Book reviews

Joan Day and Ronald F Tylecote (editors), **The Industrial Revolution in Metals**, Institute of Metals, London, 1991. vi + 318 pages. ISBN 0-901462-82-9. £37.50 (HMS members: £30.00 + £2.50 postage from the Institute of Materials)

One of the problems for any professional or academic is keeping abreast with the constant outpouring of monographs and journal publications, not only in terms of time but also cost. Single-volume surveys of the literature are therefore especially welcome. This collection looks at the great surge of technical innovation which gave Britain the commanding lead in metals production from the second half of the eighteenth century into the early nineteenth. Five chapters cover the development of techniques and production in the following subject areas: 'Tin Preparation and Smelting' (Bryan Earl), 'Lead Ore Preparation and Smelting' (Lynn Willies), 'Copper, Zinc and Brass Production' (Joan Day), 'Iron in the Industrial Revolution' (R F Tylecote), and 'Steel in the Industrial Revolution' (K C Barraclough). Joan Day also provides a lengthy introduction and Barraclough adds a brief appendix on the chemistry of metal manufacture. Each of the contributors, an expert in their respective fields, attempts a broad survey from the latest research, which is documented in the numerous footnotes at the end of each chapter.

HMS Members will already be familiar with the content of some of the various sections. However, it is a tremendous convenience having the material in one volume. Barraclough's contribution, for example, is nothing less than a condensation of much of his two-volume **Steelmaking Before Bessemer** (1984); Day usefully summarises her work on the Bristol brass industry; and the others present findings from a wide range of journal articles and primary sources that are not easily available.

Both a sampler and a reference work, this volume is fascinating to dip into, less easy to review. The articles stand alone: but together they describe the initial transfer of skills from Europe to Britain; attempts to utilise coal in place of scarce wood supplies; and the development in little over thirty years, from 1678 onwards, of most of the basic techniques for producing the most important metals by using coal fuels. The introduction makes a brave attempt to sketch most of the other factors involved as events gathered pace: the steam engine, rolling mill technology, and the growing level of industrial activity which reversed an old trend by increasingly attracting Continental 'spies' to Britain after the 1750s.

Not much time is spent in actually defining the term Industrial Revolution, though in the introduction it is said that for the metallurgist the revolution stemmed from 'new techniques arising from the exploitation of coal'. Ironically, the main impression of the book is the gradual **evolution** of metallurgical skills in Britain both before and during the so-called Industrial Revolution. One wonders, in strictly metallurgical matters, whether the term is really such a good one, especially since, as the editors admit, one of the major revolutions (in steel) did not happen until the second half of the nineteenth century, when the Industrial Revolution in the accepted sense was over. If there was a revolution, it certainly does not appear to have been a scientific one: several chapters show that chemical principles were unknown, that the main protagonists were skilled artisans, and that scientists had little part to play in metallurgical development.

Until now many of the standard monographs on metals in the Industrial Revolution had been written by economic historians, in which technical matters were not always accurately presented. This volume redresses those failings and is a monument to many years of work by British historical metallurgists (many of them, of course, HMS members). The sense that the book is partly a monument to a generation of scholarship is increased by the fact that two of the contributors, K C Barraclough and R F Tylecote (the latter the prime mover of the enterprise), did not live to see its publication.

In contrast to the miserable offerings of most university and academic presses, it is good to see the Institute of Metals still producing books on high-quality paper, liberally laced with drawings, engravings and photographs. Two small 'extras' would have improved the book further: information on the background and affiliations of the authors; and a bibliography drawing together some of the basic works listed in the footnotes. Event without those, it is an indispensable reference work.

Geoffrey Tweedale

Letters to the Editors

From L M Hogan

May I add some comments to the most informative article by J P Schotsmans on Monsieur de Réaumur (*Historical Metallurgy* 24(2)). The selection of comments by contemporary scientists is revealing but may give some misleading impressions, or at least impressions different from those that I have obtained in recent reading.

