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Tools and Toolmaking in New England

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Tools for New England's Clockmakers and Watchmakers

Bob Frishman

Today there still exists a romanticized notion of early New England clockmakers. We like to imagine an old, avuncular, if not a bit grumpy, leather-aproned gent hunched over his crowded bench, patiently filing a small piece of brass by candlelight (*Figure 1*). Such images, however, belie the intricacy of clockmaking and the skills it demands. As seen even in fifteenth-century images of clockmakers, more than a few hand tools were needed to create a complicated accurate instrument that not only continued ticking but that kept time somewhat closely commensurate with what the best timekeeper of that era—the sundial—was displaying. While that non-mechanical ancient instrument *told* time, it did not *keep* time, but it was the arbiter of accurate timekeeping for setting watches and clocks until electrical time-distribution systems became widespread after the middle of the nineteenth century.



Figure 1. Oil on canvas signed "Roberts," sold at auction July 10, 2021, Lot 16. Courtesy of Schmitt Horan & Co.

The Pilgrims brought no clocks or watches with them from England, nor tools to service them, but John Endicott, the Puritan governor of the neighboring Massachusetts Bay Colony, had his name along with the date 1630 engraved on an English brass sundial made by William Bowyer. A pocket sundial told time for Roger Williams when he fled Boston to establish his more tolerant colony at Providence in 1636.¹ Mechanical timekeeping was not widely available in New England until many years after the *Mayflower* struggled across the Atlantic Ocean in 1620. The craft flourished to such an extent in England that King Charles I granted a 1631 charter to the Worshipful Company of Clockmakers to regulate the trade in the empire's capital city. However, British clockmakers did not arrive in New England until almost the end of the seventeenth century, when there was sufficient business for them there and when they could evade laws forbidding such skilled craftsmen from emigrating. A few clocks were imported sooner and were maintained by other tradesmen, primarily blacksmiths and silversmiths, with tools and know-how adequate for basic repairs.

These were not woodworking tools. Clockmakers were not joiners or cabinetmakers; they worked with metal, not wood. While scholars and collectors might now refer to a "Mulliken" clock, for example, the family of Massachusetts clockmakers for whom it is named had nothing to do with fashioning its wooden case. When the Mullikens were working during the eighteenth century, a "clock" was only the brass and steel machine. The furniture that housed it was commissioned and crafted by others. When clocks were itemized in early estates, "clock and case" signified that a machine encased in wood was among the possessions of the deceased.

Jonathan Mulliken's 1782 probate inventory has recently been discovered; sadly, he died at just thirty-six years of age.² This list

¹ Endicott's sundial is now in the collection of the Peabody Essex Museum in Salem, Massachusetts, while Williams's pocket sundial is in the collection of the Rhode Island Historical Society in Providence.

² Jonathan Mulliken, Newburyport, Essex County, MA: Probate File Papers, 1638–1881, July 8, 1782, 19086:18. A circa 1770 Jonathan Mulliken longcase clock stands at the Custom House Maritime Museum in Newburyport. The author recently restored this impressive clock, mostly using tools that would have been familiar to Jonathan, as a donation to the museum. Visitors now can hear the same ticking and the same bell sounding the hours that the clock's maker and first owners heard in that seaside town 250 years ago.

confirms that he worked with far more than a few hand tools, and as an active tradesman probably not by candlelight but rather by bright sunlight shining through his shop windows. Jonathan had nearly two hundred files, seven vises, and six hammers that he routinely used to strengthen brass, an alloy of copper and zinc that work-hardens when pounded. Hammering brass was a common procedure that was necessary to ensure that wheel teeth, movement plates, and other clock parts were sufficiently strong. Soft brass would wear quickly and bring angry customers. Far costlier than Mulliken's hammers, and equally necessary, were his two "watch engines." These would have been his most expensive pieces of equipment. Without these hand-powered gear-cutting machines, it would have been difficult to slice teeth into wheel edges with uniformity and to produce the correct number of teeth.

