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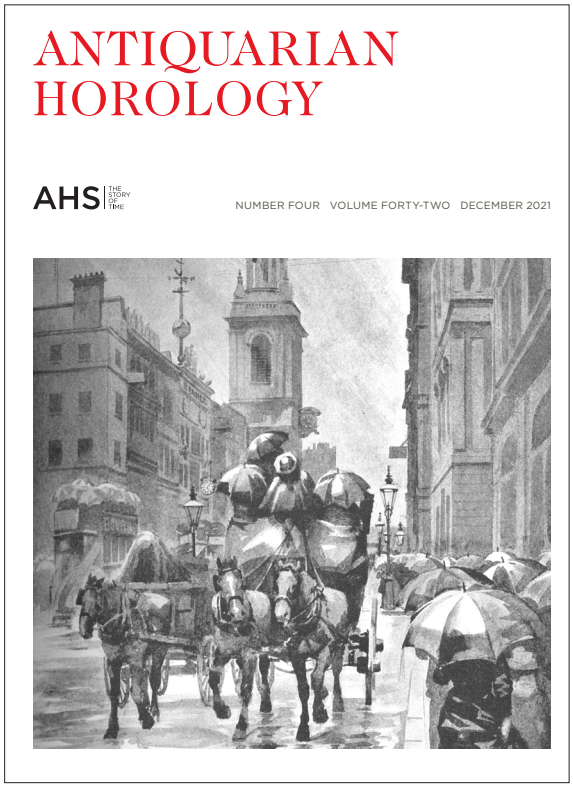
Antiquarian Horology, Volume 42, No. 4 (December 2021), pp. 493–510



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Harrison and Ellicott on watch wheel finishing, with notes on Samuel Hoole

Anton Howes* and Anthony Turner**

In this article we discuss two previously unpublished letters by John Harrison and John Ellicott, preserved in the archives of the Royal Society of Arts. The letters discuss the finishing of wheels for watches, and that by Ellicott identifies the watchmaker Samuel Hoole (1692–1758) as a pioneer of mechanisation in the late 1710s. We provide an account of this hitherto invisible inventor.

Introduction

The character and pace of technological advance in Britain in the eighteenth century has been the subject of considerable debate. Yet while much study by general historians and economic historians has focussed on the industries that contributed most to economic growth – cotton, iron, and steam power – recent studies have highlighted the fact that innovation occurred in a much broader range of industries. Morgan Kelly and Cormac Ó Gráda, for example, have used the prices of 3,200 stolen watches listed in the records of the Old Bailey to show that between 1685 and 1810 the price of watches fell by 75 per cent. What is less well understood, however, is exactly how this occurred, with Kelly and Ó Gráda concluding that much of the innovation leading to it was driven by 'anonymous artisans' and 'invisible innovators'.[1]

Although many of those innovators will no doubt actually be well-known to specialist historians of horology, there are gaps in our knowledge. Especially well-documented are improvements to watch design, produced by the introduction in the 1670s of the balance spring watch, disputed by Christiaan Huygens, Robert Hooke,[2] and others, the introduction of jewelling, innovation in escapements, and the insistence by leading makers such as Thomas Tompion and George Graham on rational work to maintain consistency of running and performance in their products.[3] Marketing innovation however also played a role, especially the introduction into England of lower-quality and therefore lower-cost Swiss watches, which forced English manufacturers also to lower prices.[4]

Yet the technical improvements that would affect watch cost, rather than their accuracy and reliability, are less understood – especially when it comes to the early development of wheel-dividing and cutting engines.[5] As the writer of a guide to the trades of London put it

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1. Morgan Kelly and Cormac Ó Gráda, 'Adam Smith, Watch Prices, and the Industrial Revolution', *The Quarterly Journal of Economics* 131, no. 4 (November 2016), 1727–1752; p. 1745.

2. For an introduction to this controversy see Jonathan Betts, *Marine Chronometers at Greenwich (*Oxford and Greenwich, 2017), pp. 10–11 and references there cited.

3. So Thomas Hatton, who thought Tompion's teeth '…better than our best cut wheels now; at least the wearing of them shew it ;' and that his movement layouts were fully rational 'for he has made a just calculation between his first and last power'. *An Introduction to the mechanical part of clock and watch work in two parts* … (London, 1773), p. 18.

4. Cf. Harrison's remarks at the end of his letter published below.

5. Anthony Turner, 'Not to Hurt of Trade': Guilds and Innovation in Horology and Precision Instrument Making', in *Guilds, Innovation and the European Economy, 1400–1800,* ed. S. R. Epstein and Maarten Prak (Cambridge, 2008), p. 272, note 28, but see now the article cited in note 40 below.

in 1747, the most notable recent advancement in terms of cost was

> the invention of engines for cutting the teeth in the several parts of the movement, which were formerly cut by hand. This has reduced the expence of workmanship and time to a trifle, in comparison to what it was before, and brought the work to such an exactness that no hand can imitate it.[6]

The names of the individuals responsible, especially before the mid-eighteenth-century, have indeed been somewhat invisible.

Thanks to two letters by the prominent, innovative watchmakers John Harrison and John Ellicott, in the archives of the Royal Society for the Encouragement of Arts, Manufactures and Commerce, an important gap in the history of early watch mechanisation can be filled.

The Society of Arts

The Society of Arts, as it was then generally known, was founded in March 1754 with the intention of promoting the public good through the use of prizes, or 'premiums', paid for out of a subscription fund of its members. These premiums could be either honorary or pecuniary, and were decided upon and then judged by the subscribers themselves, voting on everything as a direct democracy – one person, one vote. Conceptions of the 'public good' to be encouraged with premiums were sufficiently broad that such things as the discovery of a cobalt mine, the planting of madder, drawings by young people, and the planting of acorns were among the earliest premiums advertised to the public, with factions of subscribers each vying for their own pet projects to be approved by the wider Society.[7]

On 3 March 1756, Dr Manningham 'by desire of Mr Grignion' proposed to the Society of Arts

> That a premium be given to any apprentices in the watch trade, dwelling in London, or within three miles thereof –
> For the best plain watch movement, (going with a contrate wheel)[8] with the teeth of all the wheels, finished by the same hand; and in order to ascertain that any movement (which may be produced for the premium) was all executed by the same hand, sufficient vouchers must be given to the Society.[9]

The Dr Manningham referred to was the physician Thomas Manningham MD (? –1794), who was proposed to the Society by one of its co-founders and vice-president, Lord Romney in 1755.[10] He was an active member of the Society, proposing that it use standing sub-committees to deal with the details of submissions for prizes and their advertisements,[11] and that there be a portion of funds set aside for inventors to apply for unsolicited bounties in addition to the advertised premiums.[12] Beyond such administrative involvement, however, he was also an influential link between the Society and the country's aristocratic and commercial elites, frequently acting as its representative. He persuaded the Duke of Richmond to open his collection of antiquities to the young people who were competing for the Society's prizes for drawing,[13] for example, and via his

6. R. Campbell, *The London Tradesman: Being a Compendious View of All the Trades, Professions, Arts, Both Liberal and Mechanic, Now Practised in the Cities of London and Westminster. Calculated for the Information of Parents, and Instruction of Youth in Their Choice of Business. ... By R. Campbell, Esq. (*London, 1747), pp. 250–51. In this, as in all other quotations from original sources and in the transcriptions of the letters, the original grammar and punctuation have been preserved, but capitalization has been modernised.

7. Anton Howes, *Arts and Minds: How the Royal Society of Arts Changed a Nation* (Princeton, 2020).

8. That is: a standard, but high-quality, movement with a verge escapement.

9. RSA/AD/MA/100/12/01/01, p. 102.

10. RSA/AD/MA/100/12/01/01, p. 20: 19 March 1755.

11. RSA/AD/MA/100/12/01/02, p. 4.

12. RSA/AD/MA/100/12/01/02, p. 145.

13. RSA/AD/MA/100/12/01/02, p. 149.

connections as deputy grand master of the Freemasons' Premier Grand Lodge of England 1752–56,[14] he recruited the Marquis of Carnarvon, Baron Carysfort, and a number of MPs as members.

