widely, and he used many abbreviations; consequently there was some difficulty in deciphering the types of iron used. Iron was referred to by either the name of the firm that made it, the location of their ironworks, or the brand stamped upon it. Sometimes, indeed, the notebook might identify the same iron in several different ways. It has not been possible to firmly identify 12 of the irons listed, although four of these can be tentatively identified as to their likely nature and origin. A full list is given in Table 1.

In the notebook, quantities of different iron in the mixtures are given simply as either 'half' (1/2), 'one' (1), or one-and-a-half (1 1/2). These probably represent 'hundredweight' (cwt); however this was not a standard measure. Thus in 1859 at Bromford Ironworks a cwt of 112lbs (50.80kg) was used, whereas at Ebbw Vale a cwt was 120lbs (54.43kg) (Percy 1864, 657–58). The weight of the charges at Hingleys varied from 2cwt to 4.5cwt; the average of all the mixtures was 3.75cwt. The most frequent charge (used in 29 of the 44 mixtures) was 4cwt. This is entirely consistent with puddling practice throughout the nineteenth century (Percy 1864, 652; Rhead 1895, 171). Table 2 lists the 44 different mixtures, in the order in which they appear in the book; each ingredient is listed by the number given to it in Table 1. Supplementary notes given in the notebook are provided as endnotes on pp 58–59.

Composition of the mixtures

Hingleys' own publicity suggests that the iron they used was 'smelted in their own blast furnaces'; consequently the firm could exercise 'complete control' over the manufacture of the iron (Hingley and Son 1910, 10–11). However, Westwood's notebook provides clear evidence that pig iron sourced from Hingleys own furnaces comprised only a small proportion of the charge for each mixture. Figures 8 and 9 show the origins of the iron used in 1891–1893, an analysis of all of the mixtures in Westwood's notebook. Staffordshire pig accounts for 47% of the ingredients (Fig 8), of which only 51% was sourced from Old Hill furnaces (Fig 7). Even presuming that Hingleys had effective control of the 'New British' works at Corngreaves prior to their formal takeover in 1896, only 69% of the Staffordshire pig used by Hingleys in their wrought iron was manufactured in their own furnaces. When taken as an average over all the mixtures in Westwood's notebook, this represents around one-third of the ingredients of any given charge.

Another interesting fact to emerge from Westwood's notebook is the apparent use of steel in some of the lower grades of wrought iron. This is completely at odds with Hingleys' adamant proclamations of the inferiority of steel :

> 'The difference between iron and steel is the difference between a regiment of soldiers in an

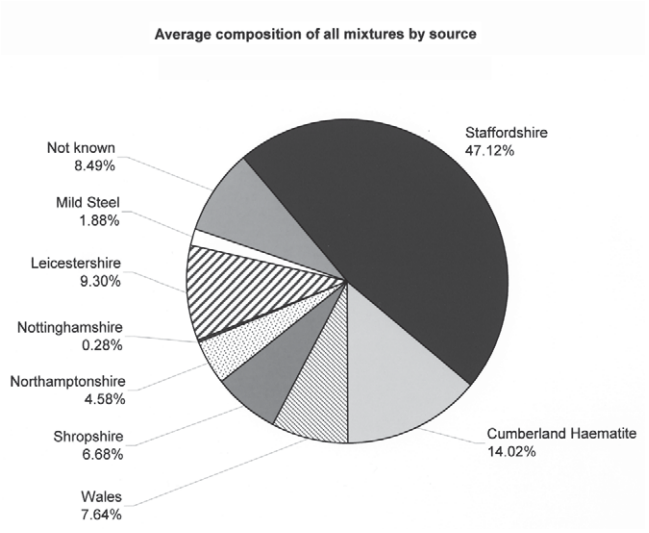

Figure 8: Chart showing the composition of all mixtures in Westwood's notebook by source.

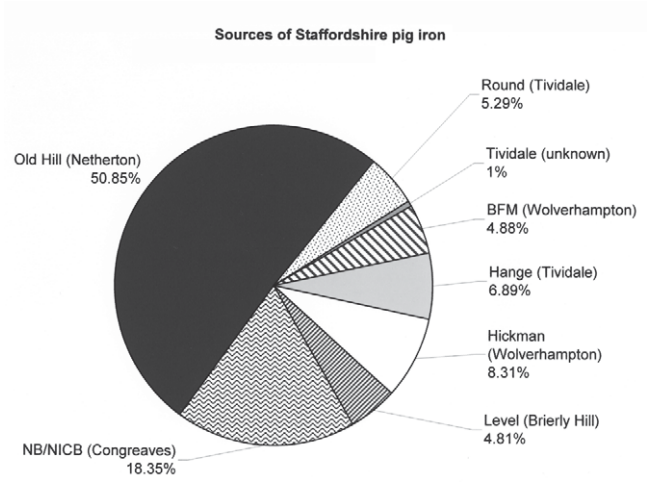

Figure 9: Chart showing the sources of Staffordshire pig iron listed in Westwood's notebook.

