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## HENRY BESSEMER AND THE STEEL REVOLUTION


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*Conclusion from No. 28 (December 1963)*

### THE TRIUMPH OF STEEL OVER WROUGHT IRON

"The Revolution we are about to announce is not in Sicily against King Bourbon, nor in France against the Emperor, but here in England. In science, in the manufacture of iron and in arts in which all the world is interested. What but a complete revolution in all our ideas is produced by the fact that a blast of cold compressed air directed on a molten metal, without any fuel . . . lashes it into most furious heat, makes it boil and bubble and throw up scum like a soup kettle under which a great fire is blazing? What but a complete revolution has begun in the whole manufacture of iron, when it is shown that we can draw off melted iron from the blast furnaces . . . into another furnace and from it . . . run off in half an hour, into any shape, cast steel or perfectly pure malleable iron, fit for all the many purposes to which steel and iron are put? The invention of the railroad, with its adjunct to telegraph, was not the beginning of a more important revolution than is, we know, now commenced in the iron trade . . .[1])."

"Its history may be suitably divided into three epochs — the first, the experimental and struggling period, which extended from 1856 . . . to 1865, when it had been taken up at several of the leading works in this country, and had been adopted in Germany, France and the United States; the second, the development period, which extended from 1865 to 1884, during which the process was developed rapidly and largely, not only in this, but in other countries as well, and the third, the stationary or retrogressive period which extended from 1884 to the present time (1895) and during which, in this country at least, the make of Bessemer steel has greatly declined . . . what is to become of the Bessemer steel industry? Is it destined to dwindle and decay, like the industry which it superseded for a time, but which now threatens to outlive it?[2])"

This is not a history of that decline of the Bessemer steel industry, which seemed so imminent in the 1890's. Indeed, a full account of that period of the relative decline of the British industry and the frightening and meteoric rise of the steel industry of the Austro-German empire would take this study far beyond its intended limits. However, it is necessary to see the first and second phases of the Bessemer steel industry in this country in perspective. The achievement of Bessemer in creating 'mild steel' was, as we know, overshadowed in Britain by Siemens' Open-Hearth process. On the Continent, the availability of the iron-ores of Alsace-Lorraine and certain metallurgical improvements made possible a rate of expansion quite outpacing the growth of both the Bessemer and Open-Hearth sections of the industry in Britain. The shock of this continental prowess gave rise to what Armytage, ironically but aptly, terms "intimations of industrial mortality[3])." And D. L. Burn, of course, had previously interpreted the period of adjustment to the metallurgical revolution started by Bessemer as a study in competition. His first section is entitled "Mid-Victorian Alarms"[4]) and his starting point is the Paris Exhibition of 1867, when British exhibits made

[1]) *The Economist*, August 1856 pp. 952–3 quoted in Gibson, "The Establishment of the Scottish Steel Industry" (*Scottish Journal of Pol. Econ.*, Vol 5, 1958).

[2]) "Before Bessemer and After", *Iron & Coal Trades Review*, 26 July, 1895. pp. 113–4.

[3]) W. H. G. Armytage, "Portends and Polytechnics; the effervescence of Civic University Colleges in England 1867—1898", *The Universities Review*, October, 1952.

[4]) D. L. Burn, *Economic History of Steelmaking* (London, 1930).

such a bad showing, and the products of the hitherto unchallenged British iron and steel industry appeared as "pieces of rusty iron" among "slovenly intruded heaps of raw material." This apprehension was to be confirmed, too, by the experience of the British iron and steel industry in the crisis, which heralded in the long period of uncertainty, pessimism and, as some saw it, stagnation. – The Great Depression of 1873–96[5]). In essence, we can see now, the discussion turned on the question of the 'rate of growth' in various sectors of the economy. In the iron and steel industry, while there was expansion, particularly in the new steel works making Open-Hearth steel, particularly in Scotland[6]) and from the mid-1880's, in the north-east of England[7]), this contrasted with the plight of the malleable iron manufacturers deprived of their former markets for wrought iron rails. Finally, as Burn argues, there was a sensational fall in iron prices, but this was due not only to competition between iron and steel but to the general economic situation of deflation.