'Mr Grignion' is likely to be the watchmaker Thomas Grignion (1713–1784),[15] who, at the beginning of his career when he worked with his father, Daniel Grignion (1684–1763), did so as a finisher for Daniel Quare (c.1657/8–1724).[16] Thomas Grignion had been proposed a member of the Society by Dr Manningham, on 7 May 1755,[17] and was himself soon active in recruiting new ones, including some leading lights of London's scientific community such as the physician Richard Conyers MD (? –c.1759), censor of the Royal College of Physicians,[18] and the coffee-house natural philosophy lecturer Erasmus King (d. 1760)[19] – a surprising introduction, considering King had assisted the experiments of one of the Society's principal founders, Stephen Hales.[20] Grignion would also, among others, later recruit the celebrated architect William Chambers (1723–96)[21] and the Birmingham printer John Baskerville (1708–75),[22] as well as donating a clock of his own construction for the Society's use – one that graces the Great Room today (Fig. 1).[23] There is also a possibility that the Mr Grignion who proposed the premium was his aged father, Daniel, given the allusion to the regulatory function of guilds, and its concern about the replacement of workers with machines:

> For some years past there have been contrivances for finishing[24] the teeth of watch wheels by engines made for that purpose, which has occasioned a neglect in teaching apprentices the manner of finishing those wheels by the hand; and as the finishing wheels is one of the most curious branches of a movement, by the neglect above mentioned many apprentices are unqualifyed to exercise their art properly, or to commence watch finishers, for it being the duty of a watch finisher to see that every part of the work be equal &c; but particularly the teeth of the wheels; the art must suffer if a part be neglected; and as London has hitherto been allowed to fabricate the most excellent performances in this art; the giving this premium may be of publick utility by making this branch of the art more general in the trade.[25]

As a non-subscriber it is unlikely that Daniel would be allowed to propose a subject so directly for the Society's consideration. Given the rather conservative and old-fashioned

14. *The Free Mason's Pocket Companion: Containing, the Origin, Progress, and Present State of That Ancient Fraternity; the Institution of the Grand Lodge of Scotland; Lists of the Grand Masters and Other Officers of the Grand Lodge of Scotland; Their Customs, Charges, Constitutions, Orders and Regulations: ... To Which Is Now Added, a Collection of the Most Approved English, Scotch, and Irish Songs* (London, 1792), p. 82.

15. Dates from Brian Loomes, *Watchmakers and Clockmakers of the World : complete 21st century edition* (London, 2006), p. 326.

16. 'Thos. and Danl. Grignion, finisher to the late Mr. Danl. Quare, at the King's Arms and Dial in Russel [sic] Street, Covent Garden'. Trade card in the J. E. Hodgkin Collection (an extensive collection of trade cards sold at Sotheby's in 1914), cited from F. J. Britten, *Old Clocks and Watches and their Makers*, …, 6th edition (London, 1932), p. 759.

17. RSA/AD/MA/100/12/01/01, p. 35.

18. RSA/AD/MA/100/12/01/01, p. 46.

19. RSA/AD/MA/100/12/01/01, p. 65.

20. John H. Appleby, 'Erasmus King: Eighteenth-Century Experimental Philosopher', *Annals of Science* 47, no. 4 (July 1, 1990), 375–92.

21. RSA/AD/MA/100/12/01/01, p. 209.

22. RSA/AD/MA/100/12/01/03, p. 115.

23. RSA/AD/MA/100/12/01/03, p. 59; RSA/AD/MA/100/12/01/04, p. 153.

24. The action today known as 'rounding up' (as Harrison also calls it in his letter), that shapes the part of the wheel tooth beyond the pitch line (the addenda).

25. *Templeman's Transactions* ii, 'Transactions relating to Mechanicks', 139–140. Dated 1754-58, unpublished, archival reference: RSA/PR/GE/118/134.

Fig. 1. Floor-standing centre-seconds clock presented to the Royal Society of Arts in 1760 by Thomas Grignion. Photo by courtesy of the Royal Society for the Encouragement of Arts, Manufactures and Commerce, London.

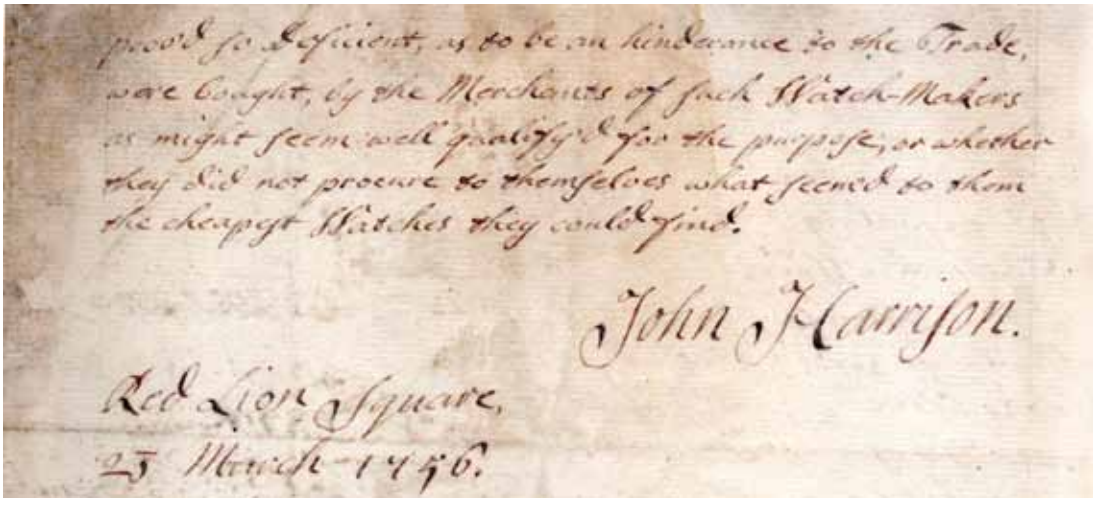
tone, however, it may be that the father is speaking through the son. That Thomas Grignion should ask Manningham to present the proposal on his behalf seems a little strange, but it was not unheard of.[26] He may have wanted to give his proposal a gloss of impartiality, by having it read from a letter. He may have seen Manningham – who frequently rubbed shoulders with marquesses and dukes – as a more effective champion for his proposal. Or he may simply have been uncomfortable with public speaking. Presenting to the assembled Society could be a nerve-wracking affair, apparently even intimidating such literary wits as Oliver Goldsmith and Dr Johnson.[27] Perhaps most likely of all, he may simply have been out of town, or on other business that evening, for the following week discussion of the proposal was postponed another week with a note that 'Mr Grignion be desired then to attend', along with John Harrison (1693–1776).[28]

Harrison was never a member of the Society of Arts, but he already seems to have been an obvious choice to the Society as an expert witness. He had, after all, already won the Royal Society's Copley Medal in 1749, even if his development of the marine chronometer was still ongoing. On 17 March 1756, Grignion and Harrison attended the Society's general meeting, but they were apparently unable to sway the assembled members either way, so the matter was referred to a subcommittee for more detailed consideration. Following the emerging custom of the Society, this committee was made up of whichever subscribers were interested in the matter, and Grignion was 'desired to speak to some of the watch trade, and desire their attendance at the same time'. This again suggests that the Mr Grignion in question was Thomas, rather than Daniel, as only a member would have been asked to act so on the Society's behalf.

26. Letters were, for example, at around the same time read on behalf of even some of the principal members of the Society, including Stephen Hales, the president Viscount Folkestone, and vice presidents like Charles Whitworth. We can only assume that they were out of town, or on some other business.

27. Howes, *Arts and Minds*, p. 24.

28. RSA/AD/MA/100/12/01/01, p. 104. The following year Harrison would himself be a contender for a Society of Arts premium in a competition to find a effective hand mill for grinding corn. Unfortunately Harrison's model was overworked, broke and was rejected. The circumstances are described in a letter from James Ferguson (also a competitor), to Alexander Irvine 17 January 1758 printed in E. Henderson, *Life of James Ferguson in a brief autobiographical account and further extended memoir* (Edinburgh, London & Glasgow, 1867), pp. 225–30.


proofs so deficient, as to be an hindrance to the Trade,
were bought, by the Merchants of such Watch-Makers
as might seem well qualify'd for the purpose, or whether
they did not procure to themselves what seemed to them
the cheapest Watches they could find.

John Harrison.

Red Lion Square,
25 March 1756.

Fig. 2. Signature page of John Harrison's letter (RSA-PR-GE-110-2-100), transcribed in full below. Photo by courtesy of the Royal Society for the Encouragement of Arts, Manufactures and Commerce, London.

Unfortunately, the records of the subcommittee's attendees and deliberations have not been found. We simply know that on 24 March 1756 Charles Whitworth (c.1721–1778), an MP and early member of the Society, reported its conclusions back to the generality of members. Whitworth, as one of the Society's early and active vice-presidents, had almost certainly chaired the meeting:

> Mr Whitworth reported from the committee appointed to take the plain watch movement into consideration, that several gentlemen of the watch trade had attended the committee, and upon due examination of the matter, and reading some letters on the subject in question; the committee were of opinion, that giving a premium for the best plain watch movement would not be of so great use to the trade as other things that might be proposed.

John Harrison's letter

Following this negative report, the Society dropped any further discussion of Grignion's proposal.[29] But we do have the prepared testimonies of at least two of the 'several gentlemen of the watch trade' that were consulted, both of which explain the committee's rejection of the idea. The first written testimony, dated the day before the committee met, was of course by John Harrison (Fig. 2), who had already been consulted:

> Some account of the cutting down[30] and of the rounding up the teeth of the wheels of watches
> It is in the first place allowed by all, that not any the best hand whatever can make the notches for the teeth, or what is generally term'd, cut the wheels from the blanks so equally by far as may be done by an engine; and in consequence thereof it must so follow, that after a long abuse, and hurry in the using of such engines, as is frequently the case, they cut down the notches or teeth unequally, it cannot be in the power of the best hand, and with the best eyes, together with the help of glasses, by what is called an equaling file,[31] to render them equal, tho' in that case, and the which is too common, they may be

29. It was briefly considered and rejected again in 1761, when the Society's records were examined by a subcommittee that systematically reviewed all prior proposals. RSA/AD/MA/100/12/01/06, p. 214.