Table 1: List of iron brands from Benjamin Westwood's notebook, showing manufacturing concerns where known

	Name(s) in book	Company/Producer	Location	Product	Brands
1a	Barr, Barrow	Barrow Haematite Iron and Steel Company Limited	Barrow-in-Furness (Lancashire)	haematite pig	BHS
1b	Grey Barrow, Greay Barrow	Barrow Haematite Iron and Steel Company Limited	Barrow-in-Furness (Lancashire)	small pig	BH
2	BFM	Alfred Hickman	Wolverhampton (Staffordshire)	all-mine Staffs pig	BFM
3	Blaven, Blaeven	Blaenavon Company Limited	Blaenavon (South Wales)	cold blast forge pig	BLAENAVON
4	Branmbo, Braymbo, Brymbo	Brymbo Steel Company Limited	Brymbo (North Wales)	mild steel	BRYMBO
5	But, Butlin	Thomas Butlin and Company Limited	Wellingborough (Northants.)	forge pig	WELLINGBOROUGH
6	Cransley	The New Cransley Iron and Steel Company	Kettering (Northamptonshire)	Northants pig	CRANSLEY
7	Evail, E Vale	Ebbw Vale Steel, Iron and Coal Company Limited	Ebbw Vale (Monmouthshire)	forge pig	EV=B, BB
8	Frud, Ffrud	James Sparrow and Son	Wrexham (North Wales)	'second quality' pig	FFRWD
9	Grinsley	not known	-	-	-
10	Haematite,Hentite, Hem	not known [2]	-	haematite pig	-
11	Hane, Hang, Hangs, Hange	Round Brothers	Tividale, Tipton (Staffordshire)	all-mine Staffs pig	ROUND HANGE, HANGE
12	Heyford	Heyford Iron Company	Weedon (Northamptonshire)	foundry pig	HEYFORD
13	H Hydrate, Hick Hydrat	Alfred Hickman	Wolverhampton (Staffordshire)	hydrate pig	SVH
14	Hall, Holl, Hollowel	Holwell Iron Company Limited	Melton Mowbray (Leicestershire)	all-mine Leics pig	HOLWELL
15	Ket, Kett	Kettering Iron and Coal Company Limited	Kettering (Northamptonshire)	grey forge pig	KETTERING
16	Level, Level Mine	Old Level (?) [3]	Brierley Hill (Staffordshire)	all-mine Staffs pig	-
17a	Lill, Lillish, Lillisa, Lilleshall	Lilleshall Iron Company Limited [4]	Lilleshall (Shropshire)	all-mine Shrops pig	-
17b	Cold Lill, Cold Blast Lill	Lilleshall Iron Company Limited [4]	Lilleshall (Shropshire)	cold blast pig	-
17c	Hot Lillishall, Hot Blast Lill	Lilleshall Iron Company Limited [4]	Lilleshall (Shropshire)	hot blast pig	LILLESHALL HB
18	Lor, Lord	Harrison, Ainslie and Company [5]	Newland, Ulverston (Lancashire)	charcoal haem. pig	LORN (see Note 5)
19	Madle Court, Made Court	William Orme Foster	Madeley Court (Shropshire)	all-mine Shrops pig	MADLEY COURT
20	Magyene	not known	-	-	-
21	May	Treforest Tin Plate Company	Treforest (Glamorgan)	Siemens steel	MAY
22	Metal	not known	-	-	-
23	Mottled	not known [6]	-	forge pig	-
24a	NB	New British Iron Company Limited	Corngreaves (Staffordshire)	Staffordshire pig	NB=IC, NBIC CORNGR.
24b	Grey NB, Greay NB	New British Iron Company Limited	Corngreaves (Staffordshire)	Staffordshire pig	NB=IC, NBIC CORNGR.
24c	NICB	New British Iron Company Limited	Corngreaves (Staffordshire)	Staffordshire pig	NB=IC, NBIC CORNGR.
25	OH, Old Hill	N. Hingley and Sons [7]	Netherton (Worcestershire)	Staffordshire pig	OLD HILL
26	Rex	not known	-	-	-
27	Round Hig	Round Brothers	Tividale, Tipton (Staffordshire)	Staffordshire pig	-
28	Round Hydrate, Ron Hyd	Round Brothers	Tividale, Tipton (Staffordshire)	Staffs hydrate pig	-
29	Stanton	Stanton Ironworks Company Limited	Stanton (Derbyshire)	all-mine Derbys pig	S.I.W.
30	Tivadle	not known [8]	Tividale, Tipton (Staffordshire)	Staffordshire pig	-
31	Tredegar, Tredgate, Tridegr	Tredegar Iron and Coal Company Limited	Tredegar (Monmouthshire)	forge pig	TREDEGAR
32	Wel, Well	not known [9]	-	-	-
33	West	not known [10]	-	-	-
34	Willurylor	not known	-	-	-
35	X	not known	-	-	-
36	Celected	selected pig iron, possibly from Old Hill?	? Netherton (Worcestershire)	? Staffordshire pig	-

Note: the superscript notes in this and other tables are listed as endnotes

> orderly array and a rabble mob... it will be clear how important it is that there should be no steel mixed with iron since the promiscuous crystalline arrangement of the steel would break up the necessary regularity of the iron crystals... Netherton Iron is genuine one-hundred-per-cent. puddled iron...' (Hingley and Son 1910, 13).

