THE CUPOLA NEAR BRISTOL

Smelting lead with pitcoal

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This is the story of an industrial innovation, the smelting of lead with mineral coal. It was not quite the first attempt to do so and may not have been the earliest successful one, but it seems to be the earliest of which any detailed record survives.[1] The process was successful and profitable, but with the unsophisticated accounting systems of the period the proprietors (or some of them) were unable to appreciate that. The missing element in the accounts was depreciation: capital expenditure was written off when paid for rather than over a number of years. The concept of depreciation appeared in the accounting textbooks of the period, but little use seems to have been made of that concept.[2]

Lead has been known since prehistoric times and was originally smelted in what were essentially large bonfires, often on hilltops, known as 'bolehills' in Derbyshire and 'bailhills' in Teesdale.[3] This process was replaced in the sixteenth century by smelting in orehearths in smeltmills, using an artificial draught. This process was not particularly efficient in extracting lead, as a lot of the lead was left in the slag, which was often resmelted in an adjacent slaghearth. An additional problem was that the fuel required was wood, which was a scarce resource. Most industries that had formerly used wood as their fuel (or derivatives such as charcoal) had switched to mineral coal (then called pitcoal or seacoal), but in smelting metals phosphorus and sulphur from the coal are liable to be left in the metal as impurities and affect its quality. In the early eighteenth century the orehearth process began to be replaced by the cupola. The cupola was a reverbatory furnace, that is one in which the fuel was separated from the material smelted. This separation prevented impurities migrating from the fuel to the metallic product, making it possible for coal to be used as the fuel for the first time.[4] This article is mainly concerned with a very early lead smelting cupola, which stood on the Somerset bank of the river Avon, just downstream of where the Clifton suspension bridge has since been built.

I

In May 1676 Sir Clement Clerke had a furnace (probably an experimental furnace) in his house in Channel Row, Westminster. There he found out how to smelt some kind of ore and offered a share in his invention to certain friends. George Skippe recorded in his diary.[5]

> 'I took .. oath of secrecy and Mr Coster and Mr Holden with me to Sir Clement Clerke and he promised me I should have a fourth part in the adventure of oare and did tell me he did not fear but it would be worth to my part 10.000 pounds.
>
> Memo. 18 December Sir Clement Clerke discharged me of this oath in the presence of Mr Coster.'

T.W.M. Johnson interpreted this as concerned with copper ore, apparently on the basis of the later business of the Coster family, but the diary does not say so.[6] Skippe further recorded,[7]

> 'Sir Clement Clerke professed of give me £100 per ann. for all the oar that is brought to stock or shall hereafter be brought in. This £100 for my share of it, but I refused and then he promised me a good quantity of said oar in my house in Channel Rowe to be a security to me for what money I have or shall supply him with and for what I and my estate shall stand obliged for him with and above what he hath already secured me for and he would draw out in a private book where the oar is digged and the manner of working it and leave the saide booke in his ladyes hands sealed up to be discovered to me by his lady when he dies or as soon as he can bring the working of this oar to perfection.'

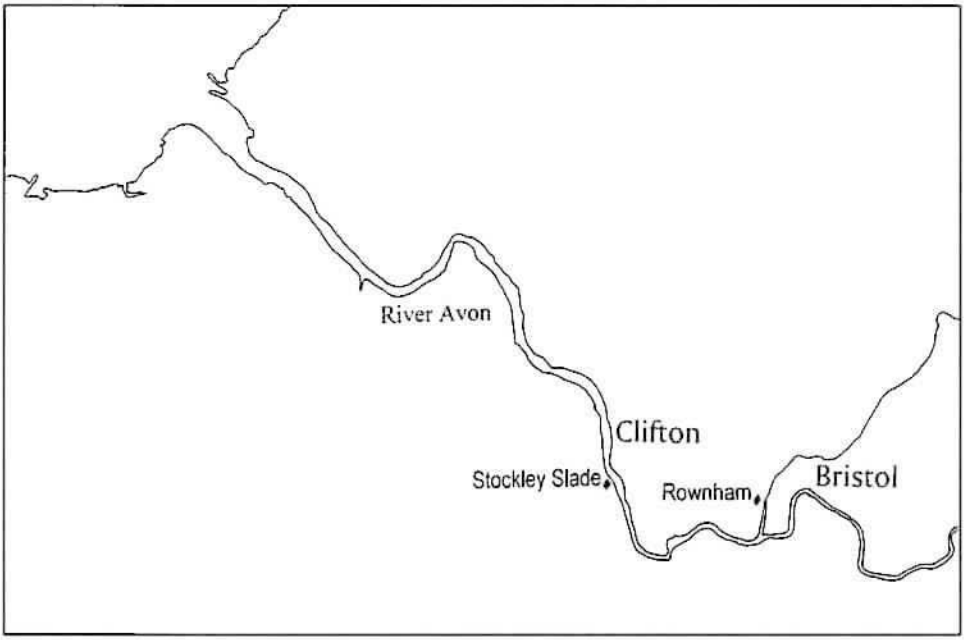
Skippe signed articles of partnership shortly after entitling him to one fifth of the profits after Clerke had received £100 per ton for the ore.[8] This enterprise is shrouded in mystery and it is not even clear what metal was involved, but subsequent events suggest it may have been lead.

Sir Clement Clerke, who had been made a baronet in 1661 without having to pay the usual fee, had married the heiress of a member of the Talbot family,[9] and had engaged in at least one previous metallurgical enterprise. The preceding one, in which Alderman John Foorth was his initial partner, related to iron, but was probably over-ambitious, and had gone wrong almost at the start because Sir Clement had mortgaged his share in it. Even before that he had been a partner in a blast furnace at Dudley. Mixed up with this also was a scheme for the completion of the nearby river Stour Navigation, a troubled enterprise that had already been in progress for over ten years and was probably never completed. When the ironworks business was disposed of, Clerke granted a share in the navigation to George Skippe. Skippe had also been Foorth's partner in the farm of the Somerset excise and like Foorth a partner in the ironworks. He was the eldest son of a gentleman from Ledbury in Herefordshire. 'Mr Coster' may either be Arthur Coster or his brother, John, both of whom will be mentioned again; the family seem to have been concerned in ironworks management at or near Lydney in Gloucestershire and Arthur Coster had been an agent of Foorth and Clerke's ironworks partnership. At this period Clerke's finances were in a bad way, but not yet beyond redemption.[10]

II

A certain Samuel Hutchinson applied in September 1676 for a patent for smelting lead and other metals with pitcoal or seacoal and was granted it that December. Later George Viscount Grandison claimed that he and Robert Thorowgood of 'Lyn Regis' [King's Lynn] had paid for this patent to be obtained and had financed him, but in March 1677 he asserted that Hutchinson was merely using his patent to 'go about to prevent those that have the right invention . . . from exercising it' and that the patent ought therefore to be cancelled.[11] Hutchinson was a member of the London Ironmongers Company and may have been the merchant who obtained a patent for several processes in 1664, including boiling salts, and melting glass.[12] Lord Grandison was a courtier and Captain of the Guard,[13] but in the subsequent litigation never claimed to have done more than put up money.