30. Slotting.

31. Slender files for getting between wheel teeth to amend cutting or dividing errors. For three slightly earlier French files, illustrated by Thiout, see Fig. 3, for simpler, rectangular section English files in John Wyke's tool catalogue, see Fig. 4.

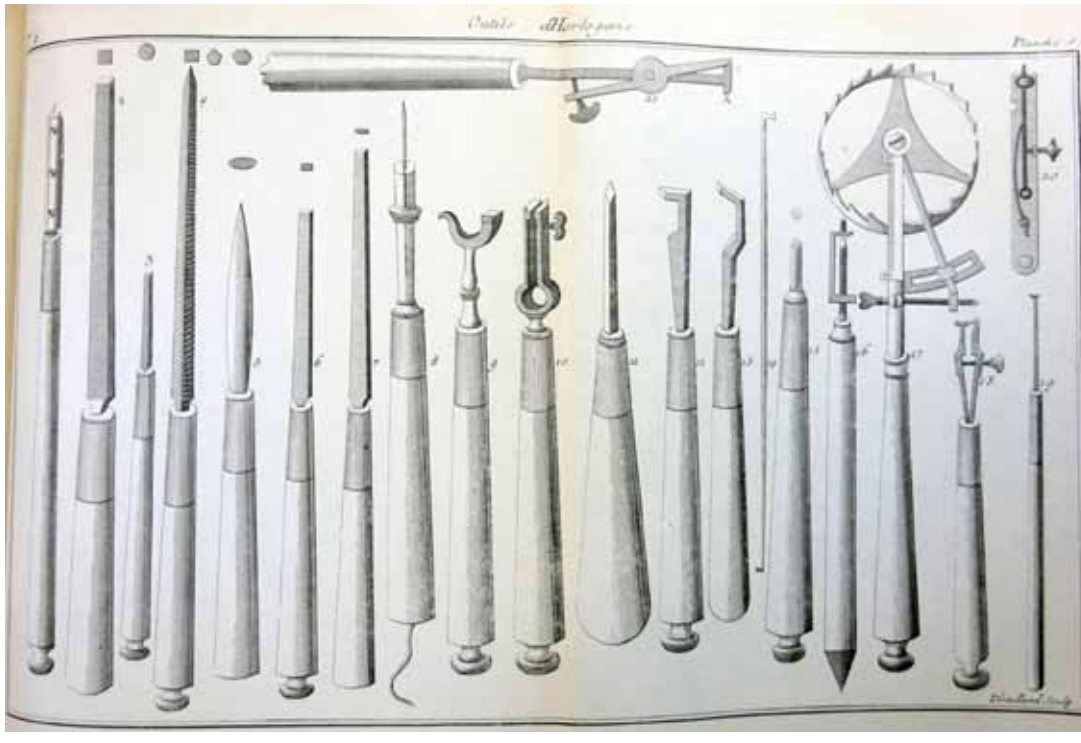


Fig. 3. Antoine Thiout, *Traité de l'horlogerie mécanique et pratique...,* 2 vols (Paris, 1741), i, plate 8. The equaling files are numbers 17, 18 and 21.

render'd somewhat better than from such an imperfect, or jaded engine; but here on the contrary it ought to be observ'd, that not admitting of any abuse to the engine, as may easily be the case, and where, as common, the plate for the dividing, cutting, &c of watch-wheels, may be at least so much as 4 or 5 inches radius, and where the divisions thereupon may be as true as if design'd for a quadrant for making astronomical observations, their result therefore upon the small radius or periphery of a watch wheel, must be, as with respect to the sense of seeing to truth itself; but notwithstanding, if not to be say'd to be mathematically true, they must however be allowed to be infinitely nearer thereto than is possible to be done by the hand and file, nay in consequence hereof, or as it were by corollary, the divisions of a plate (at their distance from the center) may be, if try'd by nice compasses, perceptibly unequal, and at the same time a watch wheel cut therefrom may, as to sense be equal, yea so, as that the eye, assisted by a glass cannot discern any inequalities therein, whereas, as it is certain these must then be some, altho' not to be discerned, so as to be amended by an equaling file: And the same may be said, even with respect to the rounding up of the teeth, yea, when that is become the chief of what is wanting; for, supposing the notches of a wheel to be cut down at a proper width, and by a perfect engine, consequently no amends to be made therein by the absurd method of an equalling file, a good hand may indeed round up such a wheel pretty well, but not so well as can be done by an engine, in that it is impossible he should always keep his hand so exactly perpendicular to the plane of the wheel, and at the same time to make the tops of each tooth exactly of the same curvature, so well I say, as in both respects are to be had from the natural properties of a good engine: Hence, it must by perfect engines, and a perfect use thereof, be the most practicable and perfect method, whereby such a matter may be completed;[32] but then, it must be allow'd, that in the using of such engines, and in order that they may

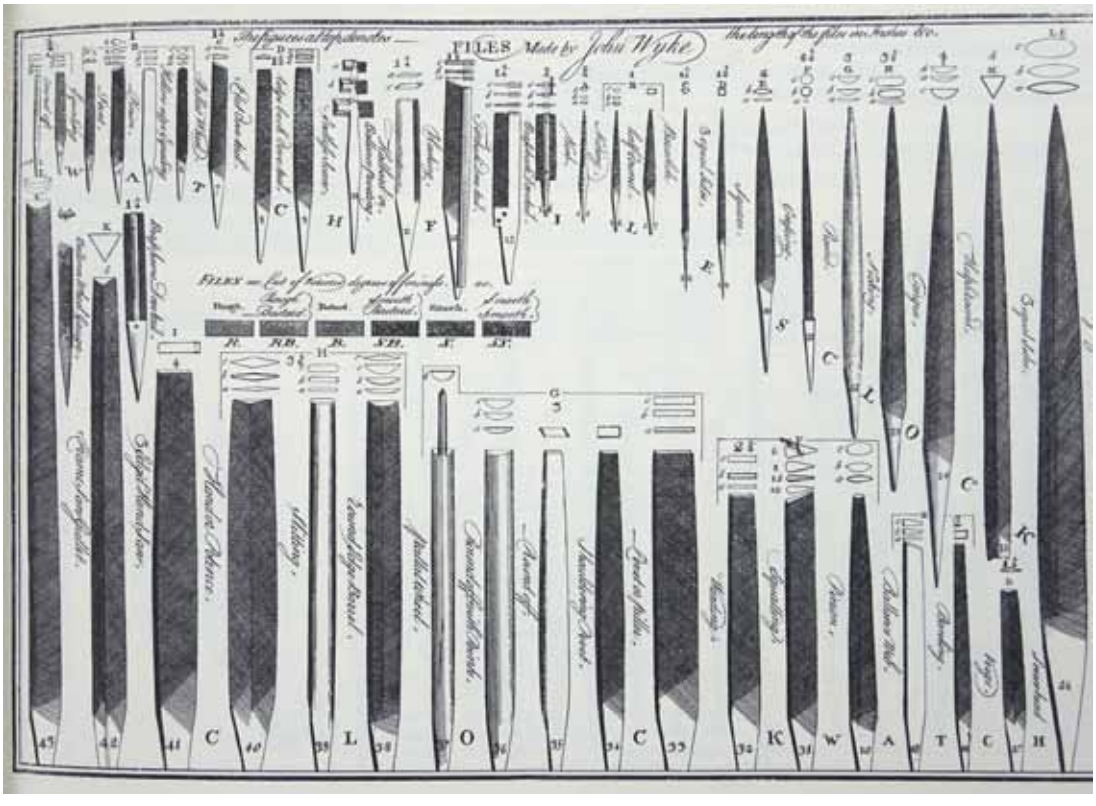


Fig 4. Plate 1 from John Wyke's tool catalogue. The rectangular section English equalising files are numbers 2 and 32. This plate was probably engraved between 1758 and 1759, see Alan Smith, *A catalogue of tools for watch and clock makers by John Wyke of Liverpool* (Charlottesville, 1978), p. 15, pp. 25–26.

retain their exactness for many years, or even for ages, it must (I say) be allow'd, that in such deliberate using of them as is necessary, there ought at least to be twice as much given[33] for the cutting down &c of one wheel, as is commonly given for a whole set; and still the price or charge of the whole would be but small, yea still, but so as to bear a small proportion to the price of a good watch. But to proceed, (after what has hitherto been said) it is much more to be observ'd that the complaint which has of late arisen from the non-performance of watches, as with respect to what has been done before, or to what ought to be, has not resulted from what has been treated of above, viz. from neither their wheels being done by engines, nor by hand; but from whence such great imperfections may principally result, can hardly be said to be the proper enquiry of any society, as being only to be rightly provided against by such persons, as unto whom it pleases God to give a talent for the purpose, and of which sort there has been for many years past, and is at present such a sufficiency as may, by proper encouragement be able to supply the world: But on the other hand, it ought rather to be the enquiry of a society to know, whether the watches which prov'd

32. A few years later in the *Encyclopédie*, Ferdinand Berthoud, although he was discussing escape wheels not trains wheels, was of much the same opinion about machines and their users. 'La justesse d'une roue d'échappement dépend sur-tout de la justesse de la machine qui sert à la tailler, elle dépend aussi des soins de celui qui le fend.' (the goodness of an escape wheel depends above all on the goodness of the machine used to shape it, it depends also on the care of he who cuts it). Diderot & Dalembert, *L'Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers* …, viii (1765), p. 308.