However, in spite of the threat to virtuous iron from 'promiscuous' steel, Benjamin Westwood lists two brands from firms producing steel. These are 'BRYMBO' (from the Brymbo Steel Company near Wrexham), and 'MAY' (for Siemens steel from Treforest in Glamorganshire). Although both concerns also had blast furnaces which produced pig iron, the use of these brands appears to have been exclusively for steel bars at Brymbo and Treforest (Ryland 1890, 144; 350). These brands are only used in five mixtures, of which the ingredients of

Table 2: Mixtures (wt%) from Westwood's notebook

Mixtures	Supplier (see Table 1)																																							
	1a	1b	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17a	17b	17c	18	19	20	21	22	23	24a	24b	24c	25	26	27	28	29	30	31	32	33	34	35	36
1. 8in. Special for $^{3}/_{8}$ in. Round	25.0	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	12.5	12.5	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-
2. Special 8in.	33.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7	-	-	-	-	-	-	33.3	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-
3. Merchant 4in.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	50.0	-	-	-	-	-	-	-	-	-	-	-
4. Crown 4	-	-	-	-	-	-	20.0	-	-	-	-	-	-	-	20.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.0	-	-	-	-	-	-	20.0	-	-	-	-
5. 10in.	-	-	-	-	-	-	-	-	-	-	-	28.6	-	-	14.3	-	-	-	-	-	-	-	-	-	-	-	14.3	-	-	28.6	-	-	-	-	-	-	14.3	-	-	-	-
6. 4in. XX	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	12.5	-	-	-	-	12.5	-	-	-	-	-	-	25.0	-	-	25.0	-	-	-	-	-	-	12.5	-	-	-	-
7. 'A Spend[id] Sample of 6in. Merchant'	-	-	-	-	-	-	-	-	16.7	-	-	-	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-	16.7	-	-	33.3	-	-	-	-	-	-	16.7	-	-	-	-
8. 'A very good Crown 4'	-	-	-	-	-	-	16.7	-	-	-	-	-	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.3	-	-	-	-	-	-	33.3	-	-	-	-
9. 'A very good' Strip 10in. x 7	-	-	-	-	-	-	12.5	-	-	12.5	-	-	25.0	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-
10. 6 Cable	16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.0	-	-	-	-	-	-	33.0	-	-	-	-
11. Cable 7in.	-	-	-	-	16.7	-	-	-	-	-	16.7	-	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.0	-	-	-	-	-	-	16.7	-	-	-	-
12. 4 XX for Ergon	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	12.5	12.5	-	-	-	-	-	-	-	-	-	-	12.5	-	-	25.0	-	-	-	-	-	12.5	-	-	-	-	-
13. 8" Special	-	22.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.1	-	-	-	-	-	-	22.2	-	-	22.2	-	-	22.2	-	-	-	-	-	-	-	-
14. 8" Flats Cable quality	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	25.0	-	-	-	12.5	-	12.5	-	-	-	-	-
15. NC 4	-	-	-	-	14.3	14.3	-	-	-	-	-	-	-	14.3	14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42.9	-	-	-	-	-	-	-	-	-	-	-
16. NC 6	-	-	-	-	12.5	12.5	-	-	-	-	12.5	-	-	-	12.5	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	37.5	-	-	-	-	-	-	-	-	-	-	-
17. Cable 7"	-	-	-	-	14.3	-	-	-	-	-	14.3	-	-	-	14.3	14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	28.6	-	-	-	-	-	14.3	-	-	-	-	-
18. Best Best Mixtures: this is 6 or 4	12.5	-	12.5	-	-	-	-	12.5	-	-	-	12.5	-	12.5	-	-	-	12.5	-	-	-	-	-	-	-	-	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-
19. 'us[u]al Special 7 BB'	12.5	-	-	-	-	-	-	12.5	-	-	-	-	-	-	12.5	-	-	12.5		-	-	-	-	-	-	-	12.5	-	-	25.0	-	-	12.5		-	-	-	-	-	-	-
20. 7in. IB Netherton	12.5	-	12.5	-	-	-	-	12.5	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	12.5	12.5	-	-	-	-	-
21. Exter SPECial 7 or 8 Cable Mixture	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-	12.5	-	-	-	-	25.0	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-
22. LTF: small round	12.5	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	25.0	-	-	-	-	-	12.5	-	-	12.5	-	-
23. LTF: $^{3}/_{4}$ round ('or will salt')	-	-	12.5	-	-	-	-	12.5	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	25.0	-	-	-	-	-	12.5	-	-	-	-	-
24. Special Best Best Cable 9in.	25.0	-	-	-	-	-	-	-	-	-	-	12.5	-	12.5	-	-	-	25.0	12.5	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25. Special 8in. for 3in. rounds	14.3	-	-	-	-	-	-	14.3	-	-	-	-	-	-	-	-	-	14.3	-	-	28.5	-	-	-	-	-	14.3	-	-	14.3	-	-	-	-	-	-	-	-	-	-	-
26. This is 2 $^{1}/_{2}$ Billettes for fring iron	-	-	-	-	-	-	-	14.3	-	-	-	-	-	14.3	14.3	-	-	14.3	-	-	-	-	-	-	-	-	-	-	-	14.3	14.3	-	-	-	-	14.3	-	-	-	-	-
27. Box piles 8 x 6 [11]	12.5	-	-	-	-	-	-	-	-	-	12.5	-	-	12.5	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	12.5	25.0	-	-	-	-	-	-	-	-	-	-	12.5
28. This is 2 $^{1}/_{2}$ Billitts fring iron	-	-	12.5	-	-	12.5	-	12.5	-	-	12.5	-	-	12.5	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-
29. 8in. Special for round 3 x $^{5}/_{8}$	25.0	-	-	-	-	-	-	12.5	-	-	-	12.5	-	-	-	-	25.0	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-
30. 4in. XX	33.3	-	-	-	-	-	-	-	-	-	16.7	-	-	16.7	16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7	-	-	-	-	-	-	-	-	-	-	-
31. X 10in. (for 5 and 6 rounds) [12]	-	-	12.5	-	-	-	-	12.5	-	-	12.5	-	-	-	12.5	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	37.5	-	-	-	-	-	-	-	-	-	-	-
32. XX 6 x $^{3}/_{4}$ for 4in. angles	-	-	-	-	-	12.5	-	-	-	-	25.0	-	-	12.5	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-
33. N H & S Cable [13]	22.2	-	-	-	-	11.1	-	-	-	-	11.1	-	-	-	11.1	-	11.1	-	-	-	-	-	-	-	-	-	-	-	-	22.2	-	-	11.1	-	-	-	-	-	-	-	-
34. Shingling Iron for Screwing [14]	-	-	12.5	-	-	-	-	-	-	-	12.5	-	-	-	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	37.5	-	-	-	-	-	-	-	-	-	12.5	-
35. Iron Made for Test [15]	12.5	-	-	-	-	-	-	-	-	-	12.5	12.5	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50.0	-	-	-	-	-	-	-	-	-	-	-
36. Special (15th February 1893)	25.0	-	-	-	-	-	-	12.5	-	-	-	12.5	-	-	-	-	25.0	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-
37. 17th June 1893 [16]	-	-	-	-	-	12.5	-	-	-	-	12.5	-	-	-	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	50.0	-	-	-	-	-	-	-	-	-	-	-
38. Special Strip [17]	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	25.0	-
39. 24th August 1893 (1) [18]	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	12.5	12.5	-	-	-	-	-	-	-	-	12.5	-	-	37.5	-	-	-	-	-	-	-	-	-	-	-
40. 24th August 1893 (2) [19]	12.5	-	-	12.5	-	-	-	-	-	-	-	12.5	-	-	-	-	12.5	-	12.5	-	-	-	-	-	12.5	-	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41. BB Cable 7in. 'and it work very well'	12.5	-	-	12.5	-	-	-	-	-	-	-	12.5	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	25.0	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-
42. This is for 6 + 7	-	-	-	-	-	-	-	12.5	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.0	-	-	25.0	-	-	-	-	-	-	-	-	-	25.0	-
43. This is Rivett Iron and very good	-	-	-	12.5	-	-	-	12.5	-	-	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	37.5	-	-	-	-	-	-	-	-	-	12.5	-
44. Screwing Iron very good [20]	-	-	-	-	-	-	-	12.5	-	-	12.5	-	-	-	12.5	-	-	12.5	-	-	-	-	-	-	-	-	12.5	-	-	25.0	-	-	-	-	-	-	-	-	-	12.5	-