According to Sir Clement Clerke, Grandison 'well knowing [Sir Clement's] understanding in the nature of metals and reducing ore into malleable metals' sent Francis Nicholson, his 'dependent or agent', who 'insinuated himself into the company of several of [Sir Clement's] servants and by their means and his pretensions of knowledge in those secrets' was able to talk on the subject to Sir Clement, telling him of Grandison's losses due to Hutchinson's failure. Sir Clement replied that lead smelting was 'very feasible and he could at any time do it'. Afterwards Nicholson brought Grandison and Thorowgood to Sir Clement's house in Channel Row, where he 'took some saltpetre and lead ore and thereout brought lead', which as Lord Grandison pointed out would not have been profitable. Sir Clement refused to



reveal more. Lord Grandison then pestered Sir Clement: he 'frequently visited him and invited him abroad to the Rammer Tavern in Chearing Cross and other places.' Eventually Sir Clement was persuaded to show Nicholson his furnaces, Nicholson swearing not to use the process without Sir Clement's consent.

This led to an agreement made in October 1678 for Grandison and Thorowgood to advance £1000 to Clerke and Nicholson, who would then pay a royalty of £1 per ton lead they made. Apparently Grandison expected 5000 tons to be smelted a year, but Clerke later denied promising that advancing £1000 would 'redound profits of £4000 or £5000,' though he believed the works could make such a profit. Nicholson took £500 of this money and 'set up works in Derbyshire . . . but the same turned to loss.' Evidently his imitation of Clerke's furnace was just not good enough.[14] According to this agreement and after a hearing before the Lord Chancellor in respect of a caveat entered by Hutchinson, Lord Grandison obtained a patent for:[15]

> 'A new invention to melt and refine lead ore in close or reverbatory furnaces with pitcoal sea coal or turf peat or other mixed fuel not mixed with wood . . . or charcoal.'

Clerke received £500 and went to Bristol, near which land was rented in March 1678/9 in the name of Arthur Coster at Stockley Slade for the erection of 'such . . . buildings as may be necessary.' These buildings are afterwards referred to as 'the cupiloe'. Stokeleigh Slade is the Nightingale Valley in Ashton Woods on the southwest side of the Avon Gorge below Bristol. The site had previously been let to John and Arthur Scratchfield in 1655 for them to build a 'house for blowing and smelting lead and lead ore,' but they evidently abandoned it as the building was called 'the old bloom house' in a lease of the quarry there in 1660.[16] Sir Clement then asked Lord Grandison for the other £500 and in June or July 1679 went up to London to receive it, but Robert Thorowgood told him on 8 July that he had paid it to Nicholson, whereupon Sir Clement declined to proceed further with the invention. Grandison later alleged there was a new agreement (without Nicholson) in March 1680/1, but later Clerke denied there had been any such, though perhaps some negotiations took place then.[17]

Clerke's response was to petition in July 1680 for a patent of his own for his 'more advantageous way of melting minerals,' proposing it should be for

> 'use . . . of such furnaces fluxes and other materials as he hath found out to be advantageous for the melting of minerals.'

The Law Officers were directed to report, but nothing apparently came of this, perhaps because Clerke could not afford the fees payable.[18] The aftermath of this remains obscure, though Lord Grandison later expected payment of £942.2.0½*d*., a debt apparently due (or partly due) from Sir Clement before 1683.[19] Sir Clement's finances were by this time in a very bad way: he was outlawed for non-payment of various debts at various dates from 1676 until 1681 and these still remained due in 1685,[20] his estate at Rudge in Shropshire (or rather his wife's) was foreclosed in 1682,[21] and an account between him and Skippe in April 1680 showed him owing £1936 to Skippe, apart from a debt secured on Notgrove in Gloucestershire, which Skippe and Sir Clement jointly owned.[22]

III

In March 1682/3 a new agreement was made including (instead of Thorowgood) Lord Grandison's new partner, Mary Ronkswood, who married Hon. Henry Howard on 13 December 1683.[23] It is convenient to refer to Lord Grandison and Henry Howard and Mary his wife together as 'the patentees'; they agreed to advance £500 to buy ore for smelting by Talbot Clerke, Sir Clement's 20 year old eldest son, for whom Thomas Baker was made trustee. The agreement provided for two distinct businesses: in essence the patentees were to buy ore and receive seven-tenths of the lead (called 'the exchange lead') to pay for the ore, and Talbot Clerke, was to keep three-tenths (called 'the overplus lead') to pay the expenses of smelting, but they were each to account to the other half for their profits (though not, it seems, their losses). The £500 was to be deposited with a merchant in Bristol to manage that side of the business, and the Clerkes suggested George Hart for this role. It was further agreed two new smelting works should be built, one in the north of England (meaning near Newcastle upon Tyne) and the other in Derbyshire, the patentees depositing £500 to buy ore for each. The patentees were also to pay for building the works, the cost being repaid them out of the first profits.

Initially the business seems to have gone well: lead was being made by July 1683. For this period the accounts of both George Hart and Talbot Clerke survive, attached to their answers in later Chancery litigation. The accounts at the cupola were kept by John Coster (Arthur Coster's brother), who took in the ore and periodically settled accounts with Hart. Hart was selling both the exchange lead and the overplus lead and paying Coster the proceeds of the latter. Hart's accounts show ore to have been bought from Robert Curtice, Richard Kinge, Robert Weddall and Sir Thomas Grosvenor; Grosvenor had mines on Halkyn Mountain in Flintshire, which Lord Grandison rented. Andrew Barry was employed to buy ore, allegedly having 'formerly been a very near friend of Sir Clement Clerke . . . [and employed] as a means to requite Mr Barry for kindnesses.' However the patentees sacked him when they found he was greatly in debt and could not be trusted unless he gave security (which he could not). The parties orally agreed also to try smelting Welsh slag, from mounds at the smelt mill at Mold in Flintshire. For this, Hart merely kept the cost of the ore and paid over the balance of the proceeds to Coster when he sold the lead. This slag assayed, like the ore, at 14 *cwt*. lead per ton. The patentees later said they should have had exchange lead on the same basis as for ore, but it would have made no difference in the end if the business had been entirely profitable. Ore was probably later also obtained from the Gwidir estate near Conwy where Henry Howard leased mines on the Grange of Greig-uwch-Glan in 1684.