33. Paid.

> so deficient, as to be an hindrance to the trade, were bought, by the merchants of such watch-makers as might seem well qualify'd for the purpose, or whether they did not procure to themselves what seem'd to them the cheapest watches they could find.
> John Harrison.
> Red Lion Square,
> 23 March 1756.

Harrison underlines the superiority of machine-finished wheels. He also points out that whether watches are finished by engine or by hand, if the workman be incompetent or the machine defective the result will also be poor. For him recent complaints about poor quality watches are not to do with how the wheels were cut and finished, and that anyway should not be the concern of the Society. Rather, it should concern itself with the sources of supply. For Harrison the retailers are the villains in propagating poor quality watches, cheapness being all, and the Society should demonstrate this. But this suggestion went beyond the Society's aims, which were to encourage invention not to investigate trade practices.

John Ellicott's letter

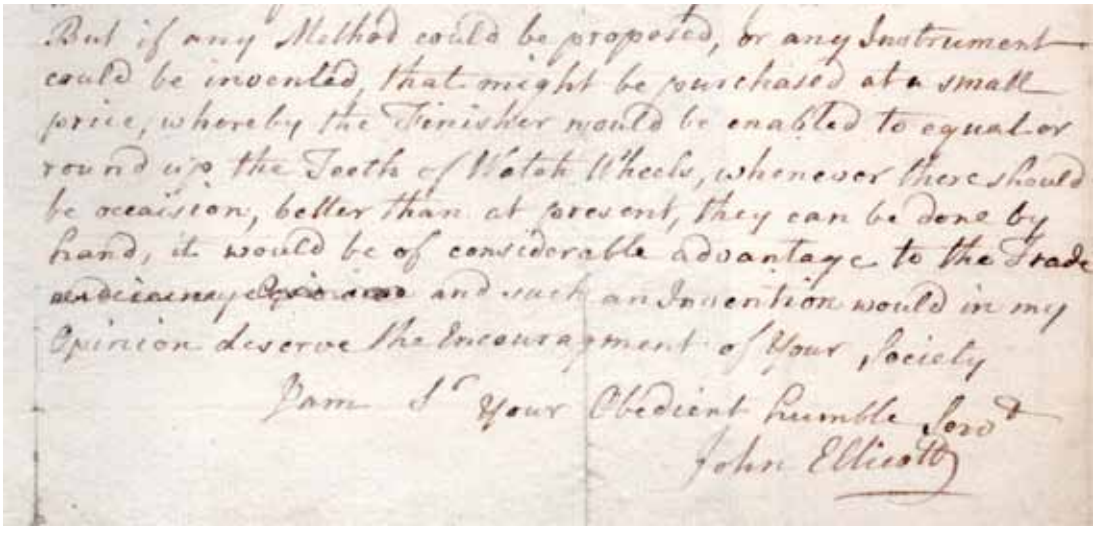
The other written testimony was by John II Ellicott (1706–1772), one of the leading watch and clock designer-retailers of his day, and a fellow of the Royal Society since 1738. He may have been one of the people 'of the watch trade' whom Grignion was asked to invite, but Ellicott already had a much older connection with the Society. His sister Mary was married to the jeweller and porcelain pioneer Nicholas Crisp (c.1704–1774), who was one of the original eleven founder-members of the Society of Arts, and the Crisp and Ellicott families seem to have been friends for at least half a century. Crisp's father in 1708 had bequeathed 'my ffriend John Ellicott of London', that is Ellicott's father, John I Ellicott (c.1673–1733), two guineas to buy a ring.[34] Just a couple of months after he was consulted by the Society on watch finishing, on 19 May 1756 Crisp proposed Ellicott for membership.[35] Regardless of how he came to be consulted, Ellicott's testimony is especially enlightening:

> At your desire I have considered the proposal for granting a premium to any apprentice in the watch trade, for the best plain watch movement (going with a contrate wheel) with the teeth of all the wheels finished by the same hand, And the reasons of giving the same premium, and I take the liberty to send you the following remarks upon them.
> That before the invention of engines for the finishing of watch wheels, when it was the particular business of the movement makers to finish the wheels by hand, there were but few who were capable of finishing them to a sufficient degree of exactness; and the wheels to the best movements were at that time generally finished by persons who made the finishing of watch wheels their constant employment. [The first engine for finishing watch wheels was invented by Mr Saml. Hoole and was compleated in the year 1719].[36]
> By the engines since invented, and which are now in use, watch wheels are capable of being finished, with much greater exactness than they can be done without, by any hand whatsoever.
> The movement maker is obliged to follow the distinctions of the person who employs him, & who will not chuse to have the wheels finished by hand, if he is of opinion, that they can be much better finished by the engine.
> Watch wheels are finished by the engine at so moderate a price, that the movement maker can employ his time to much greater advantage than in finishing wheels by hand.
> It cannot therefore with reason be expected that a movement maker will permit his apprentice to spend his time in learning a branch so much to his disadvantage
> I grant that a finisher ought to be capable of

34. J. V. G. Mallet, 'Nicholas Crisp, Founding Member of the Society of Arts, Part II: Crisp and the Society', *Journal of the Royal Society of Arts* 121, no. 5198 (1973), 92.

35. RSA/AD/MA/100/12/01/01, p. 141.

36. The passage in brackets is an asterisked note, clearly an afterthought by Ellicott.


But if any Method could be proposed, or any Instrument could be invented, that might be purchased at a small price, whereby the Finisher would be enabled to equal or round up the Teeth of Watch Wheels, whenever there should be occasion, better than at present, they can be done by hand, it would be of considerable advantage to the Trade and such an Invention would in my Opinion deserve the Encouragement of Your Society

I am Sir Your Obedient Humble Servt
John Ellicott

Fig. 5. Bottom of signature page of John Elllicott's letter (RSA-PR-GE-110-2-101), transcribed in full here. Photo by courtesy of the Royal Society for the Encouragement of Arts, Manufactures and Commerce, London.

equalling or amending the teeth of the wheels when necessary, and is not to be accounted a compleat workman if he is not capable of doing it. But if the wheels are better finished by the engine than they can be done by the hand, there will not be so frequent occasion to make any alteration in them now, as there was formerly, and the greater perfection that the engines are brought to, the less will the teeth of the wheels require any amendment.

The making of the movement, and finishing are now become two distinct branches of the trade,[37] and there are but very few apprentices who have served their time to a movement maker who commence finishers, in comparison with those who have served an apprenticeship to a finisher, and as these last are seldom employed any longer in making movements, than is sufficient to learn them to turn and file, they are by no means qualified to become competitors for a premium with those who have served their whole time to movement making.

Upon the whole as the design of granting this premium seems to be, to give encouragement to the finishers to learn to finish watch wheels by hand, I am much afraid it will fall short of answering the good intentions of the gentleman who proposed it.

But if any method could be proposed, or any instrument could be invented, that might be purchased at a small price, whereby the finisher would be enabled to equal or round up the teeth of watch wheels, whenever there should be occasion, better than at present, they can be done by hand, it would be of considerable advantage to the trade, and such an invention would in my opinion deserve the encouragement of your Society.

I am, Sir, your obedient humble servt
John Ellicott

Watch wheel finishing

Both Ellicott and Harrison agreed that the finishing of watch teeth by hand was inferior to the use of a good machine. This may have been similar to the one illustrated in the tool catalogue of John Wyke (Fig. 6), in a section probably engraved after 1770–71,[38] but showing a tool that existed earlier. Tantalisingly, Ellicott in his note states clearly that the machine for finishing watch wheels

37. This remark may imply that the separation had taken place quite recently, within Ellicott's lifetime. For a description of the two tasks see Betts, *Marine Chronometers at Greenwich*, p. 78.