Jonathan also owned lathes, crucial for turning and shaping parts, and many drills, scrapers, broaches, tweezers, stakes, collets, "Chizzels," punches, calipers, nippers, pliers, and saws. He used large and small dividers in place of more specialized depthing tools that were rare and employed mainly by makers of high-precision instruments. Either method was needed to lay out a clock's gear-trains so that the wheels and pinions would mesh properly to transmit maximal power without skipping, binding, or jamming. A large oil stone would have kept Mulliken's tools sharp. His magnifying glass, nowhere near today's optical quality, would nonetheless have allowed him to closely examine and finish smaller bits and pieces.

To fabricate his own metal screws and to thread the holes he drilled to receive those screws, Mulliken owned a large screw plate with twenty-four associated taps. Modern-day appraisers, seeking to determine originality, as well as repairers must be alert to the presence of non-standard handmade screws in clocks from this era. A common technique for repairers is to put a screw back into its original hole after they remove a part, rather than search their parts tray later, trying to find the correct oddball screw that smoothly tightens only in one hole.

Although an extant set of wooden molds for casting brass gears reportedly has Mulliken provenance, implements for casting are not

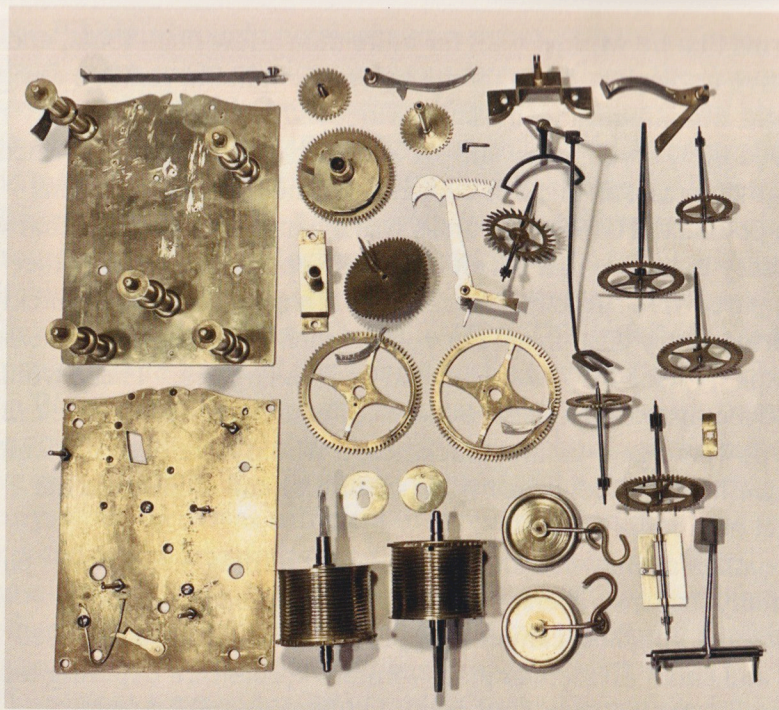


Figure 2. Disassembled movement of Jonathan Mulliken tall clock. Author photo.

in the inventory.³ If Jonathan undertook this activity, crucibles, pots, ladles, tongs, bellows, and furnaces should have appeared. However, lists often are incomplete, and a “Borax box” indicates that he was melting metal since that substance is used in the process. A “blow Pipe” also suggests that he was heating and joining metals.

When we consider all the movement parts of a Jonathan Mulliken longcase clock (*Figure 2*), it becomes apparent that such precise components could not have been made without sophisticated, varied, and specialized tools and equipment. A closer examination of a wheel-cutting engine reveals this complexity (*Figure 3*). The machine’s horizontal brass disk, or “index plate,” and its rings of dozens of holes are clearly visible. The count of these tiny holes corresponds to the number of teeth desired in the wheel being cut as the gear is advanced one position at a time.

