Phase 2 of the Quelch Lantern Clock Restoration: A Perilous Journey

The Reinstatement of a Balance Verge in an Early 17th-Century Oxford Lantern Clock

BY GEOFF COX (UK) AND STEPHEN BARASI (UK)

This article complements an earlier one describing both the history and movement of an early 17th-century lantern clock made by Richard Quelch of Oxford (Figure 1).[1] This account covers the *reconversion*, a term used by White,[2] of the long pendulum clock to its original balance wheel (balance verge) mechanism.

This brief introduction will consider the development of balance wheel clocks in the early years of the 17th century up to the point when the first pendulum clocks began to replace them.

First-Period Lantern Clocks (1580–1640)[3]

A Very Close Relative of the Gothic Clock or a Distinct English Variant?

There has been considerable debate among horologists regarding the origins of the English (London-made) lantern clocks. Robey[4] has described the development of Continental Gothic lantern clocks over a period of at least a century before London-made lantern clock production started. Both German and Flemish clocks can be identified with clear stylistic and mechanical differences between the two forms. However, both types were made largely from steel parts with very elaborate and ornate designs and typically (among other characteristics) the balance wheel was suspended by a cord.[5]

Figure 1A. The finished Quelch clock awaiting the second phase: the crown wheel balance reinstatement. PHOTO BY GEOFF COX.

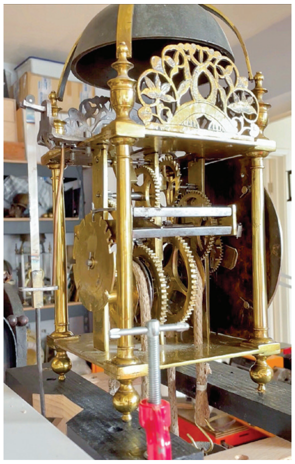

Figure 1B. A view of the hammer spring and counter showing a chamfer on the latter, typical of second-period work. Note that the original stepped potence remains, supporting the escape wheel originally to clear the balance arbor. PHOTO BY GEOFF COX.

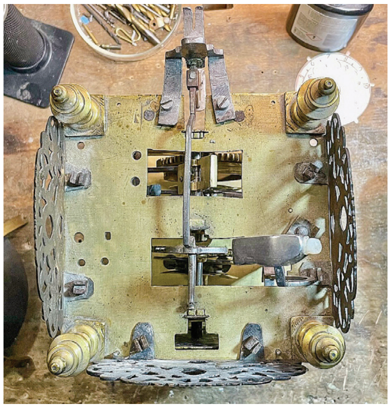

Figure 1C. The top plate from above, including a number of unfilled holes originally used to carry the balance wheel mechanism, possible fly cover, and the two rear side holes for top hinge pins before the rear pillars. PHOTO BY GEOFF COX.

Figure 1D. Set of modern two-handed gearing parts removed from the updated clock, replaced in phase 1 of this project. PHOTO BY GEOFF COX.

Following the religious persecution of Dutch Huguenots by the Spanish, many arrived in London in the last decades of the 16th century. Some settled in the Blackfriars area of London just north of the River Thames.[6] Their arrival coincided with waves of the bubonic plague, mainly between 1563 and 1603. Records reveal that 670 members of the Dutch community in London died from the plague, including the Dutch clockmakers John Vallin and Francis Nowe.[7] Both these makers had produced clocks dated 1598 and 1588, respectively, although in very small numbers.

Weight-driven mechanical clocks had been made in England since the 13th century mostly for cathedrals, monasteries, and the ancient universities. A clock made for St. Albans Abbey with an elaborate astronomical movement had an early form of verge escapement with a foliot controller (a swinging arm that was a precursor of the balance wheel[8]). In contrast to these church-associated clocks, the only ones found in domestic settings were those in royal households in the early 16th century.[9]

Thus early 17th-century London clockmakers were likely to have been influenced by the recently introduced Continental lantern clock tradition as well as long-established English clockmaking skills. Until about 30 years ago, many horologists suggested that the London form of the lantern clock was a direct development from Gothic clocks, thereby challenging the idea of the development of a distinct English form. However, White argued very strongly that "the old theory that only London weight driven clocks of the late Elizabethan and early Jacobean period were made to a bastard Gothic or 'transitional' design can be rejected out of hand."[10]

It is now accepted that London makers such as Harvey, Stevens, and Bowyer drew on both Continental sources and traditional English turret clockmaking to develop a clearly distinct lantern clock form. This London style of lantern clock differed from the Continental form in that most of the components were brass and the balance wheel was suspended from a top balance cock. These and many other differences relating to construction details have been extensively noted by Robey.[11] The less ornate style of London-made lantern clocks compared to the Gothic form may reflect the Renaissance classical style becoming established in England. These influences are also found in both English furniture and architecture of this period.[12]

Balance wheels were fitted to all English lantern clocks until the introduction of the short pendulum in 1657. Probably one of the first clocks to be fitted with a crown wheel pendulum was one made by Peter Closon circa 1660, an illustration of which is shown in White's seminal work.[13]

The pendulum (initially a short form then a longer version with anchor escapements) was considerably more accurate and often ran for a full day. However, balance wheel clocks continued to be made as late as 1696.[14] This is partly due to them being cheaper to make than the pendulum form and possibly the natural conservativeness of some makers. It was also the case that makers, even in the very early years of London clockmaking, would buy large quantities of clock parts from suppliers and expect to use up the stock before embarking on newer designs.

How Many Balance Wheel Lantern Clocks Are Now Considered Original?

There has been a great deal of confusion and controversy relating to the originality of existing balance clocks. While some authors claim that there are unlikely to be any such truly original clocks,[15] others have suggested there are a limited number that may be original. Robey[16] has reviewed the evidence for the existence of original balance wheel clocks in detail and has identified 10 criteria to be met before a clock can be regarded as original. Applying this comprehensive list, he concludes that seven clocks are largely original and a further seven are original but have had significant parts replaced.