38. Smith, *A catalogue of tools for watch and clock makers by John Wyke of Liverpool*, pp. 136–7.

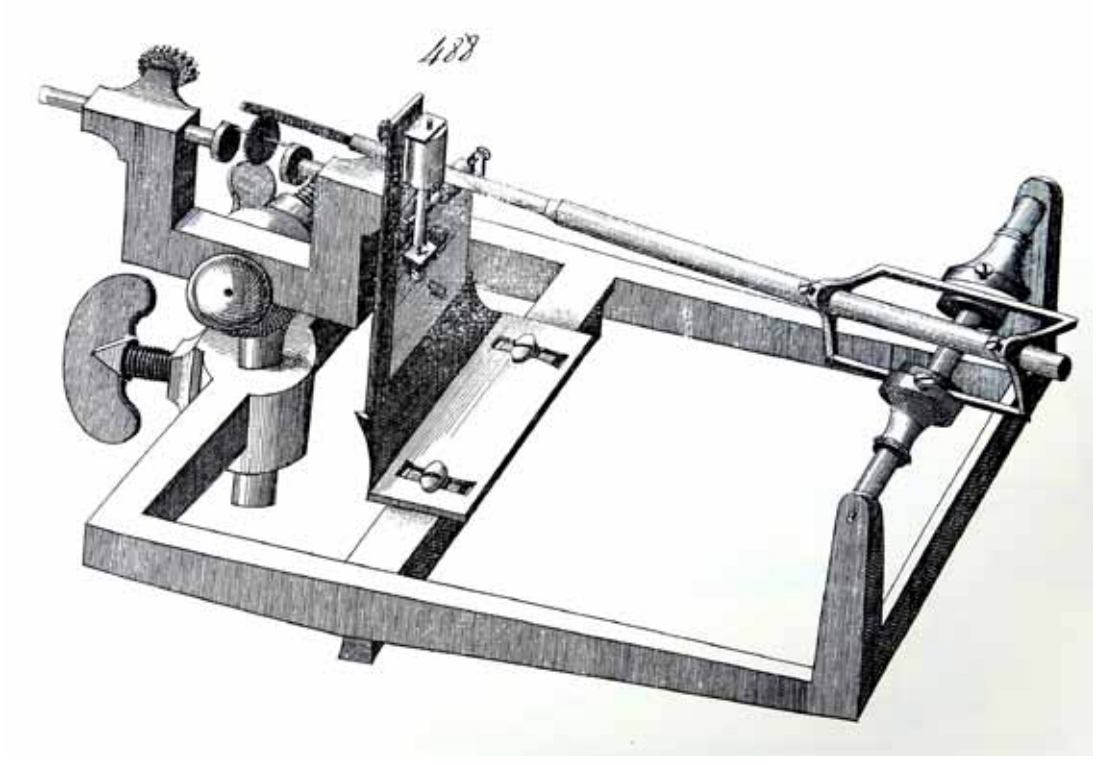


Fig. 6. A finishing machine from John Wyke's tool catalogue, plate 59, the plate probably engraved 1770.

was invented by Samuel Hoole (1692–1758), who produced his first example in 1719. We thus have the identification of one of the 'invisible inventors' who so improved English watches in the early eighteenth century.[39]

A machine for finishing watch teeth, such as continued to be used in English watchmaking thereafter, was probably based on the existing wheel engine used for slotting wheel blanks. It both divides a wheel and cuts the full teeth. The invention did not relate to the wheel engine itself, but to the form of the rotary cutter used in that engine. Rather than employing a straight-sided cutter which cut a simple rectangular slot, the improved engine was most likely fitted with a cutter which had the profile of the addendum of the teeth formed on the cutting edges, in order to ensure that the tips of the teeth had the precise shape required in one cut. The improvement was a natural development of machines or engines designed to divide the wheel and to cut the teeth. Dividing plates date back to the sixteenth century and were commonly used throughout the seventeenth. By at least the mid-seventeenth century they were mounted in a frame and associated with a manually rotated cutter to execute both tasks, and London already had specialised makers of such machines in the 1670s.[40] The next logical step would then have been to mechanise the finishing process, especially as it allowed the tool used to be held always at the same angle to the face of the work – something exceptionally difficult to attain by hand.

39. Ellicott's note is perhaps to be related to Hatton's even more tantalising remark 'the great secret of finishing engines, which were first invented here [London], and improved by the Lancashire workmen, and in particular by Phithian and Garnet, from whom the secret was stole by Millar and others' (Hatton, *An Introduction to the mechanical part of clock and watch work in two parts*, p. 382).

40. For a discussion of early dividing plates and wheel-cutting engines see Anthony Turner, 'Dividing plates and wheel-cutting machines: some seventeenth-century evidence', *Antiquarian Horology*, xl 2019, 514–524.

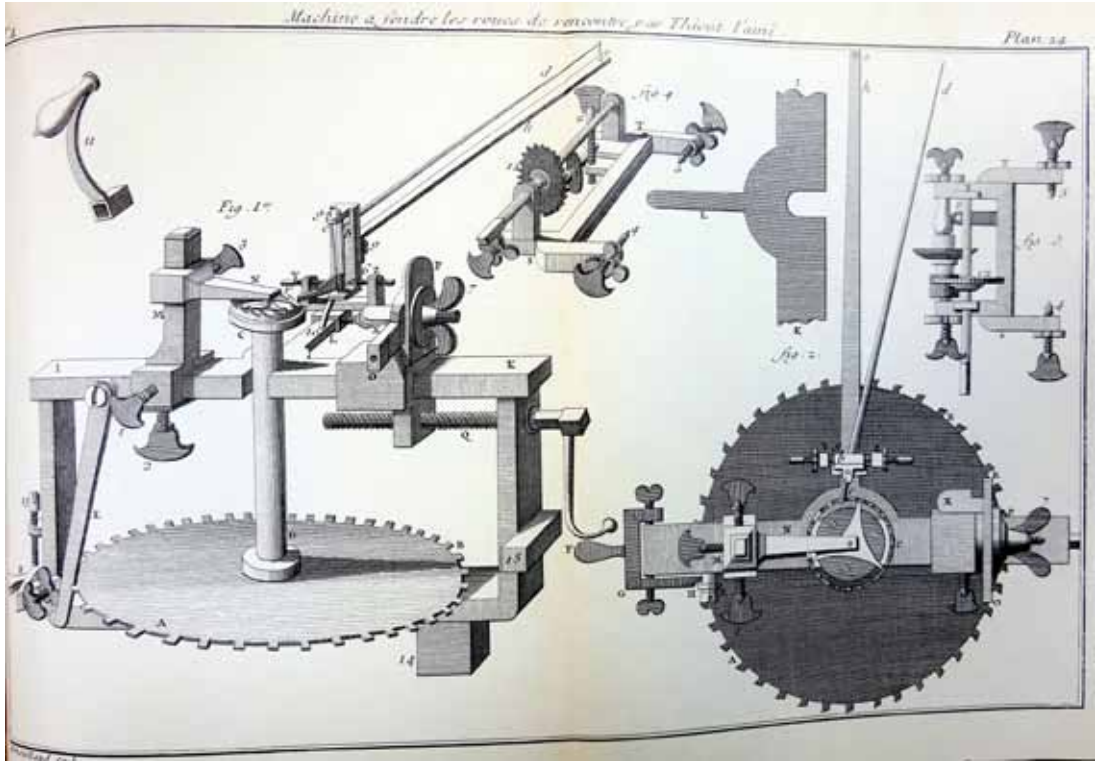


Fig. 7. A machine for both cutting and equalising wheel teeth, from Antoine Thiout, *Traité de l'horlogerie mécanique et pratique…*, 2 vols (Paris, 1741), plate 24.

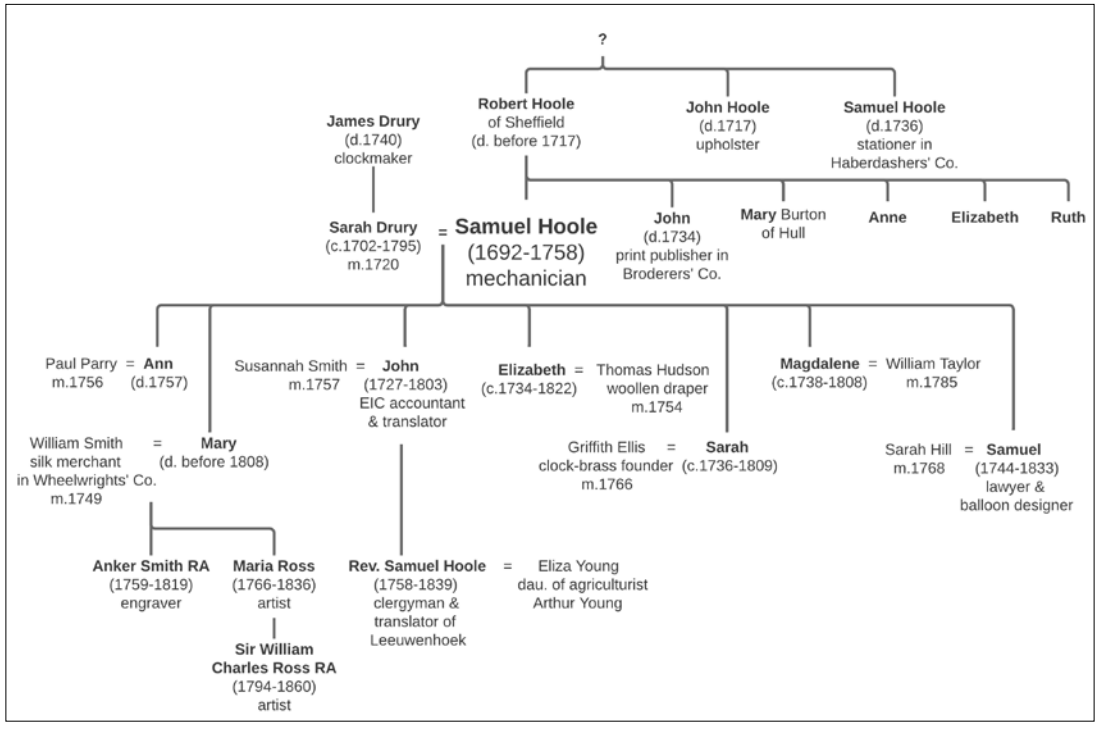
It is highly likely that this was the step Hoole made in 1719, although in the absence of other evidence we cannot be sure that he was alone or even the earliest in making such an improvement. Hoole's machine may simply have been the earliest of which Ellicott was aware. Certainly by 1756 there were other models to choose from as Ellicott himself mentions the 'engines since invented, and which are now in use'. In France, Thiout had developed a machine which both cut and equalised escape wheel teeth, describing it in his *Traité* of 1741 (Fig. 7), but his discussion of an improved version of Sully's old slotting engine has no mention of the addenda.[41] Another machine, by Armand Vincent de Monpetit (1713–1800), was shown to the Académie des Sciences in January 1753.[42] De Monpetit's machine 'polishes the divisions of the teeth, and gives them the most perfect equality, as well as such profile as the … maker requires for the goodness of his watch'. It could be used for wheels of any size, and as much work could be done in an hour as could be executed by three workmen in a day. It could even be used by a blind child, since once the wheel had been positioned all that was needed was to turn a handle. A fail-safe system ensured that if the wheel was incorrectly placed, or had already been worked, the machine would cease operating.[43] Other machines would be described in the *Encylopédie*.[44]