The scholar Penrose Hoopes has documented the tools of a famous Connecticut clockmaker, Daniel Burnap (1759–1838), in a

³ These molds are currently in a private collection in Massachusetts.



Figure 3. Eighteenth-century wheel-cutting engine. Courtesy of Willard House and Clock Museum.

list that is augmented by the record he kept of his apprenticeship.⁴ Burnap trained under English immigrant clockmaker Thomas Harland, who arrived in Connecticut in 1773. Working in Harland’s shop in 1779, Burnap wrote a digest of all he was learning from his highly skilled master. This memorandum book is a unique and valuable record of technical terms baffling to a layman, but when deciphered the notes describe all the steps in making an eight-day tall clock movement. The book does not mention tools, but these may be inferred from parts cast, hammered, filed, cut, drilled, engraved, and polished.

Hoopes’s list of Burnap’s tools is extensive and represents the broad array needed to produce the metal clock movements and dials that museums and collectors now cherish. The list was compiled from his surviving tools, since an estate inventory has not been discovered. Certainly, many more of his tools were discarded or dispersed during and after his lifetime. Several official clockmaker inventories have been reproduced, with scholarly commentary, in horological publications.⁵ Even given signed and dated inventories,

⁴ Penrose R. Hoopes, *Shop Records of Daniel Burnap, Clockmaker* (Hartford: Conn.: Connecticut Historical Society, 1958). A photo of Burnap’s wheel-cutting engine is on p. 149. Eight associated cutters needed for different sizes and shapes of gear teeth are also illustrated. The machine itself may be viewed at the Connecticut Historical Society in Hartford, which houses one of the most extensive collections of early American clockmaking implements.

⁵ Among the most important of these is vol. 1 of *The Longcase Clock Reference Book*, by English scholar and publisher John Robey (Mayfield, England: Mayfield Books, 2013).

caution always is necessary when examining such documents. Key items may have been sold or passed down before the clockmaker's death or overlooked or misidentified by inexperienced appraisers. The relatively small sampling of such inventories—only about twelve from Connecticut are known—may not be truly representative of the trade as a whole.

Burnap owned two lathes, one large and the other small with a "Live Spindle Attachment." Whether "turns" or "throws," and whether powered by a hand wheel or a foot treadle, these lathes were far simpler and more primitive than motorized versions used by more modern horologists, but they were still capable of accurate work at the hands of skillful users. Along with his screw plates were "Wire Plates" for forming round and half-round metal rods. He had an "escutcheon stake" for making fancy metal plates to surround case keyholes. Burnap also owned engraving tools and an engraving pillow, indicating that he possessed those skills as well; he applied them to creating his brass and silvered-brass clock dials, and perhaps to non-horological engraving jobs. A planishing hammer would have flattened and smoothed the large brass dial plates prior to his engraving numbers, lines, circles, flourishes, and his proud signature.

Most important for Burnap's work, and for today's industrial historians, were the nine templates and patterns that allowed him to repeatedly and correctly fabricate the fifty-plus parts in each movement. After he designed and tested a successful movement and created associated templates, he could make part after part, clock after clock, without going back to the drawing board. One rectangular movement-plate template was complete with etched circles indicating the size and placement of the intermeshing wheels.⁶ Other templates of his were for producing hands, escapement pallets, or "anchors," and the "rack" and "rack hook" that governed the hour-striking system. Several more patterns made from wood and lead were listed for making wheels, bells, barrels, pillars, bell hammers, and capitals for case columns.

Clearly, clockmakers needed to know many details of how to make clocks that worked. They received instructions on dimensions, shapes, tooth counts, layouts, metallurgy, and step-by-step

⁶ Hoopes, *Shop Records of Daniel Burnap*, 159.

procedures during their apprenticeships and recorded them in notebooks that were sometimes called "calliper books." Sadly, except for Daniel Burnap's volume described above, almost none of these notebooks survive today. If they did, we would know more about what tools were used and in what ways.