Interestingly, Loomes[17] has described a clock by John Quelch (the son of Richard Quelch) that, at auction, appeared in a very grubby and completely unrestored state. Although incomplete, the clock has a balance wheel that Loomes concludes is original, suggesting that Robey's list of original balance wheel clocks may grow over time.

Whether clocks originally fitted with a balance wheel and converted to pendulum escapement should be returned to a balance wheel is open to debate. It has been performed less often in recent years; however, the unusual design and origin of the present lantern clock supported the decision to reconvert to a balance wheel.

The following account records the process of the reconversion by Geoff and may represent one of the very few detailed descriptions of a balance verge reinstatement, including many technical aspects of the problems encountered and overcome.

The Castings and Making the Parts

The parts required to reinstate a balance verge (Figure 2) comprise:

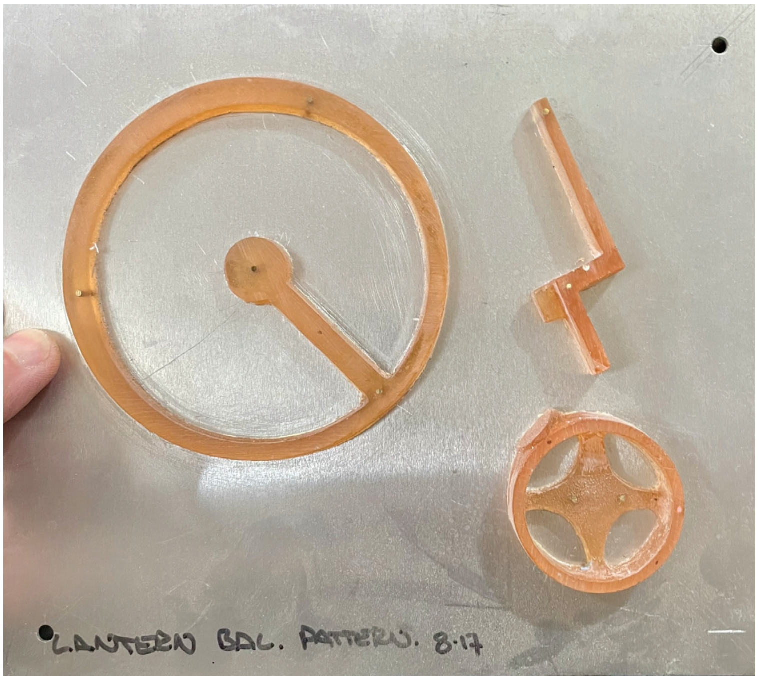

Figure 2. (left) Resin pattern detail and (right) the casting. PHOTOS BY GEOFF COX.

- Balance casting (machined, filed, and fitted) in yellow brass
- Crown-wheel casting (machined, filed, and fitted) in yellow brass
- Top plate mounting upper balance arbor verge potence casting (machined, filed, and fitted) in yellow brass
- Lower potence block (machined, filed, and fitted) in yellow brass
- Bespoke single piece steel balance verge arbor (with the two impulse pallets)

In rare cases, past pendulum conversions to early lantern clocks have allowed the original crown-wheel potence to be used (through which the balance verge arbor runs). Such is the case with this Richard Quelch clock. If this component does not remain, a suitable casting or machined component is required.

The castings can either be sand cast in yellow brass from patterns or cast models in wax for finer resolution investment castings. If the restorer is lucky, he can cast what is required from scrapped period clockmaking brass compo material.

Machining, Filing, and Fabrication

The crown wheel always has an odd number of teeth to allow the escapement of movement. It is consequently not typically possible to use a dividing plate to equally locate the teeth. It was necessary to plot a line of paper tape exactly the length of the circumference of the machined crown wheel blank and carefully divided into 19 equidistant lines at right angles to the length horizontally. The tape is carefully stuck around the outer diameter of the blank, and the marked lines used to locate the vertical slots on a small mill using a rotary table. These become the impulse pallets of the crown wheel (each at a ~15 degree slant to allow for less recoil). The radii were handwritten, filed, and cut (Figure 3).

The Going Train of a Balance Verge: Current Constraints

Geoff has now had the experience of successfully reinstating six 17th-century lantern clocks, all by noted makers. Each case is an unknown due to the needs and styles of that example. Each is a different engineering adventure in its own right, beyond getting the escapement correct. This lantern clock has presented more challenges and limitations than most.

It's well documented that balance verge lantern clocks have a reputation for very poor timekeeping. Despite having conventional wheel-and-pinion tooth counts from known examples (including counts published in the 18th century as well as modern essays), Geoff has personal experience with varying performance from those he's reinstated together with those that have crossed his bench.