In particular, the Baron d'Holbach and Grignon are both quoted as favouring the phlogiston theory in opposition to Réaumur's findings. The phlogiston theory was confusing and gave rise to very vigorous debate. Hence it may be that the comments quoted were intended to be critical, but as I understand it, there was no real conflict between Réaumur's conclusions and the phlogiston theory. Réaumur concluded that the measured increase in weight in the conversion of wrought iron to steel (actually due to the absorption of carbon) was due to the absorption of "sulphurs and salts". In this he was using the current terms, derived from alchemy, which assumed that calx (i.e. a metal oxide) was converted into a metal by absorption of an "igneous principle" derived from charcoal. The igneous principle was identified with sulphur until a German chemist, Stahl, gave it the name "phlogiston" and changed the role of sulphur [1, pp. 33–141]. The phlogiston theory was new when Réaumur was conducting his experiments. In writing of "sulphurs and salts", it is reasonable to assume that he was referring to the igneous principle by its old name. (Salts were included because Réaumur had shown that certain salts accelerated the cementation process). Other workers following Réaumur quickly renamed his sulphurs and salts as "phlogiston". In view of the theoretical ideas of his time, and his own knowledge of the baneful effects of mineral sulphur [1, p. 40], it seems most unlikely that Réaumur was proposing the absorption of mineral sulphur into the iron. The identification of his sulphur with phlogiston would be automatic for protagonists of that theory.

Schotsmans advances several good reasons why the French iron industry was reluctant to expand steel production despite Réaumur's work. Wertime [1, p. 209] proposes another. Despite his brilliant study of the influence of grain structure on properties, Réaumur missed the importance of minor impurities, especially phosphorus, on the properties of steels. Small amounts of phosphorus actually improve the properties of wrought iron, which has negligible carbon content, but when the carbon content is increased, to make steel, a small phosphorus content causes embrittlement, or "cold shortness". Phosphorus also impedes the cementation process for steel-making by inhibiting the absorption of carbon into the iron. Although these effects were not known with certainty until much later, it was known in England that wrought iron produced from English ores was not suitable for cementation. A highly successful cementation industry was built up in England by use of Swedish iron, which was essentially free of phosphorus, and also free of sulphur, which causes "hot shortness" [2]. Swedish iron was also used in Germany.

Most of the French irons which Réaumur recommended for steelmaking had a reputation for cold shortness, which indicates a relatively high phosphorus content. Hence attempts to make good steel from these irons was doomed to failure, including the Réaumur's own establishment of a cementation works at Cosne on the Loire [3].

Wertime [1, p. 208] comments that "a fatal error marred the French monarchy's hope of inspiring the rise of steel manufacturing in France. Concerned about protecting France's blast furnaces and forges from the competition of high grade Swedish wrought iron, it enacted in 1704 a tariff law that in effect taxed Swedish wrought iron much more heavily than Swedish steel. The result — since cementation steel manufacture depended on very pure iron — was to stunt France's industry almost as it was being born".

In the eighteenth century, France was a clear leader in the great expansion of chemical research in that century, culminating in Lavoisier's establishment of the bases of modern theoretical chemistry. Lavoisier clearly determined the roles of oxygen and carbon in the processes of combustion, reduction and oxidation (or calcination). It is ironic that a well-meaning commercial decision should have robbed the nation's industry of the fruits of that knowledge.

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1. **T A Wertime**, *The Coming of the Age of Steel.* University of Chicago Press, 1962.
2. **K C Barraclough, "Steelmaking Before Bessemer"** in vol 1, *Blister Steel.* Metals Society, 1984.
3. **M F Le Play, "Memoire sur la Fabrication et le Commerce des fers à Acier dans le Nord de l'Europe"**, *Annales des Mines*, ser 4, 1 x (1846), 209 ff. Quoted by Wertime [1]

From Manfred B Wolf

The paper by R F Tylecote on Oxidation Enrichment Bands in Wrought Iron [1] is a thoroughly stimulating contribution: the effect of scale formation on enrichment of residual ("tramp") elements in steel tends to be often overlooked — even for hot shortness studies in modern steelmaking, e.g. continuous casting [2].