In the latter part of his reply to the Society

41. Thiout, *Traité de l'horlogerie mécanique et pratique,* i pp. 65–6 and plate 24.

42. A prolific inventor, Monpetit is best known for his 'eludoric painting', a method of fixing painting in oil and water on glass. See E. Bénézit, *Dictionnaire … des peintres, sculpteurs, dessinateurs et graveurs*, 12 vols (Paris, 1976), vii, p. 508; Sarah Lowengard, *The Creation of Color in Eighteenth-Century Europe* (New York: Columbia UP, 2006), ch. 12.

43. Jaubert, *Dictionnaire raisonné universel des arts et métiers* …, new edition 3 vols (Paris, 1773), ii, pp. 422–23.



The Hoole family tree.

of Arts, Ellicott, like Harrison. made a suggestion of his own. He proposed that the Society should encourage the development of a method or a tool

> … that might be purchased at a small price, whereby the finisher would be enabled to equal or round up the teeth of watch wheels, whenever there should be occasion, better than at present, they can be done by hand.

He is thus pointing towards a device that would be realised towards the end of the eigteenth century – the 'rounding up' or 'topping' machine. Little at present is known of its origins,[45] although at least one form of it was improved by the Neuchâtelois Phinée Perret (1777–1851), in around 1800.[46] All this, it should be emphasised, primarily concerns watchmaking. For clock teeth, matters could be different.

Samuel Hoole

Ellicott's throwaway remark concerning Hoole offers new and early evidence for the origins of finishing machines. The inventor he credited, Samuel Hoole, was the son of one Robert Hoole of Sheffield (see family tree). He arrived in London aged nine (c.1702) to be educated by an uncle.[47] This uncle is likely to have been either John Hoole (d.1717), of the Upholders' Company, or Samuel Hoole (d.1736), of the Haberdashers' Company, who was a wealthy stationer and father-in-law to the publisher Jacob Tonson, founder of the Kit-Cat Club.[48]

44. Diderot & Dalembert, *L'Encyclopédie*, plates IB, IIb & IIIb, reproduced in Theodore R. Crom, *Horological shop tools, 1700–1900* (Melrose, 1980), pp. 88–91. Crom also illustrates a later c. 1800 machine; figure 878, p. 437.

45. Crom, *Horological shop tools*, 590 for example, although he gives a clear, brief, description of its uses, knows nothing of its origins.

46. André Cavin, 'L'outillage des penduliers', chapter 10 of Alfred Chapuis, *Histoire de la pendulerie neuchâteloise* (1917), p. 328.

47. *The European Magazine, and London Review* (Philological Society of London, 1792), 163.

This connection with publishing may explain why Samuel Hoole was then apprenticed on 8 February 1709 to Henry Overton (1675/6–1751), nominally of the Broderers' Company,[49] but actually a successful print publisher at the sign of the White Horse, without Newgate. In 1714 Overton would also take on Samuel's younger brother John Hoole (d.1734) as an apprentice,[50] who by the mid-1720s had become his business partner but died young from a 'Pleuretick Fever' that lasted four days.[51]

How Samuel Hoole came to be involved in the watch trade is unclear. As well as pictures, Overton specialised in the selling of copper-plate-printed maps and hand-writing sample books, which might have involved contact with engravers. But the only mention of horology in Overton's early catalogue is of 'a great variety of prints for watch-engravers, jewellers, and other artists; by Grib[e]lin.'[52]

In 1720, the year after Ellicott says he invented his finishing machine, Hoole married Sarah Drury (c.1702–1795), the daughter of James Drury (c.1673–1740), clockmaker. Hoole was then described as being of the parish of St Bartholomew Exchange,[53] but all later records, from at least 1727 right up until his death, place him in the parish of St Stephen, Coleman Street – the same parish as his father-in-law, and in the heart of one of London's principal watchmaking communities, at Moorfields (Fig. 8).[54] One of Hoole's daughters, Sarah (c. 1736–1809), would in 1766 marry the Moorfields clock-brass founder Griffith Ellis, whose sister, Jane, married into the Mayor family, the leading clock-brass founders in Moorfields .[55]

The details of Hoole's career, however, are vague. His youngest son, also named Samuel (1744–1833), described him as having 'carried on a branch of the watch-making business, (which by the use of some newly invented machines, of his own construction, he had rendered very profitable)' – an allusion, we can safely assume, to the watch wheel finishing engine.[56] Hoole never patented his invention, so to render it profitable it seems likely he would have kept the machine hidden, using it to do finishing for others without letting them know how it was constructed. Such a strategy was not uncommon. As John Carte noted

> every good Workman has some particular Instruments that he works withal, which are usually of his own Invention, whereby it often happens that one Workman shall work quicker and yet better then another; and such good Workmen are shy of letting another see and peruse his private Tooles.[57]

48.See the wills of both uncles: The National Archives (TNA), Kew, Surrey, England; Records of the Prerogative Court of Canterbury, Series PROB 11; Class: PROB 11; Piece: 677 for uncle Samuel, and Piece: 559 for uncle John. Both mention a deceased brother, Robert, who was the father of Samuel Hoole. This is confirmed by the will of Samuel's brother, John. The names of their sisters – Mary, Elizabeth, Anne, and Ruth – correspond exactly with the daughters of Robert named in uncle Samuel's will. For the brother John's will, see: PROB 11; Class: PROB 11; Piece: 668.

49. London Metropolitan Archive; Reference Number: COL/CHD/FR/02/0377-0383.

50. John Hoole was apprenticed to Overton in 1714. See: TNA, Collection: Board of Stamps: Apprenticeship Books: Series IR 1; Class: IR 1; Piece: 3.

51. 'Deaths.' *The London Journal* no. 809 (28 December 1734).

52. *A catalogue of maps and prints from off Copper-Plates which are printed and sold by Henry Overton, at the White Horse without Newgate, London. Where all gentlemen, merchants, and country chapmen may be furnished with them, at the best hand; he being the sole proprietor of all the said copper-plates*. [s.n.],1717, p. 24. Eighteenth Century Collections Online, accessed on gale.com.

53. On whom see Brian Loomes, *Clockmakers of Britain 1286–1700 (*Ashbourne, 2014), p. 165. For the marriage record, see: London Metropolitan Archives; Reference Number: P69/STE1/A/003/MS04450.

54. 'News.' *Daily Journal*, 31 October 1727; *An Alphabetical List of the Livery-Men of London* (London, 1733), p. 82, lists him as being at '25 More-fields'.

55. *Stamford Mercury*, Thursday 1 May 1766; for horology in Moorfields see John Robey, 'Moorfields and Clock-Brass Founders', two parts, *Antiquarian Horology* xxxiii 2012, 479–86; 609–23 (616–17).

56. Samuel Hoole, *Anecdotes Respecting the Life of the Late Mr. John Hoole ... To Which Are Added Some Pieces Written by the Deceased, Never before Printed* (London: Evans and Ruffy, 1803), p. 2.

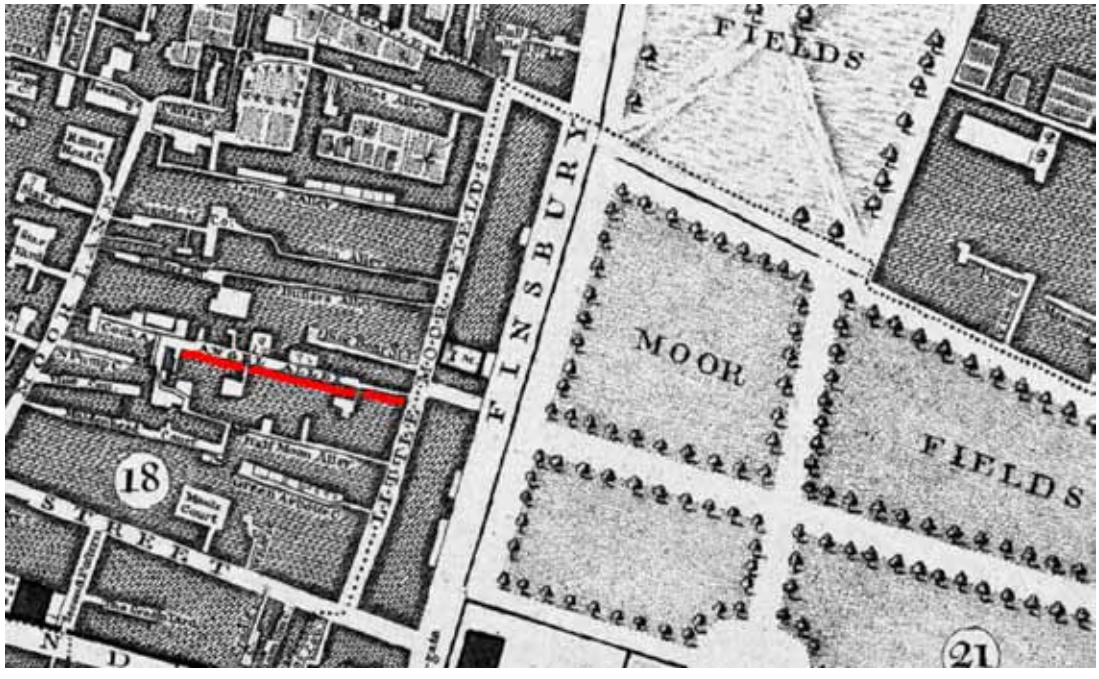


Fig. 8. Moorfields in *c.* 1740. Angel Alley, where Hoole lived, is shown in red and butts onto Little Moorfields, where his sister-in-law, Jane Ellis, lived, running parallel with the side of the fields.