One of the earliest practical English-language how-to books on the subject was not published until 1696: *The Artificial Clock-maker* by William Derham.⁷ It made scant mention of tools and instead offered histories of the trade and extensive mathematical formulae for computing the proper number of gear teeth and pinion leaves. Part of the book's extended title promised that "the Art of Calculating Numbers for most sorts of Movements is explained to the capacity of the Unlearned." A few sample sentences suggest that this resource may have challenged even learned students:

Thus suppose you had use for a Wheel of 1440 teeth, with a Pin. Of 28 leaves, you may make it into 3 Wheels and Pinions, viz. 4 36 7) 8, and 1)5. For if you multiply the three Wheels together, viz. 36, 8 and 5: and the three Pinions together by themselves, viz. 4, 7 and 1, you will find 1440 to arise for the Wheels, and 28 for the Pinions....⁸

Several later editions of Derham were published. The 1759 update added comments on the Gregorian calendar belatedly adopted by England and its colonies in 1752. The calendar correction eliminated eleven days when the date jumped from September 11 to 21, leading many outraged citizens to complain that their lives had been shortened. Each new year began on January 1 rather than on March 25. Continental Europe had made the shift in 1582 to better reflect the earth's annual journey around the sun and adjust for the loss of eleven minutes per year in the outdated Julian calendar. The English resisted, not wanting to accede to a Vatican-inspired directive. Derham's 1759 edition also featured a fold-out equation-of-time table showing the conversion of sundial time to clock time for each day of the year. Since a sundial's indications vary by as much as sixteen minutes slow or fast during the seasons, clockmakers who set and adjusted timepieces based on sundial

⁷ W[illiam] Derham, *The Artificial Clock-maker: A Treatise of Watch, and Clock-work* (London: Printed for James Knapton, 1696).

⁸ Derham, *Artificial Clock-maker*, section 2, p. 14.

readings needed this chart. Most yearly almanacs, such as *Poor Richard's*, devoted a page to this table as well.

An ordained clergyman, Derham produced many other scientific treatises and was the first to accurately determine the speed of sound. However, his horology book was not owned or read by most clockmakers. Learning clockmaking from a book in the eighteenth century, as from online videos today, would have been frustrating, challenging, and probably unsuccessful for most people. Master clockmakers were opposed to such instructional books, fearing they would reveal the trade's secrets that they preferred to impart directly and solely to their apprentices.

In addition to notebooks, inventories, how-to books, and scientific treatises, two other sources that document the clockmaker's trade and the tools needed to practice it include advertisements and catalogues. The earliest colonial clockmakers emigrating from England brought with them their tools, which they then either passed down or sold off. In 1757, Boston merchant Benjamin Church advertised the sale in his auction rooms of a parcel of watchmakers' tools.⁹ While some of Mulliken's and Burnap's tools were handmade by the clockmakers, often during their apprenticeships,¹⁰ many more that were owned and used by less skilled artisans were sourced from local merchants and hardware dealers who imported them from English jobbers such as John Wyke.

Wyke's firm was in Liverpool, a major toolmaking center. Over many pages, his important eighteenth-century English tool catalogue illustrates the hundreds of tools and small machines available for English and New England horologists to purchase and use in their craft.¹¹ One metal file was never enough, and the dozens offered in

⁹ *Boston Gazette*, August 29, 1757. If Church's name sounds familiar, it is because he was the father of the Revolutionary War turncoat Dr. Benjamin Church, who revealed information about the Massachusetts Minutemen to British General Thomas Gage during the occupation of Boston.

¹⁰ Hoopes lists several that clearly were of Burnap's own construction. *Shop Records of Daniel Burnap*, 97.