The very first report about the detrimental effect of copper on surface hot shortness is attributed to Plin in his *Natural History* published about 78 A.D. [3]. Intergranular cracking by liquid phase formation will result from local concentrations exceeding 9% Cu, such enrichment being the consequence of surface scaling (Fig. 1) — as also illustrated by Fig. 5 in Tylecote's paper [1].

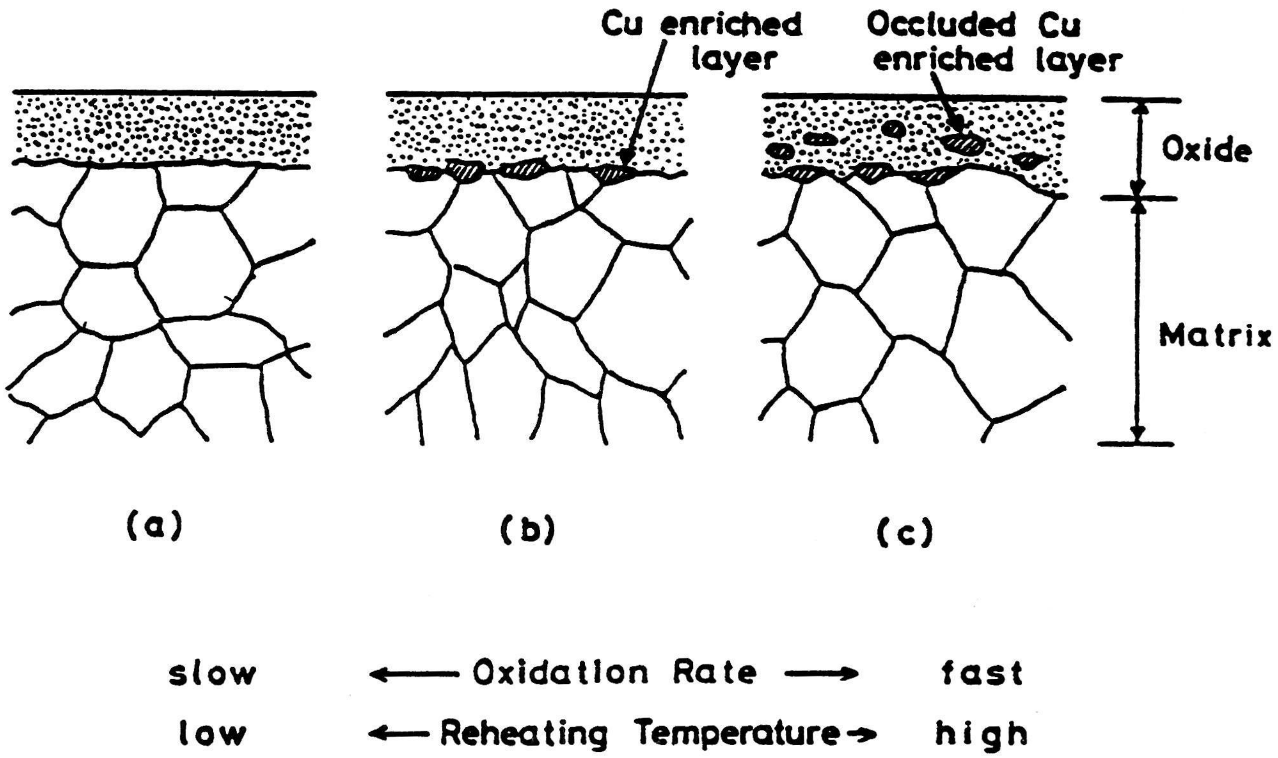

Fig. 1: Copper enrichment at steel surface as function of scaling conditions, schematic[4]

While the peritectic temperature of such a Fe-Cu phase reduces to about 1100°C, the additional presence of arsenic, antimony and/or tin will extend its melting range down to between 650 and 800°C [5]. The latter two elements being strong ferrite formers, they also shift the liquid phase existence to much lower copper concentrations (Fig. 2).