Initially there was a deficit, but eighteen months or so later there was a surplus of £602.2.3*d*. on the smelting account and Talbot Clerke proposed a dividend of £301.1.1½*d*.

He went to see Mary Howard in Bristol, but she demanded the inclusion of a disbursement of £942.2.0½*d.*, which, according to an account of George Hart (not surviving), she and Lord Grandison had 'laid out in buying and sending in ore and other charges about the works.' Talbot Clerke complained he had nothing but the profit of the works to maintain himself and his father and mother, and offered to pay this as soon as he could. He wrote to his father for his accounts, but was 'ashamed' when he next saw Mrs Howard, because his father had refused to send the accounts and had ordered him not to settle accounts in the country, but to come up to London and settle them there. In London he saw Lord Grandison and Henry Howard, who were persuaded to sign the account on Clerke writing out an order to John Coster to pay £131.14.6*d.* towards the disbursement and Clerke paid them their dividend. However Talbot Clerke succeeded in taking away both the order and the account for copying and failed to return the payment order or a copy account, presumably on his father's instructions. Unfortunately it is not clear how the £942.2.0½*d.* was calculated: it does not seem to include the £500 deposited with Hart, which he still had, but it may include a deficit on the ore and exchange lead account. On the other hand the need for Sir Clement's accounts suggests it arose (or included something from) before March 1682/3.[24]

Some preparations had also been made for further works in Derbyshire and in the North of England near Newcastle and £250 allegedly paid to Thomas Baker for building them in November 1683 and October 1684. Mr Wade and Mr Sharpe were hired to look after the two works, sites were selected and a beginning made on collecting materials, but when Sir Clement and Talbot Clerke reached Newcastle they found that Robert Thorowgood, the patentees' agent there had merely provided a quantity of bricks and had no instructions to provide money. On the other hand the patentees later accused the Clerkes of not going there and of converting the money to their own use. Perhaps Thorowgood, as Grandison's disappointed former partner, was not the most appropriate agent. Possibly he had his own side to the story, but unfortunately, though Talbot Clerke made him a defendant, neither he nor Francis Nicholson appears to have filed an answer.[25]

IV

Up to this point the business seems to have proceeded smoothly and probably fairly harmoniously. About July 1683 George Skippe had a report from his son of great profits being made and had been promised an allowance out of them towards the debts which Sir Clement owed to him,[26] but there were ambiguities in the situation, particularly as to the patentees' losses on the previous business with Sir Clement: he said he had expected the documents as to the old arrangement to be delivered up when the new one was made, but Grandison had at the time said he had not got them with him and would sent them. Talbot Clerke referred to a consideration of £1200 being paid for the new agreement, which appears to be the total of Sir Clement's liabilities in respect of the old agreement and a bond, probably for a loan. Grandison said he had delivered these documents to a third party, probably meaning that they were being retained as security for due performance of the new one. Another difficulty arose concerning the transfer of Talbot Clerke's interest out of the name of his trustee, Thomas Baker: this was provided for in the March 1682/3 agreement, but Viscount Grandison demanded alterations, wanting a full partnership in all the works, whereas Talbot Clerke would only agree if he was the manager and on the previous basis; Grandison claimed that Sir Clement had said the agreement could be amended when Talbot Clerke came of age. Additionally there was the issue as to the amount of exchange lead to be provided in respect of slag. On all of these issues there were conflicting statements in the subsequent litigation, which the court does not seem to have resolved, except that the final account did not charge Talbot Clerke with any of his father's debts, nor with losses on the ore account.

After the difficulties over passing the accounts on 13 January 1684/5, the relationship broke down completely. Grandison took the view that Talbot Clerke owed him a lot of money and would not advance him any more. At first Hart continued receiving lead to sell, but it seems Clerke was now using another agent to sell the overplus lead. Hart's account, describing these sales as unsettled, says, 'The cost and quantity of ore sent in from which the above lead proceeds to the cupola cannot be settled and adjusted well without the books Mr Coster keeps of what oare he received at the works and he refuses to let me have it.' The patentees attached a cargo of old iron on its way to the works, though they later released it, and also a debt of £130 in the hands of Samuel Plomer, a Bristol plumber, probably actually £136.9.2*d* for lead sold to him and David Raynon, which were marked 'in dispute' and 'attached' in the account. This was said to be in respect of the £250 paid to Thomas Baker towards building the additional works. To make matters worse, some one intercepted a letter from Sir Clement to his son and this was brought to one of the patentees, probably Mary Howard. In this Sir Clement advised his son not to mark the lead with 'my lord's mark' but with 'TC', to take all possible care to prevent attachments, not to send more than five tons of lead to Bristol at a time, and to be careful of his person, meaning to be careful of being arrested, advice no doubt to be expected from a hardened debtor such as Sir Clement. Talbot Clerke also alleged the patentees had set up a rival works near Bristol, which was subsequently named (in the Master's report) as at 'Mendiffe' [?Mendip]. In February 1684/5 the patentees did provide some ore, but the agent refused to take it in 'and threw the bags into the common way whereby the bags were rotted and the ore wasted,' and he forbad the carriers to bring more.[27]

The issue was further complicated by a project agreed upon in December 1683 to make common lead into white lead at Putney, where Sir Clement Clerke and Dame Sarah (his wife) were then living. This too was carried on in the name of Thomas Baker as Talbot's trustee, but the location suggests the business was actually to be conducted by Sir Clement. The capital of £1000 was provided by Edward Fitzgerald Villiers, Lord Grandison's son, who became an equal partner with Talbot Clerke's trustee, but with the right to withdraw at the end of a year, and his money was further secured on Talbot Clerke's interest in the works at Bristol. Baker stated that no merchantable white lead had been made; if so, it is hardly surprising that E.F. Villiers should have exercised his option to withdraw.[28] To pay him off, £1000 was raised by mortgaging the Laund Abbey estate in Leicestershire, which had been entailed and hence not swallowed up by Sir Clement's debts.[29] This was deposited with Mr Duncumb, a goldsmith in Cumberd Street (sic), who placed his seal on the bags, but neither Lord Grandison nor Sir John Broderick, in whose possession the partnership agreement was, had a power of attorney to receive the money and several months later when no receipt had been provided Talbot Clerke took the money back, perhaps so as to use it to buy ore for the cupola at Bristol.[30]