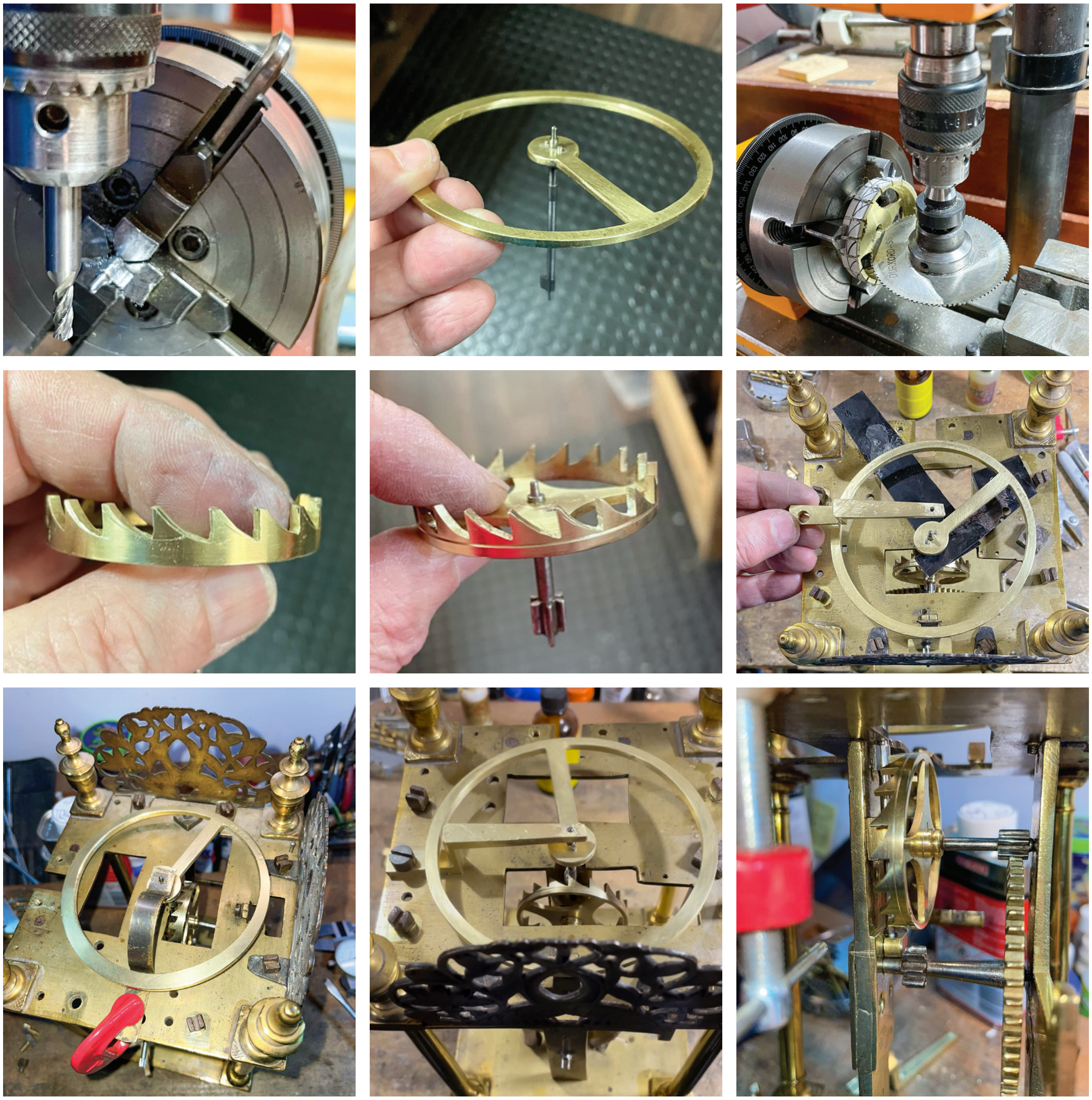
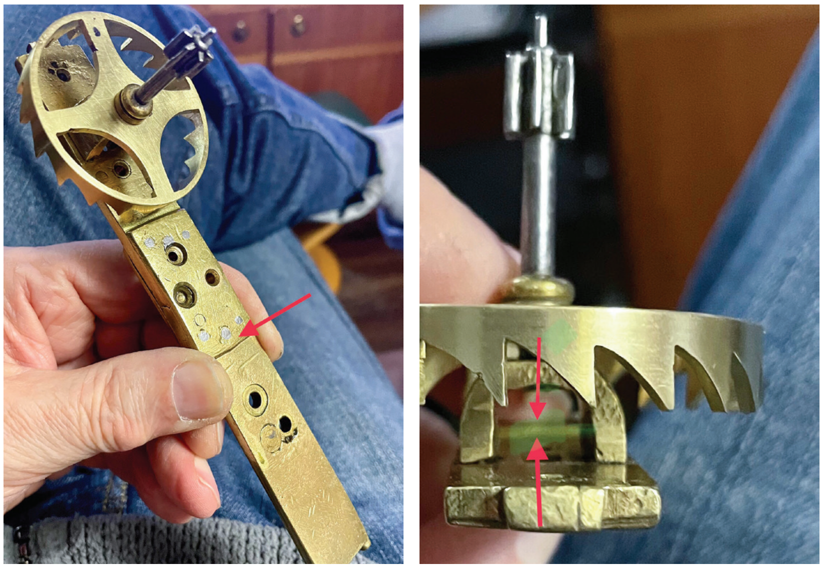
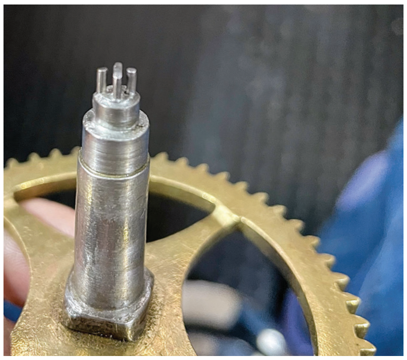

Figure 3. Machining, filing, and fabrication. PHOTOS BY GEOFF COX.

Timekeeping accuracy ranges from minutes to hours per day. Brian Loomes has more than likely had the opportunity to study hundreds or more 17th-century English lantern clocks, probably more than anyone else. He has written that the Edward Norris 1660 lantern clock that Geoff had reinstated for him "performed better than 1 minute per day in a constant temperature [environment]"[18] after optimizing its timing with small drive weight adjustments. Of course, the error is subject to considerable change with changes in temperature!