However, the immediate task is to look at the development of the Bessemer steel itself, to trace its introduction as the raw material of modern heavy industry, railways, shipbuilding, engineering etc.; and, if we can, to study its econonics, the cost advantage of steel over wrought iron.

The fortunes of the Bessemer steel industry during our period were overwhelmingly tied up in the use of steel for rails. As Skelton, economist of the iron and steel industry said: "the iron rail trade was the first attacked." Wrought iron rails wore out quickly; even at the outset, steel seemed a better proposition even if it was much dearer per ton. Bessemer and his supporters argued that the steel rail might be of lighter construction and economies made that way. The first test rails of authentic Bessemer steel to be laid down were at Crewe Station in 1861. A year later, a comparative test was made outside London, at Camden, when one section of steel rail outlasted seven wrought iron rails laid on to the line of track[8]). The price of Bessemer steel was then reckoned by John Brown of Sheffield to be £ 22 per ton. In 1865, the price fell to £ 17 per ton and the next year even further[9]). In that year, 1866, the first order for steel rails came from America. According to Dredge, it was sent by the Erie Railroad Company to Messrs. John Brown & Co. — an order for 1,000 tons at £ 25 per ton. In England, a start had been made; 63 miles of steel rails were laid on the London and North Western Railway[10]). This company had its own converter at the railway works at Crewe. The victory of steel rails over the traditional iron was in sight. A conservative railway company like the Great Northern Railway Company might hedge — in January 1869 it called for tenders for 200 tons of steel rails and 5,000 tons of iron; but the difference in price between iron and steel rails narrowed, reflecting the greater economies possible with the converter and in the next decade the defeat of the iron rail was accomplished. In 1869 the price of steel rails was then £ 9, and of iron rails £ 6.10s. and there was a hope of a further reduction of the £ 1 Bessemer royalty which expired in 1870[11]). The effect of this competition is to be seen in the following figures:

GREAT BRITAIN: PRODUCTION OF RAILS 1870—82 (1,000 tons)[12])

| | Wrought Iron | | Steel | |
|---|---|---|---|---|
| 1870 | | 1,350 | — | — |
| 1 | 1,000 | 1,370 | 200 | — |
| 2 | 975 | 1,270 | 250 | — |
| 3 | 750 | 1,005 | 300 | — |
| 4 | 700 | 1,005 | 350 | — |
| 5 | 300 | 865 | 400 | — |
| 6 | 250 | 855 | 470 | 400 |
| 7 | 200 | 820 | 565 | 510 |
| 8 | 120 | 775 | 700 | 630 |
| 9 | 70 | 675 | 560 | 520 |
| 80 | 170 | 350 | 810 | 730 |
| 1 | 150 | 150 | 1,080 | 1,020 |
| 2 | 60 | 60 | 1,280 | 1,230 |

[5]) Burn, *op. cit.* Chapter III "Competition and the Crisis of the 1870's."

[6]) Gibson, "*The Establishment of the Scottish Steel Industry.*"

[7]) W. A. Sinclair, "The Growth of the British Steel Industry in the late 19th century". *Scottish Journal of Pol. Economy*, Vol. 6, 1959.

[8]) In 1857, according to Mushet, who forged an ingot and had rails rolled from steel made at Ebbw Vale, a similar test was carried out at Derby Station.

[9]) According to Dredge, *loc. cit.* In 1866, with the price at £ 12 per ton, the royalty payable to Bessemer was £ 2 per ton, but there was a 'drawback' of £ 1 per ton if rails were rolled from the ingot.

[10]) Dredge, loc. cit. pp. 944—5.

[11]) Burn, *op. cit.* p. 22. Burn however quotes a Barrow steel maker as thinking that a further reduction was not possible.

[12]) This table is reproduced from Burnham and Hoskins, p. 158. The second series of figures refers to data published by Sir David Dale; source is not given for the first set of figures.