Table 3: Typical compositions of pig iron (from Percy 1864, 536–549)

(wt%)	Staffordshire		Red Haematite		Northamptonshire		South Wales
	Old Hill	Netherton	Whitehaven	Newland	Heyford	Butlins	Blaenavon
	'Nos. 4 & 5 pig'	'strong forge pig'	'No. 4 forge pig'	'Charcoal iron'	'pig iron, first melting'	'mottled pig'	'Common forge-pig'
Fe	94.78	96.14	94.96	96.45	91.35	94.51	94.67
C	2.78	2.81	2.21	2.83	2.64	2.10	2.64
S	1.56	0.57	2.63	0.59	4.63	2.11	1.68
S	0.09	0.06	0.1	0.03	0.07	0.13	0.08
P	0.48	0.29	0.03	0.1	1.31	1.07	0.27
Mn	0.32	0.13	0.07	-	trace	0.08	0.66

only three can be fully identified. These are shown in Figure 10 (Mixtures 15, 16 and 17). These three are described by Westwood as 'N[etherton] C[rown] mixtures, the lowest grade. The use of steel would have had the attraction of lowering the sulphur and phosphorus contents; cost might also have been a factor.

It is theoretically possible to estimate the composition of some of the mixtures recorded in Westwood's notebook. Table 3 shows the compositions of some typical forge pigs produced during the 1860s in Staffordshire, Cumberland, Lancashire, Northamptonshire and South Wales. According to Percy (1864, 542), No. 4 forge pig was 'preferred in South Staffordshire for puddling'. However, there was considerable variation in the products of these furnaces over time. Moreover, the chemical changes which took place during the puddling, shingling and reheating processes were such that the resulting iron would have a very different chemical composition from its raw ingredients. The main chemical objective of puddling was to reduce the carbon content of the iron; the process also reduced the amount of silicon and phosphorus although this was less controllable and the reduction of phosphorus was particularly problematic (Percy 1864, 658–65). It would have been sensible, therefore, to choose iron with low silicon and phosphorus contents at the outset. It is not surprising that the higher grades of iron use much greater proportions of Staffordshire, Shropshire and haematite pig, and eschew altogether the relatively high-phosphorus Northamptonshire pig.

Grades of puddled iron

Benjamin Westwood's notebook calls into question the generally accepted notion that the different grades of puddled iron were only arrived at by increasing the number of reheating and forging operations. It is evident from the notebook that careful selections were made of different pigs depending on the intended nature of the resulting puddled bar. Unfortunately, other factors which might explain some of these selections, such as the condition of the furnace, the use of fluxes, and the availability of certain types of iron, are missing from the notebook. Westwood also provided no indication of costs in his notebook, and this would have been a further consideration in the selection of iron (and steel) for puddling.