Hoole was occasionally described in the newspapers as a 'watchmaker',[58] though only one work that may be his – a long-case clock by an 'S. Hoole London' – has so far been recorded (Fig. 9).[59] A family tradition, published in 1860 over a century after his death, maintained that he had created a watch within a finger-ring for the young George III,[60] although the only known ring-watch matching this description was produced by John Arnold in 1764, six years after Hoole's death. This source is riddled with errors, though usually relating rumours with a grain of truth. Possibly Hoole had created a small watch – even an entire ring watch – that after his death reached Arnold's hands to be adapted and presented to his monarch. But the mid-eighteenth century history of the ring-watch remains to be investigated.

Otherwise, Hoole's mechanical reputation was made on the stage. By 1739, if not earlier, he was employed as a machinist by John Rich

57. Anthony Turner (ed), *John Carte on horology and cosmography. A transcription with introduction and notes of Bodleian Library ms Carte 264 ff. 18r–57r.* (Turner & Devereux Occasional Paper N° 5), Ticehurst & Le Mesnil-le-Roi 2014, p. 56. Cf. Hatton, *An Introduction to the mechanical part of clock and watch work in two parts,* p. 382, that 'particular [ie specialised] tools … are kept up, under the name of secrets, which chiefly belong to watch-makers'.

58. See, for example, 'News', *Read's Weekly Journal Or British Gazetteer*, 1 June 1754; and 'News', *Whitehall Evening Post* [1770], 14–17 January 1758.

59. F. J. Britten, *Old Clocks and Watches & Their Makers, Being an Historical and Descriptive Account of the Different Styles of Clocks and Watches of the Past, in England and Abroad, to Which Is Added a List of Ten Thousand Makers*, 2nd ed. (London 1904), pp. 474 and 630. Britten showed only the hands, which he dated to 1770 (though they could be earlier). They were contained in a collection of clock hands only, so the clock from which they came may already have disappeared by 1900. Whether G. H. Baillie, *Watchmakers and clockmakers of the world* (London, 1929 and many later editions) was simply following Britten in his entry 'Samuel Hoole, London 1758–1770. Le clock', cannot be known, although his addition of the full Christian name and an earlier date suggests that he may have seen a complete clock by Hoole.

60. 'Memoir of the Late Sir Charles Ross, R.A.,' *The Athenaeum Journal of Literature, Science, and the Fine Arts*, June 2, 1860, 764

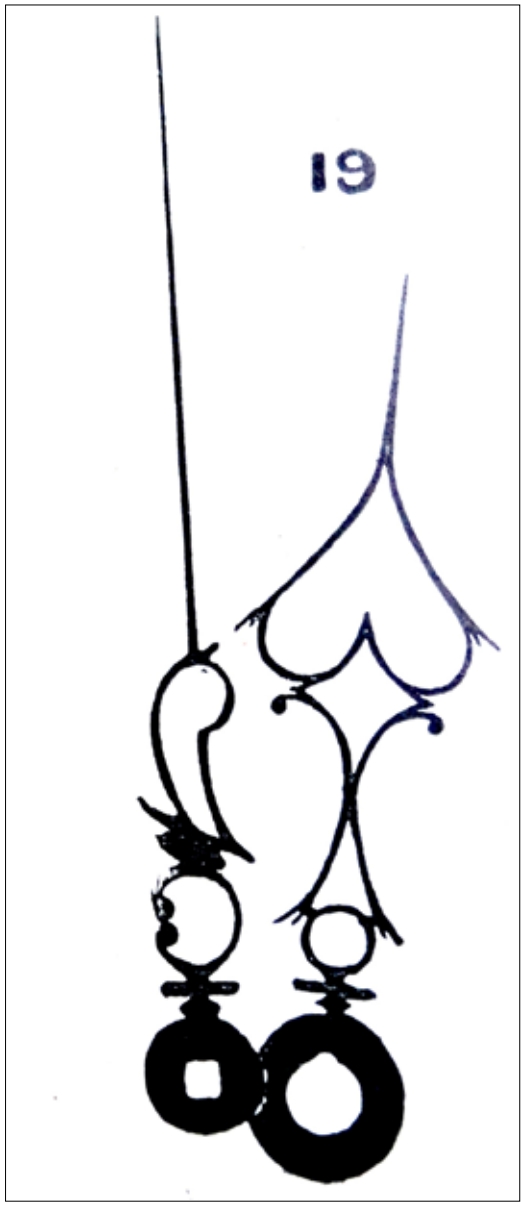


Fig. 9. Hands from a long-case clock by S. Hoole from F. J. Britten, *Old Clocks and Watches & Their Makers*, ... 2nd ed. (London, 1904), p. 474 (detail)..

at the Theatre Royal in Covent Garden.[61] The most famous of Hoole's constructions was revealed on 12 February 1740 for the pantomime of *Orpheus & Eurydice, with the Metamorpheses of Harlequin* – a gigantic mechanical serpent, estimated at sixteen or seventeen feet long,[62] and about a foot and a half wide in circumference at its thickest point, it was said to be 'so lively, as to frighten half the ladies who see it … being wholly a piece of machinery, that enters, performs its exercise of head, body and tail, in a most surprising manner, and rushes behind the curtain with a velocity scarce credible.'[63] A Swiss visitor who happened to see it on opening night, when the king and royal family were present, described how it seemed to startle one of the king's guards who was facing away from the stage, who dropped his musket and drew his sabre to the audience's great amusement. 'Covered with scales of a golden green with small red spots', he recounted,

> its eyes are sparkling like fire; it winds its way round the scene, lifting its head and part of its body very high, and hissing frightfully. This monster, driven by springs and clockwork movements, is one of the most fantastic inventions imaginable.[64]

Rumours of its cost ranged from two to over five hundred pounds. It appears to have toured the country, appearing in Ipswich the following year,[65] and was still being used decades later, though by the 1780s its

61. Hoole, *Anecdotes*, p. 3.

62. *Ipswich Journal,* Saturday 12 December 1741 for the estimate of sixteen feet; John Hill, *Orpheus: An English Opera ... With a Preface, Appealing to the Publick for Justice, and Laying before Them a Fair and Impartial Account of the Quarrel between the Author and Mr. Rich, Who Intends in a Few Weeks to Perform Such an Entertainment without His Concurrence* (London, 1740), p. 6, says seventeen.

63. *The Scots Magazine*, Friday 7 March 1740, 113–14.

64. César de Saussure, *Lettres et voyages de monsr César de Saussure en Allemagne, en Hollande et en Angleterre, 1725–1729 : Avec un introd. de B. van Muyden* (Lausanne, Paris, and Amsterdam 1903), pp. 275–76, http://archive.org/details/lettresetvoyages00saus. Note that De Saussure's correspondence was edited and rearranged by his descendants for publication. Although de Saussure's letter is dated 1729, a footnote on p. 277 informs us that the description of the play he saw then was substituted by the much more interesting account of Rich's *Orpheus & Eurydice*, which he saw on a different visit to London in 1740. This must have been on the opening night, 12 February, as that was when the royal family were reported to have seen it: 'Advertisements and Notices', *London Daily Post and General Advertiser*, 13 February 1740.

mechanism was prone to breaking down.[66]

Another theatrical automaton attributed to Hoole was a peacock.[67] This was probably used a number of times during Hoole's lifetime, and had reappeared by December 1783 for the pantomime of *Friar Bacon, or Harlequin's Adventures in Liliput, Brobdingnag, etc.*,[68] when it seemed too large for the scene in which it appeared. Given its size, a reviewer suggested that it appear alongside the other giants of Brobdingnag,[69] and the theatre appears to have responded a couple of days later by making the change.[70] As with the serpent, the peacock was well-received: 'a peacock is introduced, and spreads its tail, which makes a most wonderful appearance, and certainly exhibits one of the completest pieces of mechanism ever presented to the public.'[71]

Hoole's penchant for creating gigantic artificial animals appears to have been inherited by his youngest son Samuel, who in 1785 exhibited a 52-foot-long hot air balloon in the shape of a fish at the Great Room of the King's Arms buildings, in Cornhill.[72] Covered with Persian silk, it was painted to look like a fish, with the curious public charged a shilling a head to view it.[73] Unfortunately, however, the public's curiosity was seemingly not enough to recover the cost of all that silk. The following year, despite his fairly successful career as a lawyer, Samuel Hoole junior was bankrupt.