In the same period, according to Burn's figures, the exports of railroad iron fell from 945,000 tons in 1872 to 464,000 in 1879[13]). However, other figures which he cites makes the decline of the wrought iron rail industry even more dramatic and disastrous than one might infer from these export totals. In the United States, where changes were apt to be great, the imports of iron rails from Britain, in 1871, amounting to more than half a million tons, completely fell away by 1876. As Burn says, "By 1876 it was recognised in England that the iron-rail trade was dead[14])." Then, only a few years later, there was to be another frantic spell of railroad building in the U. States, when her own extravagant records in railway extension were broken. Between 1880 and 1882, 27,000 miles of track were laid in three years. The Steel makers, making the most of their new opportunities, shipped 2.8 million tons of steel rails across the Atlantic during that boom[15]). The Bessemer steel industry was launched on a wave of expansion. The rail shops, "triumphs of engineering organisation" were geared to the output of these immense outputs at a very low cost of production. We have quoted earlier the comparative costs of steel rails during the early years of this development; unfortunately we do not have any exact comparable figures for the cost of production by the late 1880's: but Skelton points out some of the comparative economies of steel. One cwt of steel needed 10 cwts of coal for its manufacture as against 30 cwts for wrought iron: there was a saving of 4 1/2 cwts of pig iron. Thus were economies to be won in the use of the two raw materials. Then, there were economies in the size and cost of the plant needed — £ 25,000 against £ 50,000 to make the equivalent of 1,000 tons of puddled bars of iron or 1,000 tons of steel ingots. Only a quarter of the number of workmen were necessary to work the Bessemer steel converters. Skelton summed up his comparisons, arriving at a cost of £ 3.13.0 a ton of wrought iron, and £ 3.7.6. for one ton of Bessemer steel[16]).

[13]) Burn, *op. cit.*, p. 27.

[14]) Burn, *op. cit.*, p. 28.

[15]) *Ibid.* p. 73. As early as 1869, according to Dredge, the three main English steel rail makers — Brown's, Cammell's and the Barrow works — supplied 102,000 tons of rails out of a total of 110,000 tons laid down. By then, however, the American manufacturers of Bessemer steel were beginning production.

[16]) H. J. Skelton, *Economics of Iron and Steel* (London, 1891) pp. 238—41. He assumed the cost of pig iron to be 40/– per ton.

Already by 1880 the output of Bessemer steel exceeded one million tons and this was nearly one half of the production of puddled iron[17]). Now, this "silent revolution" when "iron rails (were) being gradually improved off the face of the earth[18])" was being effected when the wrought iron industry itself had been expanded to meet the mounting demand of the world's countries for railways. There was a very real basis for this demand as is evidenced by the statistics of miles of railway completed in the world[19]):

| | |
|---|---|
| 1840 | 5,262 miles |
| 1850 | 23,304 miles |
| 1860 | 65,558 miles |
| 1870 | 127,887 miles |
| 1880 | 221,887 miles |

The 1870's, as will be apparent, was a decade of large-scale extensions, and the year 1870 was in fact a year of 'mania' with lines projected in America, India, the Balkans and Central Europe. According to Burn, Russia alone ordered from the Cleveland rail rollers £ 3 m of railway equipment. In all, at the peak of the boom, in 1872, exports of iron amounted more than three million tons, of which railway iron was about one-third. At that time, the north of England, the chief manufacturing district of iron rails[20]), was producing 325,000 tons[21]).

The measure of the changing fortunes of this industry, as a result of the competition of steel, can be seen from the fact that ten years later only 5,000 tons was being made at Cleveland. Twenty out of the forty-four puddling firms in the district, according to Burn, became bankrupt. These had owned 821 out of a total of 2158 furnaces[22]). In fact, a number of firms had seen the danger signs and tried to break into the market for constructional iron and plates for shipbuilding; but all this was of no avail.

In Wales, "the old established Welsh makers

[17]) Siemens-Martin (O.H) steel, in addition, amounted to another one quarter million tons, whilst the basic Thomas Steel was only just beginning to get into its stride with a total of 10,000 tons.

[18]) *Circular of Messrs. Shaw and Thomson*, December, 1877 reprinted in *Steel News*, Dec. 1952, p. 11.

[19]) W. J. Larke, "The Iron & Steel Age", *Iron & Coal Trades Review*, 1927, p. 129.

[20]) Scotland, the other important centre of the malleable iron district was not so involved; the bulk of production here went into the local shipbuilding industry.