The patentees said they had attached the cargo of iron (later released) because it was paid for with their money and they did so because Talbot Clerke 'with his agents servants and workmen shut themselves within the said cupulo or workhouse and there smelted lead ore which was bought with [the patentees'] money and [their] refusing to permit Mr Hart or any on [the patentees'] behalf to have any inspection thereof.'[31] The inevitable result was litigation and by May 1685 Chancery proceedings had been started. At one stage the patentees, Talbot Clerke, and Thomas Baker were all suing each other, Baker's objective being to be relieved of his trust, because the Clerkes had failed to indemnify him according to their promise. Sir Clement joined in to clear himself of the claims against him, only to be met with the plea that the patentees ought not to have to answer while he remained outlawed.[32]

The first issue to be dealt with in the litigation was who should run the works. The Lord Chancellor ordered both sides to provide security, which presented no problem to Lord Grandison, but a severe one to Talbot Clerke, and eventually his sureties were found to be insufficient. The patentees further alleged their agent, George Hart, whose inspection of the works had been ordered by the court, had been 'with violence . . . beat of[f] from coming to the works or taking account thereof' and 'the work houses [had been] fortified with armes pikes and other weapons of war in hostile manner so that none dare approach' them. The court ordered that the patentees should have possession of the works, and, when eventually they obtained it on 20 February 1685/6 with the aid of the sheriff, they alleged that Talbot Clerke and his brother, Clement, had taken everything away and demolished the works. The brothers were arrested for contempt, but they were subsequently proved not to have been guilty of such. In the meantime, in April 1687 there was a full hearing and the matter was in the usual way referred to a Master for him to report on it and take accounts. The taking of these accounts proved to be exceedingly prolonged. The report which the Master eventually produced in April 1690, though somewhat incomplete, was confirmed that December.[33]

This report was not a wholly satisfactory one, partly because Viscount Grandison had failed to take part in the hearings before the Master at the proper time, and his objections, made at a late stage, that the Master should have started from an earlier (abandoned) draft report were rejected, but damages for several other breaches of contract, in particular for failing to provide enough ore in February 1683/4 and for a full year from February 1684/5 and setting up the rival work at 'Mendiffe', were never assessed. The works had been managed by Gravely Claypoole during the patentees' possession and until at least April 1688, making a profit of £429.14.8½*d.* Talbot Clerke stated Lord Grandison had offered him £900 per year for his share of the works from the time possession was taken from him, but the Master passed Claypool's account and found £106.12.5*d.* due to Talbot Clerke in respect of the litigious claims.[34] Strangely the final decree made in December 1690 appears never to have been drawn up and it is not clear whether this was because the claims were settled or abandoned.[35] J.N. Rhodes noted that Lord Grandison did not renew his agreement with Sir Thomas Grosvenor for mining rights on Halkyn Mountain, Flintshire, and that his last shipment of ore was in September 1690. He attributed its non-renewal (and his discontinuation of smelting) to his support for James II as a fellow Catholic,[36] but there may have been other reasons, as will appear.

V

While the litigation was in progress, another group were attempting to smelt lead, again somewhere near Bristol. Lord Grandison also proceeded against them in Chancery, accusing them of relying on Samuel Hutchinson's patent and conspiring with him and the Clerkes. Henry Gibbs, John Hodges, and Edmund Driver denied any connection with them and asserted that Viscount Grandison's patent was not valid under the Statute of Monopolies because he was not the true inventor, and that such proceedings were triable at law and not in Chancery.[37] Accordingly that great supporter of the royal prerogative, Lord Jeffreys, as Lord Chancellor, directed a trial at law of an issue that would determine whether smelting lead with seacoal was or was not a new invention. The Chancellor however gave the initiative for organising the trial to Lord Grandison, who did nothing, and had no incentive to do so since he had been granted an interim injunction.[38]

Previous to these proceedings, Viscount Grandison had had Hutchinson's patent declared void by the King and Privy Council on the grounds that Hutchinson was not the true inventor. John Hodges had responded by petitioning for Grandison's to be declared void, but on receiving a long statement from Lord Grandison and apparently without hearing Hodges' answer the Privy Council dismissed the petition, on the inadequate basis that Hodges was not the inventor either.[39] In May 1688 Grandison complained in Chancery that the defendants were proceeding against him and obtained an injunction to stop this, the court repeating its previous order for the plaintiff to try an issue, which he still did not do.[40] This injunction was contrary to the Statute of Monopolies, and should have rendered some one liable to the 'paines, penalties and forfeitures ordained in the Statute of Provision and Praemunire' of 1393,[41] but perhaps Hodges was unwilling to take steps that might have placed him in prison for contempt or have provoked a constitutional crisis. Such a crisis was in fact by then not far away, for the trial of the Seven Bishops took place only weeks later and with its failure James II's attempts to develop an absolute monarchy ignominiously collapsed, leading to his abdication before the year was out. Following the abdication and Jeffreys' fall and death, the defendants, who claimed to have witnesses ready to prove their case at law, obtained a rehearing of their case in July 1689 and Lord Grandison's case was dismissed. He apparently did not even appear at the hearing.[42] The nature of the evidence intended to be presented is not known, but may have referred to the efforts of John and Arthur Scratchfield on the same site or those of Dud Dudley and others at Okham Slade in Clifton.[43] Nevertheless the result was clearly that Grandison's patent was invalid. The works of Gibbs, Hodges, and Driver were also somewhere near Bristol, possibly 'above the bridge at Rowham', where a rival works was bought in 1693 by the Company for Smelting down Lead with Pitcoal. Hodges also took out an Irish patent.[44]

In the meantime, having been prevented from smelting lead, Talbot Clerke and some partners used a cupola to smelt copper and they had copper on sale in London by 1688. The location of this cupola is not clear, but some of the early smelting may have been carried out near London where Talbot Clerke sent ten tons of copper ore in 1688: it can hardly have been at Stockley Slade, since that was in Grandison's possession from January 1685/6 with Gravely Claypoole as his agent in smelting lead there.[45] A patent was taken out for this process by Sir Robert Clerke, Robert Brent and Talbot Clerke in January 1686/7,[46] and this led to the establishment of two copper works at Redbrooke in Monmouthshire and ultimately to a successful British copper and brass industry.[47]