¹¹ This catalogue has been reprinted by the Winterthur Museum with modern explanatory commentary. John Wyke, *A Catalogue of Tools for Watch and Clock Makers by John Wyke of Liverpool* (Charlottesville, Va.: Henry Francis du Pont Winterthur Museum, 1978). Charles Hummel (1932–2025), a Winterthur curator with decades of service there, wrote the reprint's Foreword. He was instrumental in obtaining, relocating, and displaying the Dominy Family clock shop and its tools, which are longtime highlights of the Delaware museum.

the catalogue might not have been enough, either. Nearly every movement part required some form of filing to reduce roughness from casting or forging, bring it to its final shape, and make it uniform. The tips of every wheel tooth needed "rounding up" after the teeth were slit.

Apprentices in many metal trades of the past endured months of filing practice, which their masters enforced before allowing them to take on other, more complicated tasks. Once a part was filed wrongly or too much, starting over was the only recourse. Inventories sometimes listed pounds of brass filings swept from the bench-tops and floors; this was valuable metal that could be melted and reused. A variety of screw plates and taps, mentioned above, were also shown on the catalogue's pages. Vises such as those in Mulliken's estate inventory were also illustrated. Another ingenious precision tool that was shown, designed to cut uniform spiral grooves on weight-cord barrels, kept those cords lined up smoothly during winding and unwinding.

All this begs the question of how much actual clockmaking these men did, especially later in the eighteenth century and into the nineteenth. Creating the blanks for clock wheels required high-temperature casting, not an easy task, as well as sources of raw or recycled brass, which was not produced in America. Making hard steel arbors and pinions was even more difficult; no inventory lists a pinion-cutting engine. Clock pinions were bought as forgings and then hand-finished. They and other steel parts were hardened for durability by heating them to a red glow and suddenly quenching them in water, a tricky procedure to do correctly. For some parts that would become dangerously brittle by over-hardening, a craftsman would then temper them at lower temperatures to reduce brittleness and stresses. Shaping the complicated parts of a rack-and-snail striking system was harder still, even though Daniel Burnap apparently could do it from his patterns.

To avoid these fabrication challenges, clockmakers regularly imported, bought, and finished blanks and forgings, sometimes as "clock sets" brought from Liverpool. These sets included forged steel arbors with integrated sliced pinions that were much easier to buy than to craft. A man could draw pinion wire, but a special sturdy bench would be needed, plus a supply of good steel and a pair of

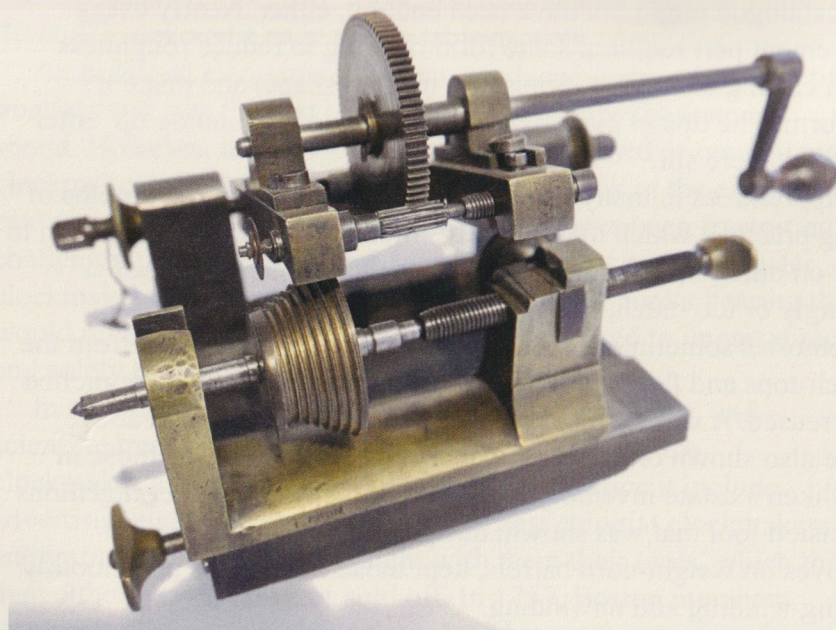


Figure 4. Eighteenth-century fusee notching engine signed "Hollands." Collection of the author.