Mixtures which can be firmly identified as lower grade iron are described by Westwood as Merchant (Mixtures 3 and 7), Crown (Mixtures 4, 5, 8, 10, 11, 15, 16 and 17) and NH&S (Mixture 33). Iron marked with the Netherton Crown and NH&S Crown brands was 'for ordinary smithing work' and for 'wagon building... and agricultural machinery' (Hingley and Son 1910, 21; Mallin 1997, 6/10). A version of the NH&S brand for cable was produced on 23 June 1893 (Mixture 33; Table 2 and Fig 10). Three further cable mixtures were recorded in 1891 as 'Netherton Crown' brand; the two seven inch mixtures (11 and 17) being very similar. Both use Old Hill, Northamptonshire and haematite pigs, together with mild steel from Brymbo. Other 'Netherton Crown' irons were produced in 1891,

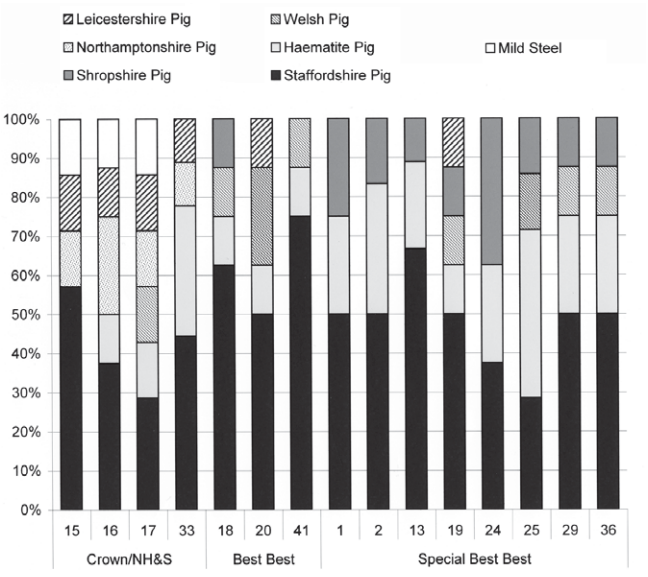

Figure 10: Chart showing the compositions of selected mixtures from Westwood's notebook by grade and source.

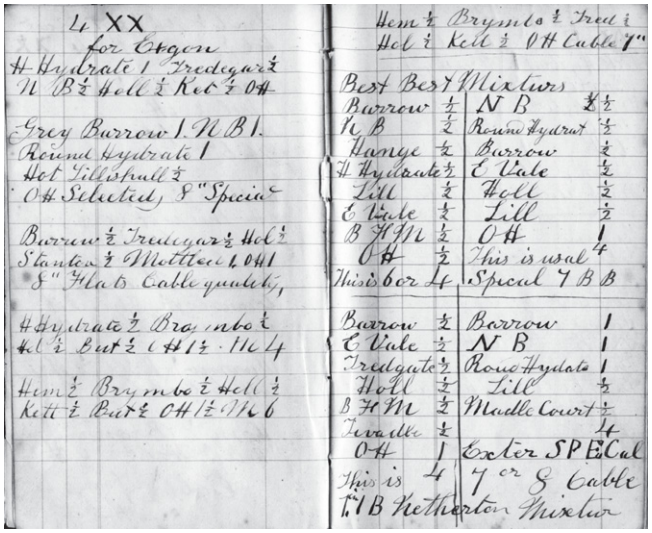

Figure 11: Pages 3 and 4 of Benjamin Westwood's notebook, from late 1891. Page 3 (left) lists Mixtures 12, 13, 14, 15 and 16 (down the page); Page 4 (right) has Mixture 17 at the top, with four 'Best Best Mixtures' —18 (left) and 19 (right) in the middle of the page, and 20 (left) and 21 (right) at the bottom.

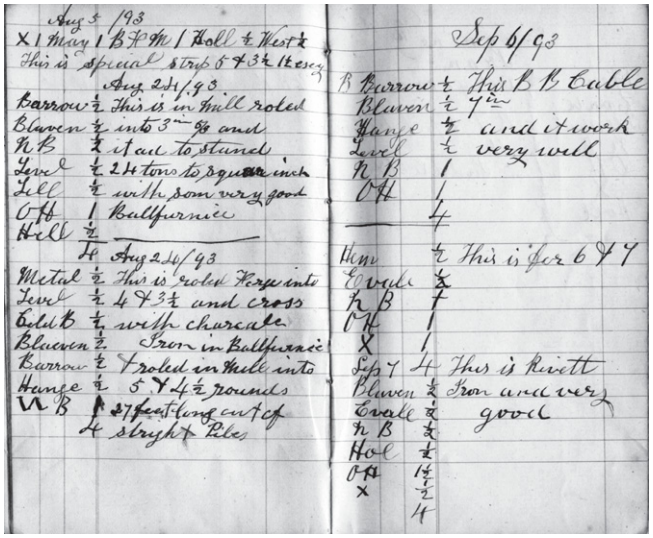

Figure 13: Pages 9 and 10 of Benjamin Westwood's notebook, August and September 1893. Page 9 (left) has Mixtures 38, 39 and 40 down the page; Page 10 (right) has mixtures 41, 42 and 43 down the page.

mixtures 4 and 8 being described as 'Crown 4' and 'A very good Crown 4' respectively. The contrast between these and Mixture 15 is worth noting, for although the latter is also described as 'N[etherton] C[rown] 4', it is altogether different in composition (Tables 2 and 3).