In 1692, when Lord Grandison's patent expired, a new start was made on smelting with coal: a royal charter was obtained incorporating the 'Governor and Company for Smelting down Lead with Pitcoal,' the original assistants (i.e. directors) including Thomas Addison and George Clerke, probably Talbot's brother. Talbot Clerke was appinted an assistant at the second meeting of the company and offered to sell his leadworks near Bristol to the company for £9000, which was satisfied by the allocation to him of half the company's shares. This was presumably the 'cupilo' at Stockley Slade. The following year, as mentioned, the Rowham cupola was purchased. The company apparently did not prove a success, though whether through trading losses or misappropriation is not clear. The company met in May 1695, and, having handed the works back to Talbot (now Sir Talbot) Clerke, dissolved itself.

This moribund company was revived in 1704 when the shareholders of the Royal Mines Copper Company, who were by then working the Grosvenor lead mines on Halkyn Mountain and other mines in that area, bought the shares in the lead company, exchanging shares in the copper company for those of the lead company. The treasurer of Royal Mines Copper Company was Dr Edward Wright of Newcastle upon Tyne, who was also a leading member of the (unincorporated) Ryton Company. He and his partners developed cupola smelting both at Ryton (near Newcastle) and in Flintshire. This may be linked to the setting up of a 'smelting house in the Bishopric of Durham near Newcastle', to which Talbot's servant John Cooke and William Lewis who had worked at the Bristol cupola for seven years had gone. The patentees denied they had built these works, suggesting they had been built by John and Robert Thorowgood and under Hutchinson's patent. The description fits Ryton and suggests that the know-how for those works was provided by Cooke and Lewis. If so, the Bristol cupola was the technological ancestor of all those used in Britain in the 18th and early 19th centuries and their technology was essentially what Sir Clement and Talbot Clerke developed for use at Bristol.[48]

Sir Clement Clerke died in debt in 1693, but Laund Abbey in Leicestershire, which belonged to his wife from the time the mortgage to pay off E.F. Villiers was raised, was preserved for his descendants. Sir Clement's poverty is confirmed by Talbot Clerke's argument for not then paying the patentees' 'disbursement', that he had 'nothing but the profit of the worke to maintain himself and his father and mother.'[49] The younger Clement Clerke, who had been arrested with Talbot, may have become a naval officer.[50] It is not clear whether Sir Talbot Clerke used the cupola after the lead company returned it to him in 1695, but some one probably did since the rent was evidently paid until about 1716. In January 1719/20 Sir John Smyth distrained for three and a half years rent for the cupola then belonging to Sir Peter Floyer and John Higgins, seizing 'the bottom of the furnace and stuff round the works which have some lead in it'.[51]

VI

The question remains as to the extent to which the cupola at Bristol was profitable. We have seen that Talbot Clerke considered that there was £602.2.3*d.* to be divided on the smelting account, whereas Lord Grandison and Mary Howard expected payment of their disbursement of £942.2.0½*d.* and George Hart's account showed a loss of £604.2.7*d.* on the ore account, after charging £100 as 'Mrs Howard's charge about lead ore,' to which she ought not to have been entitled since Talbot Clerke specifically charged nothing for his time and expenses. The ore account was also burdened with Mr Barry's salary, which may not have been money well spent, but having been paid correctly appears in profit and loss accounts.

Since there are detailed accounts both by Talbot Clerke and George Hart scheduled to their answers, and these were examined by the Master, who made some adjustments to them, it is possible to make a rational assessment of the business as a whole. The Master additionally passed the accounts of Gravely Claypoole, who managed the business after the patentees got possession of the works.[52] Both accounts are relatively unsophisticated charge and discharge accounts and do not show any closing stock, nor is there any capital account, but some assessment of the business is possible. The Master found that no exchange lead had been provided for 94 tons of slag, but this quantity does not appear in the account and like £52.11.11½*d.* for half the profit from 29 December 1684 until the time the patentees got possession is to be ignored as belonging to the succeeding period. Clerke, who was responsible for making the majority (in number) of the payments, listed them for each month in a limited number of categories. By analysing his expenditure by category the total smelting costs can be worked out (see table 1). The addition of George Hart's expenditure on ore to this and the deduction of the proceeds of sale of the lead provides a simple profit and loss account for the whole business for a period ending in December 1684 (see table 1). This shows an overall profit of £111.18.8*d*, excluding Mrs Howard's 'expenses.'

John Coster's salary as Clerke's clerk (i.e. manager) was £8.6.8*d.* per month (i.e. £100 per year), which indicates that the account covered a period of 22 months, but his first payment was in July 1683 covering four months. However the first sum for 'workmen's wages' is slightly over double the amount for the succeeding months, suggesting that the accounts cover about 20 months of production, the preceding period no doubt having been spent in putting the furnaces that Sir Clement Clerke had built into order. Mary Howard, stated that when she went to Bristol she had advanced £400, which was probably repaid out of early receipts and it was 'three months . . before any considerable quantity of lead could be smelted.'[53] After this expenditure on workmen's wages crept up from £17.6.4*d.* in August 1683 to £30.16.8*d.* in December 1684 suggesting growing production as the erection of additional furnaces was completed; this was a process which Mary Howard had encouraged. During the period about 468*t.* ore and 460¾*t.* slag were sent in producing respectively about 325½*t.* and 317¾*t.* lead, both ore and slag usually assaying at 14*cwt.* per ton. In addition John Coster charged £20.10*s.* as spent on ore, but it is not clear what happened to the lead from this; since the amount is relatively small, I have ignored it in my computations, whose results follow. The lead produced from the final parcel of slag came about 5*t*.13*cwt*. below