[21]) Burnham & Hoskins, *op. cit.*, p. 158.

[22]) Burn, *op. cit.*, p. 29. One of these was the firm of Hopkins Gilkes makers of the ill-fated wrought iron Tay Bridge.

largely withdrew from business in 1877, before their resources were dissipated[23])" and this presaged, as we know, a re-organization of the industry of that region. At Dowlais, as was mentioned earlier, we can observe the experience of a company which took out an early licence. One might refer that the subsequent events were instructive and point to the period when the Bessemer process became a real success.

During the first epoch of the Bessemer innovation, up to 1865, it is clear that the Trustees regarded their sad enthusiasm for the new process as "an unfortunate transaction". According to the first agreement with Bessemer they had paid £ 5,000 costs down, the balance was to be paid in two instalments of £ 2,500 each after 3 and 6 months. By December, when it was evident that the Bessemer experiment was going to be unsuccessful, the Trustees naturally were not anxious to pay the last instalment, even though they conceded they had entered into the agreement "on the chances of failure or success." They wrote to Bessemer asking "whether some future efforts ought not to be made by you to render your Patent applicable to the mixtures of ores used at Dowlais before you insist on our fulfilment of the strict letter of the bargain." They further averred "while we believe that we have[24]) done all in our power to aid your experiments we do not think that these experiments have received from you all the attention which we expected you to bestow." Finally, putting it to Bessemer that his reputation and interests were "to a greater extent bound up to the event" they asked for a postponement of the payment until "you can declare to us that you have tried in vain to remove the difficulties which have hitherto thwarted us." The outcome of this approach was that, after an interview with Bessemer, Dowlais paid the outstanding sum "to ged rid of what they considered an unfortunate transaction." A new agreement was drafted but not signed.

There the matter lay until 1861, when Charles Attwood of the Weardale Iron Company apparently approached Dowlais about the possibility of taking over the defunct Bessemer licence. Attwood owned mines in the North of England producing some non-phosphoric iron ores, also ores which could be smelted into spiegeleisen, as ingredient of the Bessemer process. It is significant, too, that now, when counsel's opinion was being sought to discover if Dowlais had any legal powers to appoint Weardale its agent under the terms of the licence, the question was raised whether the original patent or licence also extended to the manufacture of steel. We know nothing of the actual negotiations between the two companies and of the probable Dowlais participation in the venture at Towlan. However, in 1861, the Weardale Coal and Iron Company did have a 50 cwt. converter in operation[25]). (It had been suggested by Counsel that since the original licence did not specify the actual location of the place of manufacture, it was open to Dowlais to sub-contract the manufacturing operations to Weardale. On the question of whether the pneumatic process, as originally licenced, applied to the making of steel, the opinion of Counsel retained by Dowlais was that it did. However, among the *Dowlais MSS* there is the curious and damaging confession by Bessemer that the manufacture of steel was a new departure, quite deduct from the patents of 1854—56 for converting pig into wrought iron: "I could not allow steel to be made under the iron licence.")

Dowlais did not take up active[26]) operations in Bessemer steel-making in South Wales until 1865. In the Report of the Trustees for the year ending 31 March 1866, it is categorically stated "During the year the manufacture of Steel under the Patent of Bessemer & Co was commenced upon, the first ingots being cast on the 5 June 1865 and the first Steel rail rolled on 10 June 1865[27])." The sum of £ 33,227 had been expended on a new Steel Works, of which £ 20,000 was being recovered from Bessemer. Up to that time 2,180 tons of steel ingots had been made[28]). There

[23]) Burn, *op. cit.*, p. 28.

[24]) *Dowlais MSS.* This and the following quotations are taken from a recital of the correspondence between Dowlais Iron Company and Messrs. Bessemer and Longsdon in a brief prepared for counsel's opinion, 1861.

[25]) Erickson. *British industrialists*, p. 154 Possibly this was transferred from Dowlais.

[26]) *Dowlais* MSS. (Folder, correspondence with Sir Henry Bessemer 1896–97). A letter dated 4 Apl 1897 describes the negotiations [in 1865 or 1866] when, according to Bessemer "on condition of their entering into a Steel licence with me at the same terms as other people, I spontaneously offered to pay back the £ 10,000 I had received for the useless iron licence."