According to contemporary publicity and directory information, Hingleys produced two variants of Netherton Crown Best. One was for 'superior smithing and engineering purposes', and included 'Netherton Best Rivet' and the other was identified with a horseshoe mark for 'horse and mule shoes' (Hingley and Son 1910, 21). No mixtures for the shoeing iron are recorded by Benjamin Westwood, and only one of the others can be firmly identified as 'Crown Best' for it was described as 'Rivett [sic] iron and very good'. This was Mixture 43 (Table 2, Figs 10 and 13), produced on 7 September 1893. 'Best Best' iron was originally the top grade, but by the 1890s Hingleys had surpassed themselves, and were producing 'Special Best Best', 'Extra Special Best Best' and 'Best Best Best' (Hingley and Son 1910, 21; Hingley and Son 1912, 25–28; Mallin 1997, 6/10). No triple best mixtures are identified as such in Benjamin Westwood's notebook, but three are clearly defined as 'Best Best'. Mixtures 18 and 20 (Table 2, Figs 10 and 11) are on a page headed 'Best Best Mixtures' and are mainly composed of Staffordshire, haematite and south Wales pigs. Mixture 41 (Table 2, Figs 10 and 13), produced on 6 September 1893, was a cable grade comprising 75% Staffordshire pig, supplemented by haematite pig and cold blast pig from Blaenavon. It was recorded by Westwood as working 'very well'. Many of the mixtures in the book which it has not been possible to identify with specific grades of iron may also belong to the 'Best Best' category.

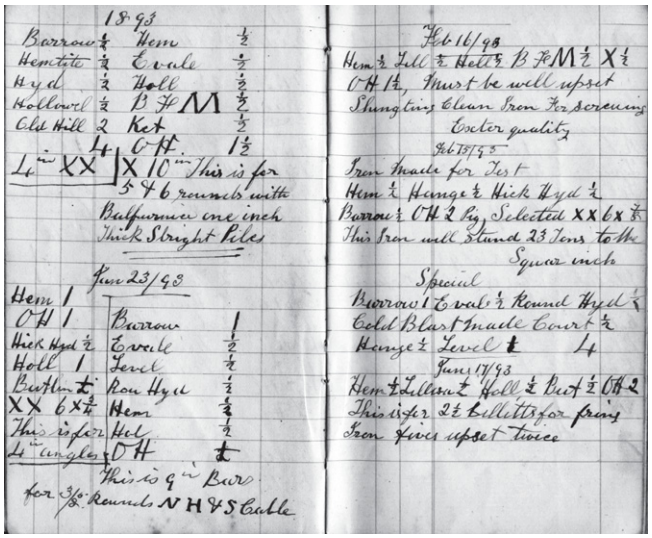

Figure 12: Pages 7 and 8 of Benjamin Westwood's notebook, from 1893. Page 7 (left) has Mixtures 30 and 31 at the top, 32 and 33 at the bottom; Page 8 (right) has Mixtures 34, 35, 36 and 37 down the page.

'Netherton Special Best Best' (NSBB) was the dominant 'Best Best' brand in Westwood's notebook. Hingleys marketed NSBB for 'heavy section requirements in railway work and engineering' as well as for situations 'where life and property depend on the quality of the iron' (Mallin 1997, 6/10; Hingley and Son 1910, 21). Although again predominantly using Staffordshire pig, these mixtures include a greater proportion of Shrop-

shire iron than other grades. Typical was Mixture 36, a 'special' produced on 15 February 1893 (Table 2, Figs 10 and 12). It contained 50% Staffordshire pig and 25% Barrow haematite pig, with the remainder composed of equal parts Shropshire cold blast pig from Madeley Court and forge pig from Ebbw Vale. Identical in composition was Mixture 29, an eight inch cable grade (Table 2, Fig 10). Other 'special' mixtures were intended to be rolled as rounds for chain-making or for use in cables. These were Hingleys' flagship products, and only the best iron was chosen 'so that no faulty iron can ever reach the chain shops' (Hingley and Son 1912, 26). Thus Mixture 24 for 'Special Best Best Cable' comprised 75% Staffordshire and Shropshire pig in equal proportions, with the remainder haematite pig from Barrow (Table 2, Fig 10). Perhaps the most interesting 'Special Best Best' is Mixture 25 of 1891 or 1892, which was for three-inch rounds (Table 2, Fig 10). This contained nearly 30% charcoal haematite pig from the Newland furnaces at Ulverston (see Table 3), the rest of the charge being made up of Staffordshire, Lilleshall, Barrow and Ebbw Vale pigs.

'Special Best Best' was clearly insufficient for some purposes, for Benjamin Westwood records the production of an 'Extra Special' cable mixture on his 'Best Best Mixtures' page (Mixture 21; Table 2, Fig 11). This used solely Staffordshire, Shropshire and haematite pigs in the ratio 2:1:1 respectively. Other special irons include specific mixtures for strips or flats (Mixtures 9 and 14), for screwing iron (Mixtures 34 and 44) and 'LTF' mixtures for small rounds (Mixtures 22 and 23). Interestingly there are two mixtures which were subjected to testing. Mixture 35 (Table 2 and Fig 13) was 'made for test' on 15 February 1893, and withstood '23 Tons to the Squar[e] Inch'. It was composed of 50% 'selected pig' from Old Hill, with 25% other Staffordshire pig and 25% haematite pig. Mixture 39 (Table 2 and Fig 13) was produced on 24 August of the same year and contained 62.5% Staffordshire pig with the remainder equal proportions of iron from Lilleshall, Blaenavon and Barrow. This withstood '24 Tons to [the] square inch'.