In *Lantern Clocks and Their Makers* by Loomes, John Robey provides information on the Samuel Stretch clock (Figure 4):

> The crownwheel is pivoted between the front bar and a bridge riveted to the centre bar to clear the vertical pallet arbor. The lower pallet pivot sits in a block riveted to the centre bar. Note the relatively large gap (not present on pendulum clocks) between the going greatwheel and the centre bar. This is usually necessary to give space for the lower support block, but here the pallet arbor is shorter than usual, the block higher and the gap not really necessary.[19]

The following are usual going train specs (also citing the Samuel Stretch example with an original balance having a crown wheel with 21 teeth):

Crown wheel: 19 teeth usual but 21 typical/ pinion of 6

Second wheel: 54/7

Great wheel: 56

Pinion of report: 4

Hour wheel: 48

The Richard Quelch lantern clock has the same original train and is fitted with a replacement 19-tooth crown wheel, but it needed the hour wheel count changed from 48 to 64. It's interesting to note that the original Samuel Stretch balance train with a short balance arbor and block is very similar to the resulting layout of the current Richard Quelch lantern clock!

Though crown wheels with 19 or 21 teeth seem to be preferred, examples with up to 25 are known. The balance verge beats at 59-60 per minute, typical of the examples.

Crown wheel balance verge trains typically need less mass to drive them compared to an anchor train, as timing the clock is achieved by adding or subtracting small amounts of drive weight. There is more friction on a verge balance than on an anchor train. The operational shortcoming of an anchor train due to wear can be overcome by adding more weight within reason, and such was the case with this clock. Adding weight has its limits, as the timing depends on running with adequate drive weight to overcome the friction of the train and run slowly enough to accurately reflect the time (with a light enough drive weight). It may be possible to slow it a minute or two an hour by adding two small timing weights to the balance. This was not uncommon, as shown in an example from Robey's article on original balances.[20]

The center post from this approximately 400-year-old clock has seen better days (Figure 5). At some stage it was broken in two and repaired/conserved with overlapping splints. This raised splint interferes

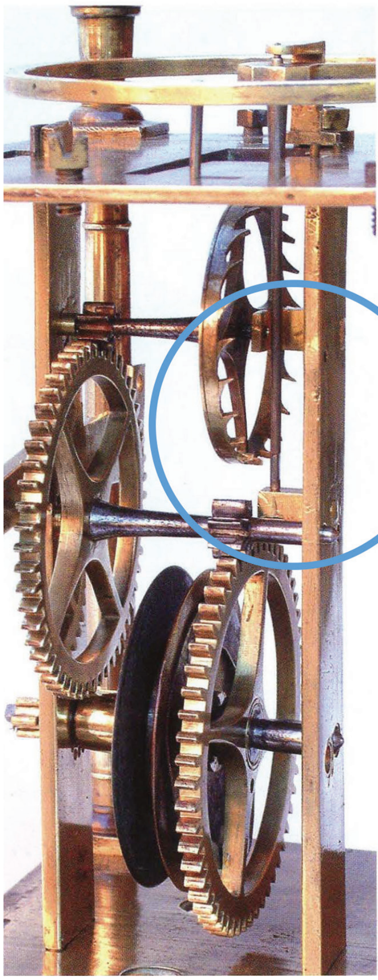

Figure 4. Samuel Stretch original short block potence that is very similar to the Quelch. PHOTO BY JOHN ROBEY AND USED WITH PERMISSION.

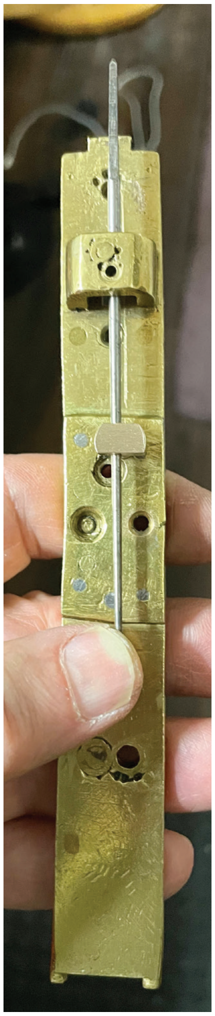

Figure 5. Center post. PHOTO BY GEOFF COX.

with the spacing where the lower balance verge arbor block needs to go. Due to the nature of fitting the anchor escape wheel and anchor, it was not necessary to line up and locate the crown wheel pinion in the center of the center post potence, which the balance arbor passes through and needs to line up with. There is very significant pinion leaf wear in this clock (Figure 6), suggesting that it may have run over the centuries with too heavy a drive weight. It's clearly evident that this clock has run for centuries with a variety of escapements.

When the clock was converted to an anchor train for improved timekeeping in the late 18th century (known by style of the work), the clock had the escape wheel arbor lined up with the second wheel arbor, which is usually offset to have space for the length of balance verge arbor and to access the lower block. This means a wheel arbor may need to be moved or offset, otherwise the balance arbor bangs into it, obstructed by the second wheel arbor pinion. It's a very narrow margin; it was just possible to gain enough clearance by cutting back the teeth less than 1 mm. It had to be done twice, gaining roughly 1.5 mm. In each case the sharp teeth were turned down and repointed by hand. Just enough clearance was gained while allowing suitable verge pallet contact location impulse and then clearance to pass. A tidier job on the crown wheel resulted and freed up the required clearance space.