muscular arms. In any case, pinion wire was used mostly for watches; larger pinion wire was much more difficult to pull through a die and was almost never used in clockmaking.¹² (Figure 4)

The full range of handmade and imported clockmakers' tools and parts can be found in reference works both old and new. The scholar and collector Ted Crom (1920–2008) published two substantial volumes that truly are the "Bibles" on this subject.¹³ Based in Melrose, Florida, Crom spent decades and large sums to collect, research, and study horological tools and then to produce his books. On more than a thousand glossy pages, he reproduced trade cards, trade catalogues and price lists, color illustrations, maps,

¹² An example of a wire-drawing bench was in the Ted Crom collection that was auctioned in 2010. *Science, Technology & Clocks featuring the Ted Crom Horological Tool Collection & Library* (Marlborough, Mass.: Skinner, May 1, 2010). The author was fortunate to be the high-bidder on one of his artifacts, an eighteenth-century fusee-notching engine (Figure 4).

¹³ Theodore R. Crom, *Horological Shop Tools—1700–1900*, 2 vols. (Melrose, Fla.: Theodore R. Crom, 1980, 1987). Copies of the two volumes are available for purchase from online sellers.

photographs of his huge collection's rare tools and of clockmakers at work, and early artworks with horological content. Each is accompanied by informative captions and lengthy explanatory texts. The books make clear that sophisticated tools and parts from England, France, and Switzerland were widely available to horologists in the eighteenth century and then in much greater numbers and levels of complexity throughout the nineteenth century. Crom's books are not clock-repair manuals, as they do not always explain in detail how and why the tools were used, but they have been quite helpful to many restorers and repairers who have viewed the old tools and contemplated their purposes. Thus, they are a vital resource for understanding the history of horological practice.

Another comprehensive resource, produced even earlier than many of the trade and tool catalogues that Crom references, is the French-language Diderot and D'Alembert *Encyclopédie, Ou Dictionnaire Raisonné Des Sciences, Des Art Et Des Métiers*, published in Paris from 1751 to 1780.¹⁴ By the time of its final editions, its compendium of practical world knowledge included more than 250 articles on horology along with nearly 70 highly detailed full-plate engravings of clocks, watches, and related tools and machines. As examples, Diderot's Plates XX and XXI depicted two views of "La Machine de Sulli pour Fendre les Roues." Henry Sully (1680–1729) was a prominent English clockmaker who did most of his important work in France. His complex machine for cutting gear teeth was a stunning artifact of hand-powered precision technology that any clockmaker over the next two centuries could have proudly owned and operated. The same applies to the device that was beautifully drawn for Plate IV, "Machine pour Arrondir les Dentures." This machine tool, shown with its various cutters and attachments, cut the final "epicycloidal" rounded tips on wheel teeth much more accurately and methodically than did a clockmaker eyeballing his file strokes.

It is important to understand that the vast majority of a clockmaker's and watchmaker's time was spent repairing

¹⁴ [Denis] Diderot and [Jean Le Rond] D'Alembert, *Encyclopédie, Ou Dictionnaire Raisonné Des Sciences, Des Art Et Des Métiers* (Paris, 1751) and subsequent editions published to 1780.

timepieces, not making them. The broad array of clockmaking tools discussed above, especially the complex specialized machines, would not have been needed for most repairs and cleanings. The market for costly new clocks and watches was quite limited, and the ones already in use needed frequent professional care. Dust, dampness, and soot were everywhere. Damage from knocks and drops and rough handling was common. Broken steel mainsprings, shattered glass watch crystals, and cracked brass gear teeth all needed attention. Steel pivots, the short ends of each arbor, which turned in the plate holes, became worn and needed grinding and polishing or replacement. Steel pinions, the small gears pushed by the larger brass wheels, became gouged by dirt-clogged gear teeth and eventually stopped turning.