[27]) *Dowlais* MSS. Report 31 March 1866.

[28]) Dowlais asked for £ 30,000 for the old licence. Bessemer describes the ensuing negotiations: "I slept at Dowlais House and after breakfast next morning while the carriage was waiting at the door, to take me to the Railway Station, Mr. Clark said should I be satisfied to deduct £ 20,000 from their first steel royalties. This I cordially accepted . . ."

appeared to the Dowlais managers, "Every indication of a fair profit occuring to solid steel rails."

The subsequent history of steel making at Dowlais must be shortly related. To summarize one's impressions of the results of this innovation, at the outset, it may be observed that, although Dowlais steel rails did not command the same high reputation as those from Sheffield, nevertheless, the profits and rate of return on the Bessemer investment were "very handsome." In 1867—68, these amounted to 52 % on an outlay of £ 41,469. The Trustees could report, "The profits already have re-couped the amount of capital invested."

The year by year[29]) reports of the Dowlais works enable us, however, to trace in more detail, the working out of the economics of the new steel manufacture as against wrought iron, particularly in the rail trade in the years up to 1879. At first, even as late as 1865—66, there were technical problems. The reports mention "the numerous experiments made with the various kinds of pig iron in the casting of the steel and in the rolling and hammering of the ingots." Indeed, "This new business of Steel making", was "from the beginning one of great anxiety and labour." However, it is clear that these technical problems were soon solved: costs were brought down continuously and, as we shall see, the problem facing the Dowlais managers was the commercial one of overcoming sales resistance to the product. With a productive capacity of four times the outputs achieved in 1866—67, there was a rich potentiality to be tapped by increasing sales. In 1868, it was admitted: "The manufacturing department has produced extraordinary results, and it is to be regretted that our powers of effecting sales of steel rails are not at all equal to our Skill in making them." Dowlais, then, had sold 7,125 tons of rails in the previous year. But as there was a good margin of profit – of £ 2.12.6 on a Cardiff selling price of £ 12.18.6, there was the possibility of price reductions to compete in the market. Since this profit margin again depended on the cost of production and Dowlais efficiency could yield a cut of 8/1 d per ton in the cost of manufacture of rails each year, this was the source of a "most profitable trade" indeed. There was a great expansion in the manufacture of steel ingots as the following figures shew:

BESSEMER STEEL INGOTS AT DOWLAIS[30])

| | | | £ s d |
|---|---|---|---|
| 1866 | 2,107 | longtons | cost 9. 2. 8 |
| 1867 | 5,793 | „ | 8. 18. 1 3/10 |
| 1868 | 8,551 | „ | 8. 6. 8 6/10 |
| 1869 | 9,088 | „ | 7. 10. 0 4/10 |
| 1870 | 19,767 | „ | 7. 7. 10 1/10 |
| 1871 | 24,228 | „ | 6. 16. 7 5/10 (a) |

By that time, just over half of the total make of the Dowlais blast furnaces was being converted into steel. By this time too, close on 20,000 tons of steel rails were being rolled and shipped to America. This trade yielded an average profit of £ 2.8.8 2/10 d per ton of steel rails as against a mere 18/3 d margin on wrought iron. This explains why the Dowlais Steel works contributed more than £ 54,102 out of a total profit of £ 174,568 — more than 30 %. It is not surprising the Dowlais Company installed another[31]) steel rail mill, a decision justified by mounting orders, a bigger profit margin and increased sales in 1871—72.

This prosperity was not to last; at least not on this scale. In 1876—77 the prices of both iron and steel rails had fallen. In March 1877, Dowlais had orders for 15,180 tons of wrought iron rails at £ 5.16.11 d per ton and 28,810 tons of steel rails at £ 7 per ton. By then, further economies were possible by running the molten pig iron direct into the converters, at a rate of 600 tons a week. Dowlais was also making its own ganister for the linings and the spiegeleisen for the final processes. So, whilst the profit on finished steel was down to £ 1.8.4 6/10 a ton, on the bigger turnovers the Bessemer steel works were able to make £ 16,335 net profit on its year's operations[32]).