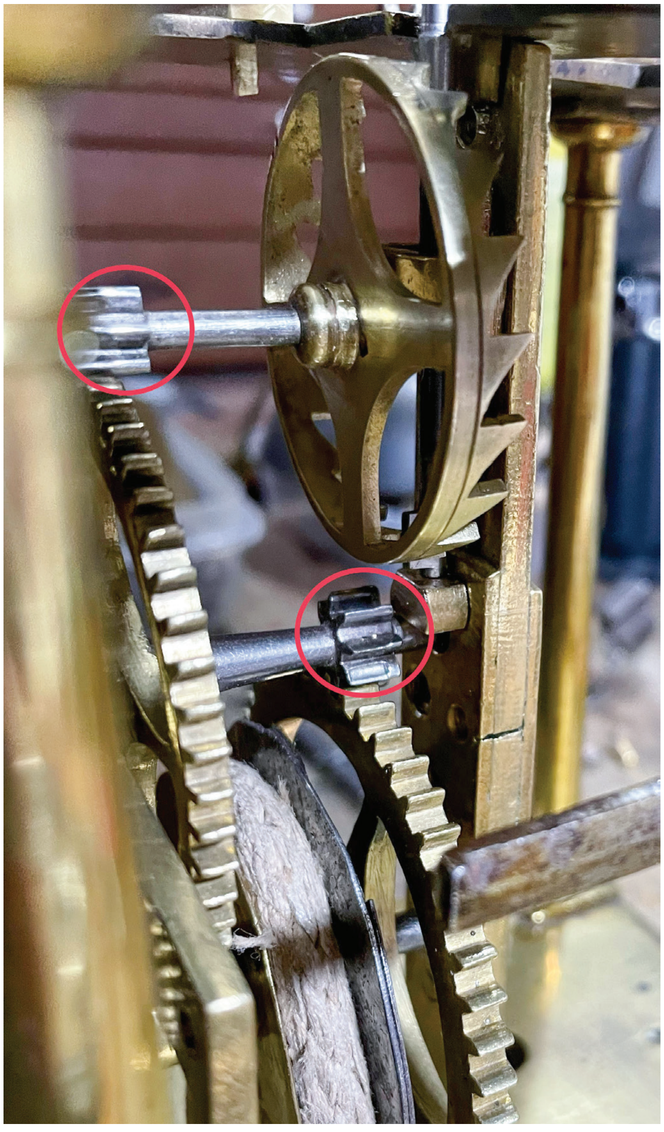

Figure 6. Pinion wear detail. PHOTO BY GEOFF COX.

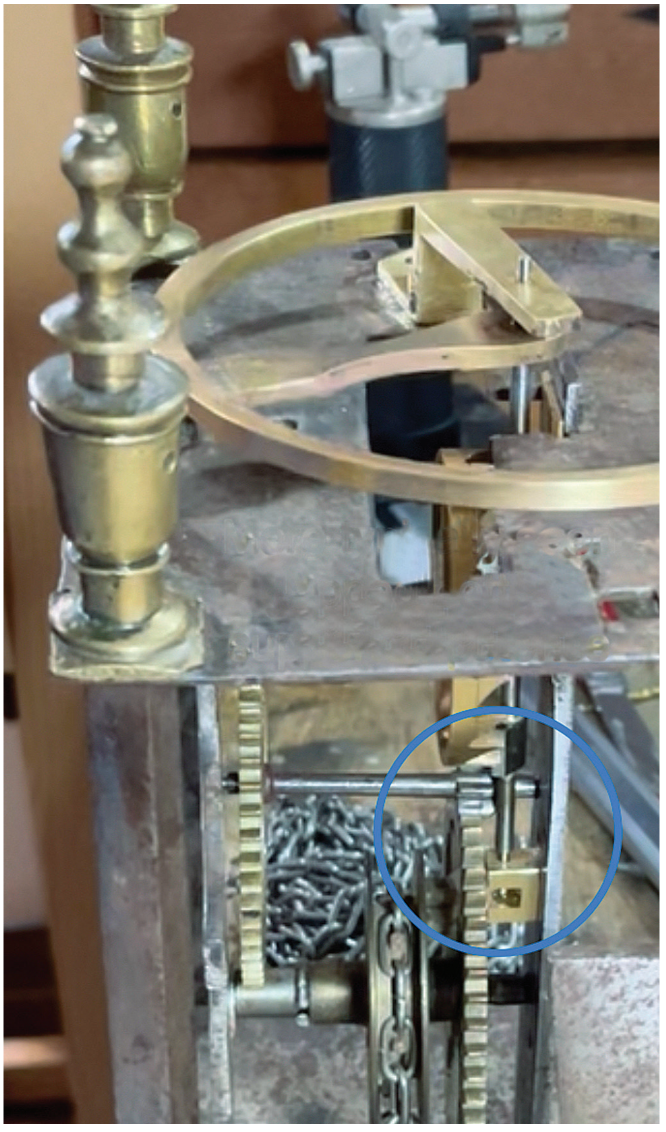

Figure 7. A typical longer verge arbor lower potence block with bottom supported pivot. PHOTO BY GEOFF COX.

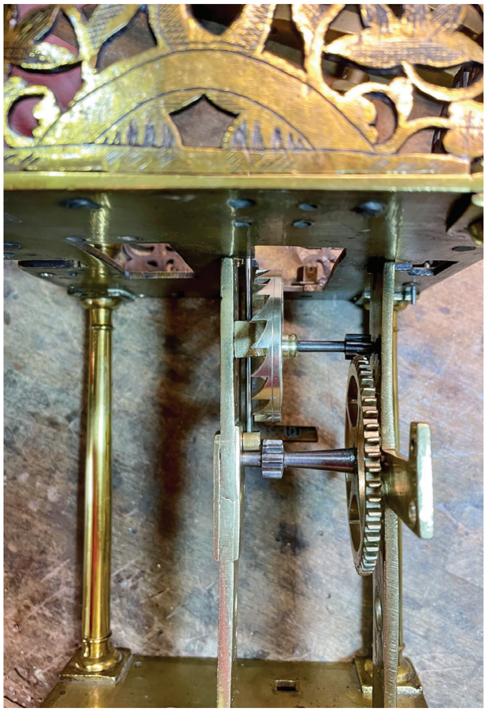

Figure 8. The short bottom verge arbor potence. PHOTO BY GEOFF COX.

Geoff didn't know if a short bottom verge arbor potence would suit. Typically, they are quite long and therefore potentially more stable (Figure 7). In this case it's not possible without moving a wheel or two over. A short version was made and just barely fit (Figure 8), but without the benefit of a bottom pivot support (less friction). Though a short distance from the bottom pallet to the bottom pivot, the bottom potence block managed to clear the second wheel arbor pinion in its current position.