Table 1
Accounts during Talbot Clerke's operation of the cupola

Talbot Clerke's expenses			
Buildings	467. 1. 5		
Labour on buildings	182. 5. 6		
Making well	9.13. 3		
		659. 0. 4	
Production expenses			
repairs	302. 6. 5		
wages workmen	449. 2. 9		
wages labourers	128. 6. 4		
old iron	376. 8.11		
coal	319. 8. 5		
ore	20.10. 0		
sundries	14.16. 2		
clerk's salary	183. 6. 8		
		1794. 5. 8	
			2453. 6. 0
George Hart's cost of ore			
Ore 467*t*.19*cwt*.0*q*.1*lb*.			
(or) 468*t*.12*cwt*.2*q*. 24*lb*.		2592. 3. 2	
slag 462*t*.15*cwt*.		1324.19. 5	
salaries	note a	278. 8.11	
			4195.11. 6
			6648.17. 6
Sales			
'exchange lead'		3691. 8.11	
'overplus lead' from ore	1034.19.11		
'overplus lead' from slag	2030. 7.10		
		3065. 7. 9	
sundry receipts		3.19. 6	
			6760.16. 2
			111.18. 8
Omissions from accounts	note b		
'Potters ore' sold		75. 0. 0	
'exchange lead' not sold 4*t*.2*cwt*.3*q*. 27*lb*.		45.12.11	
			120.12.11
Crude profit			232.11. 7
Adjustment by capitalising building costs			
cost of buildings (as above)		659. 0. 4	
less depreciation (2 years)		146. 9. 0	
			512.11. 4
Adjusted profit			745. 2.11

Notes:
a. £100 charged as Mrs Howard's expenses has been omitted from this computation.
b. Adjustments made by the Master

Source: schedules to PRO. C 10/269/18; C 5/85/26, presented as described in text.

assay, suggesting there was some still at the cupola when relations broke down between Clerke and the patentees. This was probably the origin of the four tons (approximately) exchange lead mentioned in the Master's final report, but this may relate to a subsequent period. The Master also found there was £75 to be divided in respect of 'potter's ore', which Clerke alleged that the patentees had picked from the ore before he received it, and these items increase the profit to £232.11.7*d.*

Applying more modern accounting procedures, the expenditure on new construction (buildings, labour on building, and on digging a well) would be treated as long term expenditure and written off (by depreciation) over a number of years; this might, for example, have been over the term of the lease or of Lord Grandison's patent. As it was, it was charged when spent, and this capital expenditure reduced profits severely. If nine years (the term of the patent) is chosen £659 is written off at £73.4.6*d* per year, of which the first two years would probably have been charged in the account, adding about £513 to the profit to make £745 for 20 months operation. This works out at an average annual profit of £447, a very respectable figure in view of the relatively modest amounts of capital that seem to have been employed. The patentees were supposed to have deposited £500 with Hart and this earned them an annual profit of £224. Even if Lord Grandison had taken into account his losses on his previous agreements with Samuel Hutchinson and Sir Clement Clerke, he would have received a handsome return on his capital. The issue of profit may be approached another way: a profit of £745 was made on smelting 647 tons of lead. This suggests the royalty of £1 per ton under Sir Clement's earlier agreement with Lord Grandison and Robert Thorowgood was not wholly unrealistic, but still probably gave rather too high a share of the gross profit to the patentees, who were after all merely financiers. Thus perhaps that agreement was too favourable to the patentees for Sir Clement to be able to perform it successfully, particularly since most of the profit resulted from smelting slag (see below). On the other hand Mary Howard said 'they were in a position to clear and did clear £1800 per year' until John Coster meddled in the sale of lead on the instructions of Talbot Clerke.[54] The basis of this figure is not apparent, but it accords with an offer made to Talbot Clerke in respects of the time after the patentees took possession.[55] Possibly the figure refers to the £3691 sales turnover of exchange lead in 22 months, in which case turnover and profit have been confused.

In principle limestone (or even iron ore) would probably have been cheaper as a fluxing agent than old iron, and lime was later used, but the Clerkes apparently did not think of that. Old iron cost £5 to £5.10.0*d.* per ton and, though not all the quantities are given, I estimate that 71*t*.15*cwt*. were consumed, contributing 12*s*. to the cost per ton of product. This use of iron and also fluorspar were described by Barba and Schlüter and may well have been an innovation by Sir Clement Clerke, at least in England.[56] The total smelting costs work out at £2.15.5*d*. per ton of lead made. Ore cost about £5.10*s*. per ton and about 28¼*cwt*. ore costing £7.5.3*d*. was needed to make a ton of lead, which could be then sold for about £10.10*s*. leaving a profit of under 10*s*. per ton lead. In addition the ore should probably bear the bulk of the £278.8.11*d*. salaries charged in Hart's account as a general overhead, which would more than absorb this profit; however possibly some of this should be capitalised as being initial expenditure on mining operations that would have born fruit in later years. In contrast slag only cost an average of £2.17.10½*d*., including delivery costs, and all but the first parcel cost less than that. At a yield of 14*cwt*. lead per ton, slag costing just £4.2.2*d*. was needed and with the same average smelting costs, a profit of £3.2.5*d*. per ton of lead was achieved. Thus on the face of it smelting slag produced almost all the profit, but this may be an oversimple solution, since there would have been advantages in smelting lead sulphide ore with slag containing lead oxide because they react together to leave lead.[57]

Gravely Claypoole's account of his administration of the works for the patentees (see table 2) relates to a period from 20 February 1686/7, when they took possession, but whose final

Table 2
Gravely Claypoole's account

Sold			
751*t*.18*cwt*.2*q*.24*lb*. lead			7573.18. 3
profits of 96 (sic) Welsh pottern ore			154.16. 3
old iron, bricks and things out of warehouse in Bristol			30. 0. 0
12 tons, lead out of James Smith's warehouse	note c		135. 0. 0
			7893.14.10
Expenses			
servants wages		967.11.11	
boats belonging to the work		23. 3. 3	
tools and utensils		49. 4. 2	
cooperage etc.		7.17. 6	
incidental charges by particulars		24.18.10	
candles		27. 2. 1	
clay potsheards and spar		86. 7. 3½	
coals		251.13. 9	
old iron		357. 0. 3	
707*t*.13*cwt*.0*q*.9*lb*. Welsh ore		3664. 1. 9	
346*t*.18*cwt*.2*q*.1*lb*. English ore		1820. 9. 8	
25*t*.4*cwt*.2*q*.21*lb*. green ore		63. 1. 6	
5 tons lead delivered Peter Sanderson for account of Brian Wade	note d	50. 0. 0	
			7464. 0. 1½
Crude profit shown	note e		429.14. 8½

Notes:
c. Receipt for lead from James Smith's warehouse actually relates to an earlier period.
d. Presumably an expense of mining.
e. No adjustments for depreciation can be made since the period of operation is uncertain.
Source: PR0, Cd38/235, V, 15 Apr. 1690.

date is unclear. During that time only ore was smelted and its average cost was £5.1.9*d*. This produced a profit of £429.14.8½*d*. on almost 752 tons of lead, or 11*s*.5*d*. per ton, with a slightly smaller consumption of old iron and the use of some 'spar', another recorded flux.[58] However this figure needs to be reduced by £135 to £294, the value of lead actually made by Talbot Clerke in a previous period. In addition there is depreciation, whose amount depends on the (uncertain) duration of the account. If it was three years the profit is reduced to £105. If that is indeed the period, production was clearly at a level considerably below what Talbot Clerke had managed, but most of his profit came from smelting slag, which apparently was not used by Claypoole.