[29]) Report for 1868.

[30]) *Dowlais* MSS. Report ending lst April 1871.
(a) The cost difference between 1870 and 1871 was accounted for by the reduction in the royalty to 2/6 d per ton.

[31]) In 1871, it is worthwhile noting that the Dowlais forges were producing 94,105 tons of finished iron — nearly as five times as much wrought iron as Bessemer steel; but the cost differences were down to £ 1.8.0 per ton in favour of wrought iron. In other words, taking into account the lower cost of manufacture and the lower rate of profit on it, wrought or finished iron had an advantage of £ 1.8.0 per ton.

[32]) *Dowlais* MSS. Report for 1877. Dowlais now also had Siemens Open Hearth furnaces and made 18,070 tons of Siemens steel as against 54,660 tons of Bessemer ingots.

By the end of the decade then at Dowlais the triumph of steel had again been demonstrated. More than twice as many Bessemer ingots were being made as puddled bars. Wrought iron was still the cheaper product, costing £ 3.2.4 $^{8}/_{10}$ d a ton; Bessemer steel 5/6 d more. However, even in the wildly fluctuating markets for rails in the post-depression period — prices of Dowlais sales of steel rails fluctuated between £ 4.2.0 and £ 9.11.5 d — these sales consistently yielded a higher margin of profit than the non obsolescent wrought iron of the First Railway Age. It is easy to understand why, in those years of uncertainty, the Dowlais Trustees were sufficiently confident in the competitive power of steel to expand production and yet to put one third of the production into reserve. The economics of Dowlais and of the iron and steel industry[33]) were geared to steel.

There was decline and withdrawal, too, in the Black Country, the traditional home of the wrought iron industry, where malleable iron was used for the many items of ironmongery — edge tools, locks, chains, nails, tubes — as well as for machinery and industrial equipment. Unfortunately we do not know much detail about this period of crisis and re-adjustment to the new forces. But as W. K. V. Gale says, "The technical developments which made cheap mild steel possible took away a great part of the wrought trade. In the last 30 years of the nineteenth century a great number of ironmakers closed their works. Some, like the Thorneycrofts of (the Shrubbery Works) Wolverhampton sold up and retired while they were still in a good financial position, but many were less fortunate[34])." However, the reliance of the oldestablished iron trades on the puddling furnace for wrought iron in the manufacture of such products as chains and anchors for the Admiralty, helped surely to keep the industry alive in the Black Country. Just before the First World War, there were still about 661 puddling furnaces still in existence: this was nearly one half of the 1,500 in the country[35]). In Scotland, however, the situation was not so acute. There had been an annual average production of around 200,000 tons a year in the period up to 1880 and, it is estimated by Gibson that the Clyde shipbuilders must have absorbed between 65% and 70% of the total production[36]). The Scottish malleable iron makers met some competition from displaced English and Welsh manufacturers; however, as Gibson says: "To them the rise of the new English Steel firms was reflected only indirectly in (this) increased competition ... so long as malleable iron retained its supremacy in ship- and bridge-building, there could be no large-scale change-over to steel production in Scotland[37])." However, when the Siemens steel from the Steel Company of Scotland won orders from the Admiralty for steel plates for its ships in the late 1870's, then the Scottish malleable iron firms began to put in Open-Hearth furnaces. This movement accounted for the great spurt in O.H. steel production in Scotland up to 1885.

Bessemer steel, incidentally, had first demonstrated its suitability for the job, in 1863, when a stern-wheel barge had been built. In the following year, according to Dredge, a paddle boat of 377 tons was built for the Humber Steam Packet Company. Two sailing ships, each of about 1,200 tons displacement were also launched in that year. By 1863, there were another six small steel ships to be added to 'Bessemer's fleet[38]). But, as one would expect, headway could not be made until steel as a constructional material had been tested and officially recognized by the Lloyds Registry of Shipping. The following table[39]) in fact, shows how little progress could be made until 1877, when the underwriters of Lloyds first accepted steel-structured ships for insurance.