Making It Work: The Adventure Continues

With the replacement balance verge fitted and adjusted properly, the clock runs happily but 1/3 too fast! The single hand indicates 1 hour in 40 minutes of running—bad news. Where then did the gearing count go wrong? The clock retained its original gearing ratio. The pinion and wheel tooth count are 100% typical of a balance lantern layout according to several observed examples and Derham's *The Artificial Clockmaker*[21] (Figure 9):

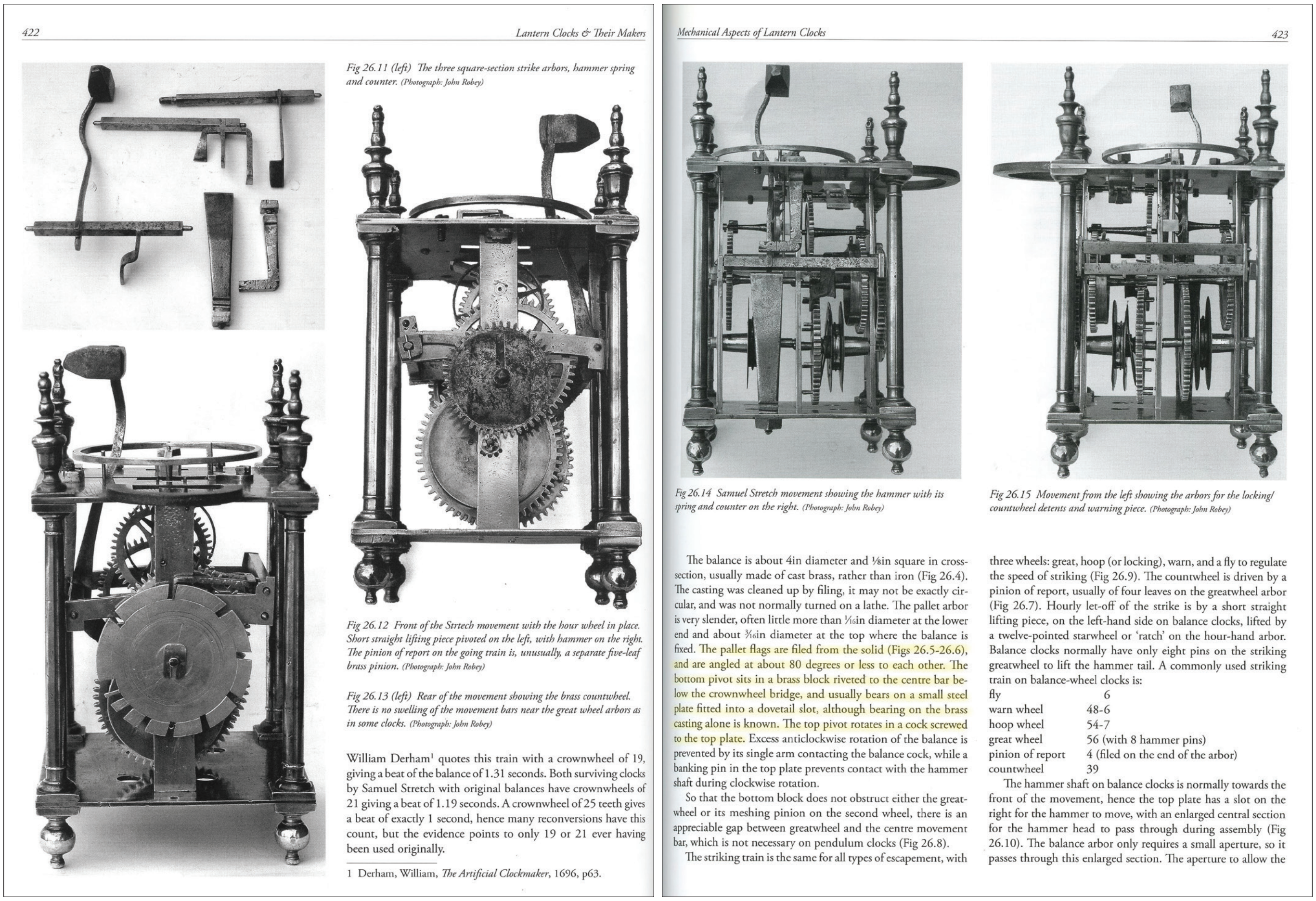

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Fig 26.11 (left) The three square-section strike arbors, hammer spring and counter. (Photograph: John Robey)

Fig 26.12 Front of the Strtech movement with the hour wheel in place. Short straight lifting piece pivoted on the left, with hammer on the right. The pinion of report on the going train is, unusually, a separate five-leaf brass pinion. (Photograph: John Robey)

Fig 26.13 (left) Rear of the movement showing the brass countwheel. There is no swelling of the movement bars near the great wheel arbors as in some clocks. (Photograph: John Robey)

William Derham[1] quotes this train with a crownwheel of 19, giving a beat of the balance of 1.31 seconds. Both surviving clocks by Samuel Stretch with original balances have crownwheels of 21 giving a beat of 1.19 seconds. A crownwheel of 25 teeth gives a beat of exactly 1 second, hence many reconversions have this count, but the evidence points to only 19 or 21 ever having been used originally.