Nevertheless the conclusion seems unavoidable that the process was a potentially profitable one for Talbot Clerke and his colleagues, but that he was prevented from realising that potential by the structure of the business and the unreasonable demands made by Lord Grandison that he should pay off Sir Clement's arrears. Having presumably insisted that his further investment in 1683 should be to a new (solvent) entrepreneur and caused the edifice of a guardianship for Talbot Clerke to be erected, and thus provided the Clerkes with a financial fresh start, Grandison was not content to treat the profit of the new enterprise as compensating him for his loss on the old one, but expected the new smelter to pay the debts of the old one. An additional problem was a lack of sophistication in the accounting systems used in that there was no provision for long term expenditure to be capitalised and depreciated. Thus capital and revenue expenditure were confused, or more specifically cash flow with profit. It is unlikely that Grandison or any of the Clerkes had any training in mercantile bookkeeping, though Hart (as a merchant) must have, and John Coster (whose relatives managed ironworks) probably did, but little use was made of the concept of depreciation at this period.[59] Nevertheless the final straw was evidently Talbot Clerke's failure after the meeting of 13 January 1684/5 to provide a copy of the account and return the signed order for Coster to make a payment towards his father's arrears. A suspicion between Lord Grandison and Sir Clement Clerke is clearly reflected in the unusual structure of the business, with the division of production between 'exchange lead' and 'overplus lead,' whose object was evidently to keep the patentees' money out of the hands of the Clerkes. This suspicion, the result of their past unhappy experiences of each other, was the ultimate cause of the failure of Talbot Clerke's business.

1. I hope to deal with the earlier attempts elsewhere as part of an article on the adoption of coal in metallurgy more generally.
2. A.C. Littleton, *Accounting evolution* to *1900* (University of Alabama Press 1933; 1981 repr.), 223–41; S. Pollard, *Genesis of modern management* (Arnold, London 1965), 237–41; H. Jones, *Accounting, costing and cost estimation: Welsh industry 1700–1830* (University of Wales Press, Cardiff 1985), 158–68.
3. D.T. Kiernan, *The Derbyshire lead industry in the 16th century* (Derbs. Rec. Soc. 14, 1989), 40–84; D.T. Kiernan and R. van de Noort, 'Bole smelting in Derbyshire' in L. Willies and D. Cranstone (eds.), *Bolehills* and *Smeltmills* (Hist. Metall. Soc., 1992), 19–21; John Pickin, 'Early lead smelting in Teesdale' *ibid.*, 25–27.
4. R.F. Tylecote, *A history of metallurgy* (2 edn, Institute of Materials, London, 1992), 113–16 153–56; D. Kiernan, *Derbyshire lead*, 119–63; L. Willies, 'Lead ore preparation and smelting' in Joan Day and R.F. Tylecote (eds.), *The industrial revolution in metals* (The Institute of Metals, London, 1991), 93–111.
5. George Skippe's diary, (Hereford Library, L.C. mss. (outsize), class W.920 Skippe) [hereafter 'Skippe's diary'], 6 May 1676.
6. T.W.M. Johnson, 'The diary of George Skyppe', *Trans. Woolhope Nat. Field Club* 34 (1952–4), 59. I have spelled the name 'Skippe' because that is the spelling he himself used.
7. Skippe's diary, 21 Jun. 1676.
8. *Ibid.* 30 Jun. 1676.
9. *Calendar of Treasury Books* iv *1672–75*, 873; J. Nichols, *The history and antiquities of Leicestershire* iii(1) (1800), 323; Shropshire Records and Research [hereafter Shropshire RR], 6000/14263–70.
10. R.G. Schafer, 'Genesis and structure of the Foley "Ironworks in Partnership" of 1692' *Business Hist.* 13(1) (1971), 29–31; Public Record Office [hereafter PRO], Exchequer bills and answers, E 112/502/70; J.H.P.P. Parker Oxspring, 'Andrew Yarranton, "Worcestershire Worthy" 1619–84: his life and work with special reference to . . . river Stour' (ts. in Worcester Library, class WQ B/Yar), vol ii, *passim*; Skippe's Diary, 10 & 11 Jul. 1676. I hope also to discuss some of these matters more fully elsewhere.
11. PRO, Privy Council Register, PC 2/65, p.506; also *Calendar of State Papers, Domestic, 1677–78*, 40.
12. B. Woodcroft, *Titles of patents of invention chronologically arranged* (1854), no. 146; the events described in the remainder of this section have been described before, though not wholly accurately, by R. Jenkins, 'The reverbatory furnace with coal fuel' *Trans. Newcomen Soc.* 14 (1933–4), 71–2 and J.N. Rhodes, 'The London lead company in north Wales, 1692–1792' (Ph.D. Thesis, Leicester University, 1970), 19–24. Jenkins, uncharacteristically, did not cite his sources, but cited sources in the State Papers and Privy Council Registers in his response to A. Raistrick, 'London Lead Company 1692–1905' *Trans. Newcomen Soc.* 14 (1943–4), 160–1, rather than the Chancery proceedings identified by J.N. Rhodes and me. There is, of course, always room for disagreement when in litigation the parties in dispute told conflicting stories as to what happened; nevertheless the course of events is usually fairly clear.
13. G.E.C., *The complete peerage*, (ed. H.A. Doubleday and others) vi (London, 1926), 76.
14. PRO, C 5/85/26, answer of Sir Clement Clerke.