Working the iron

The notebook contains some hints about the puddling process itself, as well as subsequent forging, reheating and rolling operations. The use of fluxes containing salt were described in many of the proto-puddling patents of the eighteenth century; fluxes with 'common salt' were certainly in use in the mid-nineteenth century (Percy 1864, 652–53). The use of salt as a flux is somewhat ambiguously suggested for Mixture 23 (Table 2); it is however also possible that this refers to later stages in the process – such as rolling, where salt was sometimes used as a catalyst to remove mill scale. Mixture 34 (Table 2), an 'extra quality' screwing iron, needed to be 'well upset' in the puddling furnace; likewise Mixture 37 (Table 2) needed to be 'upset twice'. References to post-puddling operations are more oblique. However, inferences can be made. Thus beneath the ingredients for Mixture 33 (Table 4), Westwood notes that 'this is 9 in Bars for $^{3}/_{8}$ Rounds N H + S Cable'. This suggests that the initial shingling produced nine inch (228.60mm) thick bars, which were then reduced on the forge and cogging mills to rounds. A more explicit description of events is given for Mixture 40 (Table 5), which after shingling was rolled in the forge mill into '4 + $3^{1}/_{2}$', that is a bar 101.60mm by 88.90mm in section. This was then put into the ball furnace and mixed with charcoal iron during the reheating process; the resulting mass was then shingled again and rolled into rounds 114.50mm and 127.00mm in diameter and up to 8.23m long. Many of the appended descriptions are however somewhat cryptic and have defied interpretation by the present author.

Conclusion

Benjamin Westwood's notebook has shed new light on operations at Hingleys' works in the last years of the nineteenth century. Three points have emerged. Firstly, it is evident that the majority of iron used for puddling was not produced by Hingleys, and indeed barely half of the iron was 'Staffordshire all-mine pig' as advertised. It is clear that Hingleys were prepared to explore a wide range of sources to obtain good-quality raw materials; moreover much of the iron would have been sought for specific properties – such as Ulverston charcoal pig or Barrow haematite pig. Secondly, the apparent use of steel in the merchant grades is somewhat unexpected; although as noted above, iron low in sulphur and phosphorus would have resulted, and cost may well have been a factor. Further research into the output of the Brymbo concern might throw more light on this aspect. Thirdly, and perhaps most contentiously, the notion of the forging process as the sole determinant of quality is challenged. It is evident from Westwood's notebook that different grades of iron were 'designed' by the selection of pig at the puddling stage. How much the composition of the charge affected the composition of the final product is not clear; it is of course likely that some of the more subtle variations were to take into account changing furnace and forge conditions. The complexity of Hingleys' mixtures appears overwhelming in the twenty-first century, when standardization is highly

prized. Unfortunately Westwood provided little information about the mechanical properties of the finished products, and no data at all on their composition. In the era before metallurgical control, the qualities of iron was understood in a more intuitive way. This was surely one of the mysteries of the art of iron working that Benjamin Westwood kept to himself; only the serendipitous survival of his pocket notebook has permitted a glimpse into the puddlers' secret world.

Acknowledgements

Many thanks are due to Margaret Simons for the extended loan of the notebook, biographical information on her ancestor Benjamin Westwood, and permission to reproduce Figures 1, 11, 12 and 13. Thanks are also due to Derek Simons for his kindness and hospitality, and to Edmund Simons, Emily Edwards and Annsofie Witkin. Additional research was undertaken in the library of the Ironbridge Gorge Museum Trust (with the helpful assistance of John Powell) and in the Keith Gale Library and Collection at the Black Country Living Museum (for which many thanks to Stephen Howard). I am very grateful to Mrs Gale for permission to use the photographs from her late husband's archive (BCLM Keith Gale Library, 1994/013/1247 (Gale 1951a), used in Figures 3, 5, 6 and 7; and for the detailed work of Dr Kenneth Mallin on the later history of the site. I would also like to thank the referees for their comments on an earlier draft of this paper.

The author would be extremely interested to hear from people with information about Hingleys, and in particular anyone who has first-hand knowledge of their products, or who can shed light on the operation of the site. Any comments on the likely properties and qualities of the iron mixtures listed here would also be welcome, as would identification of the 'unknown' brands. Discussion of comparable evidence from other sites would be very helpful.