1 Derham, William, *The Artificial Clockmaker*, 1696, p63.

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Fig 26.14 Samuel Stretch movement showing the hammer with its spring and counter on the right. (Photograph: John Robey)

Fig 26.15 Movement from the left showing the arbors for the locking/countwheel detents and warning piece. (Photograph: John Robey)

The balance is about 4in diameter and ⅛in square in cross-section, usually made of cast brass, rather than iron (Fig 26.4). The casting was cleaned up by filing, it may not be exactly circular, and was not normally turned on a lathe. The pallet arbor is very slender, often little more than 1⁄16in diameter at the lower end and about 3⁄16in diameter at the top where the balance is fixed. The pallet flags are filed from the solid (Figs 26.5-26.6), and are angled at about 80 degrees or less to each other. The bottom pivot sits in a brass block riveted to the centre bar below the crownwheel bridge, and usually bears on a small steel plate fitted into a dovetail slot, although bearing on the brass casting alone is known. The top pivot rotates in a cock screwed to the top plate. Excess anticlockwise rotation of the balance is prevented by its single arm contacting the balance cock, while a banking pin in the top plate prevents contact with the hammer shaft during clockwise rotation.

So that the bottom block does not obstruct either the greatwheel or its meshing pinion on the second wheel, there is an appreciable gap between greatwheel and the centre movement bar, which is not necessary on pendulum clocks (Fig 26.8).

The striking train is the same for all types of escapement, with three wheels: great, hoop (or locking), warn, and a fly to regulate the speed of striking (Fig 26.9). The countwheel is driven by a pinion of report, usually of four leaves on the greatwheel arbor (Fig 26.7). Hourly let-off of the strike is by a short straight lifting piece, on the left-hand side on balance clocks, lifted by a twelve-pointed starwheel or 'ratch' on the hour-hand arbor. Balance clocks normally have only eight pins on the striking greatwheel to lift the hammer tail. A commonly used striking train on balance-wheel clocks is:

fly	6
warn wheel	48-6
hoop wheel	54-7
great wheel	56 (with 8 hammer pins)
pinion of report	4 (filed on the end of the arbor)
countwheel	39

The hammer shaft on balance clocks is normally towards the front of the movement, hence the top plate has a slot on the right for the hammer to move, with an enlarged central section for the hammer head to pass through during assembly (Fig 26.10). The balance arbor only requires a small aperture, so it passes through this enlarged section. The aperture to allow the

Figure 9. The pinion and wheel tooth count of the Quelch clock are 100% typical of a balance lantern layout according to examples and Derham's *The Artificial Clockmaker.* PHOTOS OF THE SAMUEL STRETCH CLOCK BY JOHN ROBEY, PAGE IMAGES USED WITH PERMISSION OF MAYFIELD BOOKS.

> William Derham quotes this train with a crownwheel of 19, giving a beat of the balance of 1.31 seconds. Both surviving clocks by Samuel Stretch with original balances have crownwheels of 21 giving a beat of 1.19 seconds. A crownwheel of 25 teeth gives a beat of exactly 1 second, hence many reconversions have this count, but the evidence points to only 19 or 21 ever having been used originally.[22]

With the exception of the new crown wheel, the time train and the gearing/pinions are original and match those used in the period, including the reuse of the original crown wheel arbor when converted to anchor. The correct gearing existed, giving Geoff a green light for the balance reinstatement without the need to calculate any new gearing. It was down to having chosen to use the typical 19-tooth crown wheel count *and* its smaller-diameter crown wheel needing to fit the limited space from the inconveniently relocated second wheel obstruction. Assuming that a 19-tooth was ideal would prove to be wrong.

The options were to either fit 33% more teeth in either the hour wheel/pinion of report or for Geoff to cut a 25- or 27-tooth crown wheel (which would be bigger and require the train complication to move to the second wheel). Geoff didn't think it would be possible to cram in an unconventional hour wheel of 64 much smaller teeth driven by a "correct" 4-tooth pinion of report.

The least destructive, most effective solution was to make a second replacement hour wheel, increasing the tooth count 1/3 to 64 from the typical 48 (Figure 10). This would be driven by a new pinion of report reduced in size to accommodate smaller teeth for the largest diameter wheel. A plastic model was machined, which confirmed that the fit and functionality were possible within the space limitations (as the hour wheel was replaced during the initial anchor pendulum clock restoration). The higher-count hour wheel solution keeps the original train/pinion arbors and is not readily visible. It was hoped the 64 smaller teeth could be scaled within the hour wheel diameter to be driven from the smallest possible scaled-down 4-tooth pinion of report fitted to the great wheel arbor. If this was not feasible, a new pinion with additional leaves would need to be fitted to the original tapered arbor (or a new pinion arbor made!) and the corresponding wheel/arbor moved over. This would result in more complication, modification, and less conservation.

With fit and function now confirmed possible, a new hour-wheel and suitable pinion of report was machined and cut (Figures 11 and 12). As the nearest modern wheel cutter was chosen, it was necessary to carefully hand-file the hour wheel tooth width, profile, and length. Since the hour wheel hand shaft position and great wheel arbor location were fixed

Figure 10. Space constraints of the 48-tooth hour wheel. PHOTO BY GEOFF COX.

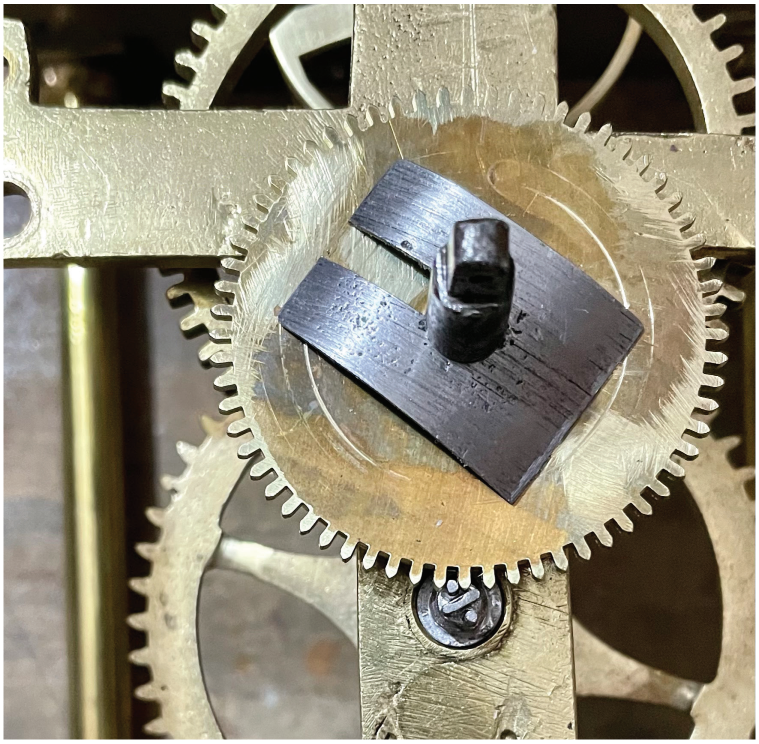

Figure 11. New 64-tooth hour wheel. PHOTO BY GEOFF COX.