Curiously, the elder Samuel Hoole had by then become the subject of an apocryphal cautionary tale of the perils of an obsession with one's mechanical abilities. In a letter in 1780, Horace Walpole reported how Hoole had 'ruined himself by making nothing but serpents of all sizes till he was in the Fleet'.[74] Much the same was said in 1804 by Richard Cumberland, who reported how Hoole's shop had crawled with mechanical snakes, but that he wasn't able to sell them: 'his stock lay dead upon his hands, his trade was lost, and the man was ruined, bankrupt, and undone.'[75] It is impossible to say where this rumour came from, but all the other evidence we have is of Hoole having become very wealthy. Apart from the more reliable reports of the serpent's extraordinary cost, as well as his having profited from his finishing engine, Hoole gave substantial amounts of money to his seven children. At some point he gave £140 to his eldest son John Hoole (1727–1803), later famous as a translator and poet, to be put into business as an accountant for the East India Company when his short-sightedness prevented him following in his father's footsteps. Hoole spent another £300 in 1749 for his daughter Mary to marry the silk merchant William Smith in 1749. And in 1754 he gave £200 – what the newspapers justifiably called 'a handsome fortune'[76] – for his daughter Elizabeth (c.1734–1822) to marry the woollen-draper Thomas Hudson. His daughter

65. *Ipswich Journal,* Saturday 12 December 1741.

66. *The Scots Magazine* reported a cost of more than £200, Hill said he had heard Rich boast that it cost £300, de Saussure heard £525, and *The Times* (19 October 1787) also said £525, adding that Hoole had also been paid £21 a night for setting it going. For its breaking down 'nine times out of ten' by the 1780s, see: 'News', *Morning Chronicle* [1770], 25 December 1783.

67. *The European Magazine, and London Review*, 163, and footnote.

68. 'News', *Morning Herald*, 9 January 1784.

69. 'Arts and Culture', *General Evening Post*, 23–25 December 1783.

70. 'News', *Morning Herald*, 25 December 1783.

71. 'Arts and Culture', *London Chronicle*, 23–25 December 1783. The reviewer's remark was an exaggeration as the peacock was one of the simpler automata to realise – hence its popularity.

72. *Sussex Advertiser,* Monday 4 July 1785.

73. 'Advertisements and Notices'. *Public Advertiser*, 2 July 1785. Hoole junior also published a short pamphlet on the invention, entitled *Thoughts on the farther Improvement of Aerostation*, which could also be bought there for a shilling.

74. *Horace Walpole's Correspondence*, xxix (New Haven, 1955), pp. 3–4.

75. Richard Cumberland, *Memoirs of Richard Cumberland: Containing an Account of His Life and Writings, Interspersed with Anecdotes and Characters of Several of the Most Distinguished Persons of His Time, with Whom He Had Intercourse and Connnexion* (London, 1806), p. 315.

76. 'News', *Read's Weekly Journal Or British Gazetteer*, 1 June 1754.

Ann (d.1757) no doubt also received a substantial dowry for her marriage to one Paul Parry in 1756, but before he had a chance to update his will she had died. Hoole left the vast majority of his wealth to his wife Sarah, who was able to bequeath a fortune of her own almost forty years later, as well as comfortably providing for their three younger children's dowries and careers.[77]

Earlier still, Hoole could afford to contribute to various charitable and cultural causes. He and his brother John subscribed to the publication in 1728 of *A View of Sir Isaac Newton's Philosophy* by Henry Pemberton – an early evidence of scientific interests – and in the late 1730s he was one of only a handful of financial backers for the publication of some of Handel's operas played at Rich's Covent Garden theatre.[78] In 1739, Hoole was one of the original subscribers to the Society of Musicians – a charitable fund for musicians who had fallen on hard times.[79] Indeed, he appears to have been an able musician himself. His son noted that he played several instruments, especially the double bass, on which he performed both at plays and oratorios, including for Handel.[80] During his lifetime, too, in the 1740s Hoole was described not as a watchmaker or machinist, but simply as 'a gentleman well known among the skillful in musick'.[81]

There is also some hint of Hoole's political sensibilities. Alongside many other liverymen of London, he gave two guineas towards a charitable fund for soldiers who had suppressed the 1745 Jacobite rebellion.[82] But an elegy by his poetical son, John, mentions 'titled slaves and guilty wealth despis'd' – an allusion, perhaps, to a radical dislike of courtly faction. He was also almost certainly a religious non-conformist: his parents-in-law James and Joanna Drury were non-conformists, both stipulating in their wills that they be buried at Bunhill Fields,[83] and he was also himself recorded in the non-parochial registers as having been buried there.[84] His son John married 'the handsome Quaker' Susannah Smith in 1757,[85] and later admitted to his friend Samuel Johnson that he had never received the Sacrament (Dr Johnson insisted that the couple be baptised forthwith, even acting as godfather to Susannah).[86] The younger son Samuel also shows up repeatedly in independent genealogical records in the 1760s, with his siblings or mother acting as witnesses.

77. TNA, Records of the Prerogative Court of Canterbury, Series PROB 11; Class: PROB 11; Piece: 1265.

78. He subscribed for the publication of *Atalanta* (1736), *Aminio* (1737), *Justine* (1737), and *Alexander's Feast* (1738). For the rather muted support of Handel by subscriptions see David Hunter & Rose M. Mason, 'Supporting Handel through subscriptions to publications: the lists of Rodelindo and Faramonde compared', *Notes* [published by the Music Library Association], 2nd series lvi (1999), 27–93.

79. *The Society of Musicians. Declaration of Trust. Dated August the 28th, 1739* (London,1872), p. 14.

80. Hoole, *Anecdotes*, p. 6.

81. Joseph Hurlock, *A Practical Treatise upon Dentition; or, The Breeding of Teeth in Children: Wherein The Causes of the Acute Symptoms Arising in That Dangerous Period Are Enquired into; The Remedies Both of the Ancients and Moderns for the Cure of Those Evils, and the Prevention of Their Fatal Effects, Are Examined Impartially; Some Errors of Consequence Corrected; Objections Answered; and A Right Practice Recommended upon Observation and Experience. The Whole Illustrated with Proper Cases and Remarks*. (London: Joseph Hurlock, 1742), p. 131. Hurlock treated Hoole's son for a combined case of measles and toothache. He describes the son as being about two years old. This must be John, which would imply that the operation took place c.1729.

82. *The report from the Committee of the Guild-Hall Subscription towards the Relief Support and Encouragement of the Soldiers Employed in Suppressing the Rebellion in MDCCXLV* (London, 1747).

83. TNA, Records of the Prerogative Court of Canterbury, Series PROB 11; Class: PROB 11; Piece: 701, and 765. Loomes, *Clockmakers of Britain 1286–1700*, p. 165.

84. TNA, General Register Office: Registers of Births, Marriages and Deaths Surrendered to the Non-Parochial Registers Commissions of 1837 and 1857; Class Number: RG 4; Piece Number: 3982.

85. Hoole, *Anecdotes*, p. 7.

86. O. M. Brack, 'John Hoole's Journal Narrative Relating to Johnson's Last Illness', *The Yale University Library Gazette* xlvii (1972), 103–8.

Hoole died in 1758, 'of a mortification in his bowels',[87] but it is unclear what happened to his business, or even what the business was exactly by the time of his death. We know that his son John was too short-sighted to take over his work as a machinist, but it was only in 1753 that Samuel took on his only known apprentice – one John Thompson, the son of Edward Thompson, deceased, gentleman of Westminster. The apprenticeship was naturally within the Broderers' Company, giving no indication of exactly what was taught. Hoole died before Thompson's seven years were up and on the reverse of the indenture record is a note that Thompson was made free 'on the report of Sarah Hoole, the wife and executor of the within named Samuel Hoole'.[88] It would seem that Sarah continued the business with the help of Thompson, and he appears to have remained involved with the family in various capacities for decades. He was a witness to the admission of Samuel junior to the Broderers' Company by patrimony in 1772, and Sarah left Thompson £5 in her will in 1794.[89] It seems likely that Thompson would have been taught some element of mechanics or watch-making, but we can only speculate that, like Samuel Hoole, he inspired wonder through mechanical invention.

Acknowledgements

We are greatly indebted to Jonathan Betts, whose comments on earlier drafts of this paper have immeasurably improved it, to Eve Watson the archivist at the Royal Society of Arts, and to Ana Martínez, Berta Joncus, Jeremy Barlow, Roger Smith and Ellen Harris for answering queries about Hoole.

87. Hoole, *Anecdotes*, p. 8.

88. London Metropolitan Archive; Reference Number: COL/CHD/FR/02/0859-0-866.

89. TNA, Records of the Prerogative Court of Canterbury, Series PROB 11; Class: PROB 11; Piece: 1265.