In the presence of nickel, on the other hand, not only the melting temperature of the Cu-phase is raised but also the solubility for copper in the austenitic iron increased (Fig. 2). Furthermore, nickel tends to particle occlusion within the scale (compare also Fig. 4 in [1]) which, again, is favourable to hot ductility. Thus, in modern steelmaking Ni-additions are often made deliberately to Cu-containing steel to preventing surface hot shortness (Fig. 3).

As a result, oxidation enriched surface layers may contain very complex phases, e.g. the following two samples of unalloyed low carbon steel from modern steelmaking:

— Sample A (from [6]): 70%Cu, 15%Ni, 10%Sn, 5%Fe.
— Sample B (from [7]): 85%Cu, 4%Ni, 5%Sn, 1%Sb, 5%Fe.

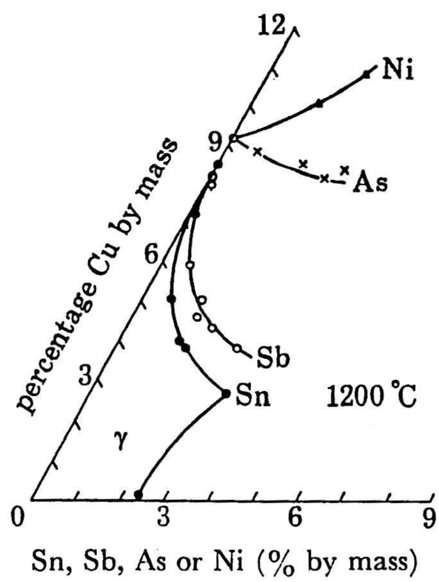

Fig. 2: Fe-corner of ternary phase diagram with Cu and Sn, Sb, As or Ni at 1200°C[6]

Hence, it can be useful to check this whole spectrum of non-oxidizing elements routinely also in studies of ancient lamination techniques, for instance — as purposefully concluded by R F Tylecote [1].

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1. **R F Tylecote** (1990) *Historical Metallurgy*, **24**, 33–38.
2. **M Wolf** (1985) *Ironmaking Steelmaking*, **12**, 299–301.
3. **D A Melford** (1980) *Phil. Trans. R. Soc. London A*, **295**, 89–103.
4. **Y Kohsaka and C Ouchi** (1983) *Copper in steel.* INCRA (New York), p. 9. 1–9.24
5. **M Wolf and H Schwabe** (1986) *Proc. 2nd Electric Steel Congress, Part II*, AIM (Florence), p. P4.8/1–34.
6. **D A Melford** (1962) *J. Iron Steel Inst.* **200**, 200–299.
7. **M H Burden, G D Funnell, A G Whitaker and J M Young** (1977) *Casting and Solidification of Metals*, The Metals Society (London), p. 279–286.

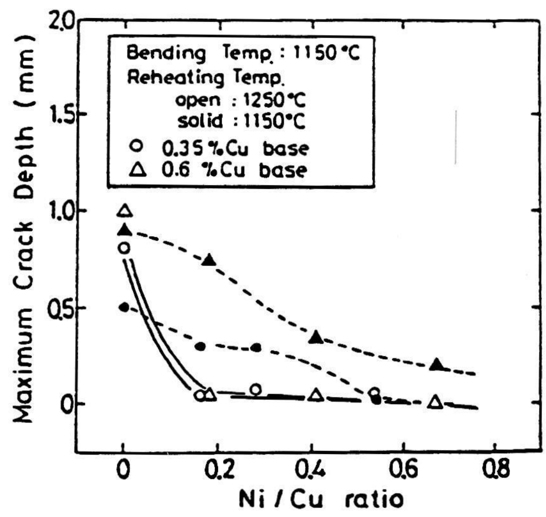

Fig. 3: Surface hot shortness versus Ni/Cu-ratio of 0.1% C-steel for two reheating temperatures[4]