distances, component diameters were very critical, with no margin for error. Many relatively short work sessions proved a success, and is usually the safest way forward on such adventures. The conversion work is sympathetic, nice and tidy, presents well, and it mechanically operates with optimal swing.

Months have passed and more than 80 work hours later, the reinstated escapement has been optimized to the extent possible in its current situation, including retaining worn but original pinion arbors. The bottom balance arbor has to be supported on the pivot shoulder without the benefit of less friction contact from the pivot bottom than is typical (via the center point) and so it is against a hardened steel support face. This, together with the accumulation of alignment errors from almost 400 years of repairs, replacements, and conversions, resulted in reliable running without incident, only ~45 minutes a day fast using a 2,160 g drive weight (143 g counterweight = 2,017 g net). It may be possible to remove (or add to the counterweight) a few grams more via flat lead shims, supplied to the owner to experimentally apply. A 2,050 g drive weight reduction (80 g counterweight = 1,970 g net) to slow down timing stops the clock on occasion from the inability to overcome friction, pinion wear, etc.

Figure 12. The 64-tooth hour wheel cutting. PHOTO BY GEOFF COX.

The following steps for future consideration to improve performance are listed in order of priority:

1. It may be possible to slow it a minute or two an hour by adding two small timing weights to the balance (as noted by Robey[23]).
2. Somehow fit a steel bottom balance arbor pinion support despite space limitations.
3. Replace the two pinion arbors. Unfortunately, there's not enough remaining material on the original pinion leaves (50% loss) to redress the worn mating surfaces and maintain tooth geometry and required thickness.
4. Replace one of the pinion arbors with extra leaves (to be determined), allowing the gearing to time properly. This would necessitate moving the second wheel/ pinion and allowing additional space for a conventional bottom cock, supporting the arbor pinion from the bottom.

The rope length/hanging height of 6" runs the clock for ~4 hours. Typically, balance verge lantern clocks have independent drive ropes/weights and run ~6 hours per winding. The run time can be doubled by fitting a longer rope on a single pulley, with the end anchored to the bottom plate to the side or the wall bracket running twice the weight. Very often there are telltale holes on the bottom of such lantern clocks, indicating this had been done.

Videos showing the clock in operation are available at https://earlyclocks.uk/rquelch-balance-recon. Figure 13 features photos of the completed Quelch clock.

Notes and References

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3. White, *English Lantern Clocks*, 42.
4. J. A. Robey, "The Origin of the English Lantern Clock, Part 1: Comparison with European Gothic clocks," *Antiquarian Horology* 37, no. 4 (December 2016): 511–21.
5. Robey, "The Origin of the English Lantern Clock, Part 1."
6. White, *English Lantern Clocks*, 46.
7. B. Loomes, *Lantern Clocks and Their Makers* (Mayfield, England: Mayfield Books, 2008), 7; see also White, *English Lantern Clocks*, 46.
8. P. G. Dawson, C. B. Drover, and D. W. Parkes, *Early English Clocks* (Suffolk, England: Suffolk Antique Collectors Club, 1982), 15.
9. Dawson et al., *Early English Clocks*, 14.
10. White, *English Lantern Clocks*, 55.
11. Robey, "The Origin of the English Lantern Clock, Part 1."
12. White, *English Lantern Clocks*, 55.
13. White, *English Lantern Clocks*, 175.
14. Loomes, *Lantern Clocks and Their Makers,* 126.
15. White, *English Lantern Clocks*, 105.
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17. B. Loomes, "John Quelch of Oxford," *Clocks Magazine* (October 2010): 11–14.
18. Personal communication between Geoff Cox and Brian Loomes, 2018.
19. Loomes, *Lantern Clocks and Their Makers*, 420–21.
20. Robey, "English Lantern Clocks with an Original Balance."
21. W. Derham, *The Artificial Clockmaker. A Treatise of Watch, and Clock-Work: Wherein the Art of Calculating Numbers for Most Sorts of Movements Is Explained to the Capacity of the Unlearned* (1696). This is the most famous of the early English-language books on horology.
22. Loomes, *Lantern Clocks and Their Makers*, 422.
23. Robey, in Loomes, *Lantern Clocks and Their Makers*.

About the Authors

Stephen Barasi trained as a physiologist in London then for a higher degree in neuroscience in Edinburgh. He worked as an academic researching in the field of sensory neuroscience and teaching medical and science students. After retirement he became interested initially in 18th-century long case clocks then in English lantern clocks. He is particularly interested in linking early lantern clocks to the history of early and mid-17th-century London.

Geoff Cox has been interested and involved in early clocks since he was a student roaming museum collections and NAWCC events during summer holidays. Completing an education at Michigan State University, the work travel that followed allowed the opportunity to network with important collectors such as Norman Langmaid and others who were enthusiastic in sharing their collections and vast experience with early English clocks. After retiring from a commercial scientific career spanning the US and UK, he shares decades of restoration experience and knowledge with others though Earlyclocks.uk.

Figure 13. The finished Quelch clock. PHOTOS BY GEOFF COX.