TONNAGES OF SHIPS UNDER CONSTRUCTION FOR REGISTRATION BY LLOYD'S UNDERWRITERS

| | Iron | Steel |
|---|---|---|
| Dec. 31 1877 | 338,770 tons | 1,110 tons |
| 1878 | 362,537 | 4,096 |
| 1879 | 438,432 | 37,669 |
| 1880 | 750,941 | 82,827 |
| 1881 | 1,081,785 | 183,818 |

[33]) *Dowlais* MSS. Report for 1880. Make of Puddled Bars & Slabs 42,187 tons. Make of Bessemer Ingots 83,460 tons.

[34]) W. K. V. Gale, "Development of Industrial Technology in the Black Country 1700—1904", *Birmingham and its Regional Setting*, 1950, p. 18.

[35]) Gale, *loc. cit.* and Burnham & Hoskins, *op. cit.*, p. 161.

[36]) Gibson, *loc. cit.*, p. 33.

[37]) *Ibid.*

[38]) Dredge, *loc. cit.*, p. 935.

[39]) J. W. Hall, "The Development of the Rolling Mill with the Advent of Steel", *Iron & Coal Trades Review* 1927, p. 159.

Finally, the question of costs was, of course, inescapable. Here, as in the manufacture of rails, large scale production enabled costs to be cut from £ 20 per ton in 1876 to £ 7 per ton in 1884. The greater strength of the mild Open Hearth Steel enabled further economies and steel soon became the cheaper material. From 10% of the Clyde launchings in 1879 the proportion of steel ships grew to nearly 100%, within the decade[40]).

The impact of this change on the wrought iron industry is to be gauged by the facts that in 1883, the production of iron plates reached its maximum, some 732,000 tons; by 1891, this line of production had all but disappeared[41]).

In sum, the total production of puddled bar iron certainly underwent a major contraction in the 1880's. In 1870, when there were about 8,000 furnaces they were turning out some 2,600,000 tons of bars; in 1882, after an erratic period of production in the 1870's, a maximum was reached — 2,841,000 tons. Ten years later, when only about a half of the former number of furnaces were at work, their make was down to roughly 1 1/2 million tons in a drop of more than 50%. The decline, thereafter, was to be progressive, until the pre-war years, 1908—14[42]). These figures mark the absolute decline of the industry. This is indicated, too, in the continuous fall in the percentage of pig iron — the raw material of both wrought iron and steel conversion — actually made into bar iron. Again, according to Burnham and Hoskins, this branch of the industry accounted for getting on for a half of Britain's 6 million tons of pig-iron in 1870. In the next ten years, the result as we have seen of the triumph of Bessemer steel, this proportion was again approximately halved[43]).

Finally, to complete the picture of this process of supersession, we have to give the figures for the rapidly expanding outputs of Bessemer steel (acid and basic); and Siemens — O. H. Steel.

BRITISH IRON AND STEEL PRODUCTION 1868-1880[44])

| | Bessemer Steel | Basic Bessemer Steel | Open Hearth Steel | Crucible Steel |
|---|---|---|---|---|
| 1868 | 110,000 | | | |
| 1869 | 160,000 | | | |
| 1870 | 215,000 | | 25,000 | |
| 1871 | 329,000 | | 28,000 | |
| 1872 | 410,000 | | 40,000 | |
| 1873 | 496,000 | | 77,500 | 5,900 |
| 1874 | 540,000 | | 90,000 | 3,300 |
| 1875 | 619,785 | | 87,969 | 4,000 |
| 1876 | 700,000 | | 128,000 | 4,150 |
| 1877 | 750,000 | | 137,000 | 3,900 |
| 1878 | 807,527 | 20 | 174,000 | |
| 1879 | 834,222 | 1,150 | 174,939 | |
| 1880 | 1,044,020 | 10,000 | 250,913 | |

[40]) Gibson, *loc. cit.*, p. 34.
[41]) Burnham & Hoskins, *op. cit.*, pp. 158—9.
[42]) Burnham & Hoskins, *op. cit.*, Table III, p. 320.
[43]) *Ibid*, p. 156. It is curious, however, that the actual figures of the production of 'puddled bars' do not confirm this trend. It is possible, however, the great drop in rail output explains this discrepancy.
[44]) Source. Figures supplied by the British Iron & Steel Federation.