Notes

1. The quantities in cwt have been converted to percentages in the tables to avoid confusion over values. References given in the text, tables and notes to the sections of rolled iron are in inches as in the original notebook; approximate conversions of the values used are : 'eight inches' (203.20mm), 'seven inches' (177.80mm), 'six inches' (152.40mm), 'four inches' (101.60mm), 'three inches' (76.20mm), '3/4' (19.05mm), '5/8' (15.89mm) and '3/8' (9.53mm).
2. Many ironworks in Cumberland, County Durham and the Forest of Dean produced haematite pig, as well as the explicitly 'Haematite' branded pig from Barrow-in-Furness. Percy (1864, 539–40) records a 'pig iron made chiefly from a mixture of red and brown haematite' at the Lays Ironworks (Dudley), and it is possible that other local suppliers smelted haematite ores.
3. 'Level Mine' is not listed as a brand in contemporary Ryland's directories. The only likely candidate is the Old Level Ironworks at Brierley Hill. This was operated by the Earl of Dudley in the 1860s (Percy 1864, 545–46). By 1890 it appears to have operated as two separate concerns — two blast furnaces in the occupation of James Holcroft, using the 'OLD LEVEL' brand for pig iron; and 18 puddling furnaces, four mill (ball) furnaces and two rolling mills under the proprietorship of Henry Hall and producing iron with the 'LEVEL' brand (Ryland 1887, 206; Ryland 1890, 213).
4. The Lilleshall company was producing 'best all mine hot and cold blast foundry and forge qualities' of pig iron in the early 1890s (Ryland 1890, 253).
5. Iron from Sparrow's Wrexham furnaces (branded 'FFRWD') and from the charcoal furnace at Newland (branded 'LORN') is likely to have been supplied to Hingleys by Henry Sparrow of Himley, near Dudley, who was the local agent for both of these concerns (Ryland 1890, 217, 331). This would explain why they are always referred to in the notebook by their brands rather than places of origin. Analysis of the Newland iron is given in Table 6.
6. Many ironworks produced mottled pig. Mottled was half way between grey pig and white pig, corresponding to a No. 4 or No. 5 iron (Percy 1864, 115–117). Analysis of Northamptonshire 'mottled pig' and Staffordshire Nos. 4 and 5 pigs are given in Table 6. It is possible that Hingley's made their own mottled pig at the Old Hill works.
7. Analysis of pig iron from Old Hill is given in Table 6.
8. There were several concerns based in and around Tividale (near Tipton, Staffordshire) who could have supplied iron to Hingleys. It seems likely that Westwood used 'Tivadle [sic]' as another means of referring to iron from the Round Brothers. 'TIVIDALE' as a brand was for corrugated iron sheets made by Hill and Smith of Brierley Hill and Tipton; 'G [crown] W TIVIDALE' was a brand used by George Wilkinson of Tipton, primarily a producer of sheet iron (Ryland 1890, 224, 372).
9. 'Well' could be an abbreviation of Wellington, Wellingborough or any other such name. 'WELLINGBOROUGH' was the brand name used by Thomas Butlin and Company, who are also mentioned in the notebook as Butlins. Other candidates include the Wellingborough Iron Company Limited (who used the brand 'RIXONS W. BORO') and the Wellington Iron Works Company, of West Bromwich, who used the brand '[crown] WELLINGTON' (Ryland 1890, 147, 412, 415).
10. 'West' is not a brand listed in contemporary directories, nor was there an ironmaking firm of that name. Possible brands for which it could be an abbreviation were used on 'Siemens steel coke iron' made in Llanelli, by the Old Lodge Tin Plate Company Limited ('WESTFA' brand) and the Western Tinplate Works Limited ('WESTERN' brand) (Ryland 1896).
11. 'This was Put in B[all] F[urnace] + made into Box Piles 8 x 6. Middle Iron 5" 15/16'
12. '1893. X 10 in. This is for 5 + 6 rounds with Balfurnice [sic] one inch Thick Str[a]ight Piles'
13. 'June 23, [18]93. This is 9 in. Bars for 3/8 Rounds. N H & S Cable'
14. 'Feb. 16, [18]93. Must be well upset. Shingling Clean Iron for Screwing. Exter [sic] quality'
15. 'Feb. 15, [18]93. Iron made for Test. This Iron will stand 23 Tons to the Squar[e] inch'
16. 'June 17 [18]93. This is for 2 1/2 Billitts [sic] for fring [sic] Iron fives upset twice'
17. 'Aug. 5 [18]93. This is special strip 5 + 3 1/2 1 1/2 esey [sic]'

18.'Aug. 24 [18]93. This is mill roled [sic] into 3 in. 5/8 and it [h]ad to stand 24 tons to square inch with Som[e] very good Ballfurnice [sic]'
19.'Aug. 24 [18]93. This is roled [sic] Forge into 4 + 3 1/2 and cross with charcole [sic] Iron in Ballfurnice [sic] + roled [sic] in Mill into 5 + 4 1/2 rounds 27 feet long out of str[a]ight Piles'
20. 'Oct. 16 [18]93. Screwing Iron very good. B 7 top + bottom. 1 1/8. Puddle 7 x 1'

References

BCLM: material in the library of the Black Country Living Museum, Dudley.

IGMT: material in the library of the Ironbridge Gorge Museum Trust, Coalbrookdale.

Gale W K V 1951a, *Wrot Iron* (an album of photographs taken at N Hingley and Sons, Netherton Ironworks, Dudley on 3rd March 1951), BCLM Keith Gale Library, 1994/013/1247.

Gale W K V 1951b, 'The making of wrought iron by the puddling process' (unpublished typescript within Gale 1951a), BCLM Keith Gale Library, 1994/013/1247.

Godden R 1987, *A Time to Dance, No Time to Weep* (London).

Hingley and Son *c*1910, *Netherton Iron: Its History, Manufacture and Properties*, (Netherton); booklet, BCLM Keith Gale Library, uncatalogued.

Hingley and Son *c* 1912, *Chain Cables and Anchors* (Netherton); catalogue, BCLM 1987/89, 4.344.

Hingley and Son 1916, *Sizes and Sections* (Netherton); catalogue, BCLM Keith Gale Library 1994/013/0457, 4.412.

Mallin K 1997, *Noah Hingley : The World's Premier Manufacturer of Ship's Anchors and Cables in the Period 1890–1918*, unpublished PhD Thesis (University of Warwick).

Mott R A 1983, *Henry Cort: the great finer* (London).

Percy J 1861, *Metallurgy: Fuel, Fire-clays, Copper, Zinc, Brass* etc. (London).

Percy J 1864, *Metallurgy: Iron and Steel* (London).

Rhead E L 1895, *Metallurgy* (London) 1935 edition.

Ryland 1887, *Iron, Steel, Tin Plates, Engineering and Allied Trades' Directory* (Birmingham) IGMT collection.

Ryland 1890, *Iron, Steel, Tin Plates, Engineering and Allied Trades' Directory* (Birmingham) IGMT collection.

Ryland 1893, *Iron, Steel, Tin Plates, Engineering and Allied Trades' Directory* (Birmingham) IGMT collection.

Ryland 1896, *Iron, Steel, Tin Plates, Engineering and Allied Trades' Directory* (Birmingham) IGMT collection.

Schubert H R 1957, *History of the British Iron and Steel Industry* (London).

Scott W B 1896, *Report of HM Inspector of Mines for the South Stafford District* (London).

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