15. B. Woodcroft, *Titles of patents*, no. 246; PRO, C 9/101/21.
16. L.J.U. Way, 'An account of Leigh Wood in the parish of Long Ashton in the County of Somerset' *Trans. Bristol and Glos. Arch. Soc.* 36 (1913), 72–76.
17. PRO, C 5/85/26, answer of Sir Clement Clerke; also bill; I have not discovered the location of these works, but L. Willies thinks they were near Staunton Harold, just inside Leicestershire, but I have not found evidence for that: L. Willies, pers. comm. cf. 'Problems in the interpretation of cupola lead smelting sites' in *Bolehills and smeltmills*, 40.
18. PRO, SP 44/61, p.4.
19. PRO, C 10/269/18, answer of Grandison & Howard.
20. PRO, C 10/219/27, plea in reply.
21. Shropshire RR, 6000/14274.
22. Shropshire RR, 6000/14275; George Skippe's diary, 6 Apr. 1680.
23. This Henry Howard was most probably a son of the second Earl of Suffolk and succeeded to that title in April 1691, although the *Peerage* indicates him to have been a widower from May 1682 to November 1691. Confirmation of his identity seems to be provided by his elder brother, the third Earl, having married Lord Grandison's sister: G.E.C., *Complete Peerage* xii(1) (1953), 466–75. Lord Grandison and Henry Howard were also associated together as trustees for the daughters of the former's brother, Edward Villiers, and this seems to have been the source of money invested in the leadworks: PRO, C 33/274, f.611.
24. PRO, C 5/85/26; C 10/269/18. The accounts are schedules to the answers of Talbot Clerke and George Hart in these actions. Grosvenor: J.N. Rhodes, 'London Lead Company', 20–21; Gwidir: *ibid.*; W.J. Lewis, *Lead mining in Wales* (University of Wales Press, Cardiff 1967), 67, both citing National Library of Wales, Wynne of Gwidir mss., no.2840.
25. PRO, C 10/269/18.
26. Herefs. RO, B38/139.
27. PRO, C 5/85/26; C 10/269/18; master's report: PRO, C 38/235, V, 15 Apr. 1690.
28. PRO, C 10/269/18; C 10/223/17.
29. Leics. RO, 6D52/7–10.
30. PRO, C 10/269/18.
31. *Ibid.*
32. PRO, C 10/219/27. I have not located Baker's bill, but it is mentioned in his answer to Talbot Clerke's: PRO, C 10/269/22; also C 33/263, f.683.
33. PRO, C 33/266–276 (even nos.) *passim*; especially C 33/276, ff.12 26 185 332; C 33/268, ff.377—78; C 33/274, ff.277 414; C 33/276, ff.146–47. I have not searched for depositions taken for the purpose of the proceedings before the Master.
34. C 38/235, V, 15 Apr. 1690.
35. PRO, C 33/276, ff.146-47. The last order was that the report be confirmed unless cause was shown, which would normally be followed by a decree being drawn up, but there is no sign of such in the entry books.
36. J.N. Rhodes, 'The London Lead Co.', 23.
37. PRO, C 9/101/21.
38. PRO, C 33/266, f.831; C 33/268, f.499; as to Lord Jeffreys generally: G.W. Keeton, *Lord Chancellor Jeffreys and the Stuart cause* (Macdonald, London 1965).
39. PRO, PC 2/71, pp. 263–64 276 293 310–12.
40. PRO, C 33/270, f.435.
41. Statute 21 Jas.I c.3, s.4; Statute 16 Ric. II c.5.
42. PRO, C 33/272, ff.245 290 500.
43. PRO, C 6/191/40; L.J.U. Way, 'An account', 72–3.
44. PRO, C 9/101/21; A. Raistrick, 'London Lead Co.', 124 160; R. Jenkins, 'Reverbatory furnace', 72. 'Rowham' is perhaps Rownham Meadow in Clifton, at the junction of the rivers Frome and Avon.
45. R. Jenkins, 'The copper works at Redbrooke and at Bristol' *Trans. Bristol and Glos. Arch. Soc.* 63 (1942), 146–7; PRO, C 38/235, V, 15 Apr. 1690.
46. B. Woodcroft, *Titles of patents*, no.253.
47. R. Jenkins, 'Copper works'; R. Jenkins, 'Copper smelting in England: a revival at the end of the seventeenth century' *Trans. Newcomen Soc.* 24 (1943–4), 74–78; J. Day, 'The Costers: copper–smelters and manufacturers' *Trans. Newcomen Soc.* 47 (1975), 47–58.

48. A. Raistrick, 'London Lead Co.' 120–32; J.N. Rhodes, 'London Lead Co.', 30–50 172; A. Raistrick and B. Jenkins, *Lead mining in the Pennines* (Longmans, London 1965), 118; PRO, C10/269/18, bill and answer of Grandison and Howard.
49. Laund Abbey: Leics. RO, 6D52/9; died in debt: R. Jenkins, 'Copper smelting in England', 74n; 'nothing but profit': PRO, C 10/269/18, answer of Grandison and Howard.
50. *Calendar of State Papers, Domestic 1689–90*, 397 mentions a Lieutenant Clement Clerke.
51. L.J.U. Way, 'An account', 77–78.
52. PRO, C 10/269/18; C 5/85/26, schedules; C 38/235, V, 15 Apr. 1690; most of the rest of this article is based on these accounts, of which details are shown in tables 1 and 2 respectively.
53. PRO, C 10/269/18, answer of Grandison and Howard; there was a deficit on John Coster's account in the early months.
54. PRO, C 10/269/18, answer of Grandison and Howard.
55. PRO, C 38/235, V, 15 Apr. 1690.
56. R.F. Tylecote, *A history of metallurgy* 113–4; L. Willies, 'Lead ore ...', 107. Amounts of iron have been estimated from their cost since not all quantities are given in the accounts.
57. This 'double decomposition' method was used by the London Lead Company in Flintshire perhaps from 1708; R.F. Tylecote, *A history of metallurgy*, 155–6.
58. L. Willies, 'Lead ore ...', 105–08.
59. See works cited in note 2.

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ABSTRACT:

One of the first cupolas for smelting lead was built at Stockley Slade near Bristol in 1678 by Sir Clement Clerke, assisted by some finance from George Viscount Grandison, but Clerke ran out of money. The project was taken up in 1682 by his son, Talbot Clerke, in a sort of partnership with Lord Grandison and others, but relations between them broke down about two years later over difficulties in settling accounts, leading to lengthy litigation between them. However the application of more modern accounting methods, with building costs being written off over a number of years rather than at once, reveals the process to have been profitable, as well as being successful. This cupola was probably the technological ancestor of all those operating in Britain in the 18th and 19th centuries.

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