This kind of slow, relentless damage and wear continues to occur in mechanical clocks today, often unbeknownst to the clock owners who think all is well until the suffering movements finally give up. Owners have stated with pride that their antique clock has run perfectly for years and even decades without service, not realizing that they have overseen the clock's destruction just as surely as they would have destroyed their automobile if they had never changed the engine oil. Today's clock "makers" are in fact repairing old, worn, grime-clogged ticking clocks that finally refuse to run. Almost never are they making new movements. A few meticulous craftspeople, with lots of free time and basement shops full of machine tools, still do make clocks, but mostly for their own enjoyment or to compete in craft contests.

Some New England clockmakers such as John Bailey, Reuben Tower, and Joshua Wilder did continue to build clock movements the old-fashioned way during the first half of the nineteenth century, but in this era clockmaking and then watchmaking became increasingly industrialized. The process began early in the 1800s with Eli Terry's mass-production of wooden-movement clocks using waterpowered machinery and an innovative design of interchangeable parts. The story of the "Porter Contract" with Terry is often told, and with the valid claim that this truly began the Industrial Revolution in New England and North America. Terry started as an apprentice to Daniel Burnap, but he worked independently by 1795 when he already was devising machines and

jigs to add ease and speed to his clockmaking. In 1806, he contracted to supply four thousand wooden clock movements in three years, at a time when individual clockmakers produced no more than a dozen clock movements per year whether made of wood or brass.

Local woods—oak, cherry, and laurel—were used to make these more affordable clocks, since costly brass was imported or came from melting old candlesticks, coins, and kitchen items. Wooden movements were not invented in New England but often were improved versions of ones made earlier in Germany's Black Forest and in other central European regions. Terry's water-powered machinery spewed out uniform interchangeable parts that could be assembled into peddler-sold clocks affordable to much of the citizenry. His machines—the new "tools" of the new century—filled riverside factories and soon replaced hand-powered handheld tools sitting on the benches of one-man shops.

Then came even bigger clockmaking factories, churning out hundreds of thousands of affordable timekeepers with familiar company names such as Seth Thomas, Ansonia, Waterbury, Ingraham, New Haven, William Gilbert, and E. Howard. Although their massive buildings seemed to burn to the ground at regular intervals, and despite economic upheavals that periodically shuttered many of them, their factory-made clocks made by factory-scale "tools" completed the transition from the costly and scarce timekeepers of earlier days.

After the middle of the nineteenth century, in time for our Civil War, the Waltham watch factory was able to successfully mechanize the mass-production of pocket watches. Complex belt-driven machines that could be operated by relatively unskilled workers were designed and built to produce nearly microscopic interchangeable components up to a thousand times faster and more reliably than hand workers. Tools no longer made the clocks and watches; tools made the machines that made the clocks and watches.

This rendered obsolete the home-based trade watchmakers who were working at their benches by windows in England and Switzerland. Those overseas piecework artisans mostly focused on making single parts, with just a few specialized tools, that then were assembled and finished by the watchmakers whose names were

engraved on the movements. Now, in Connecticut and Massachusetts, factory workers, sometimes half of them women, produced parts for hundreds or even thousands of reliable, accurate watches per day, mostly in concert with automated, complex belt-driven machinery and machine tools. More skilled factory workers assembled, tested, and adjusted the new watches, tasks which could not be automated and which still relied on hand tools, good vision, and manual dexterity.

This author is among the horologist repairers who not only still use many of these old tools but who also admire, study, and collect them. In the past, horologists were among the most elite of craftsmen, fashioning clocks and watches first for only the wealthiest royal and noble patrons, and then increasingly for middle-class consumers. Their precision work, their scientific breakthroughs, and their roles in society's advancement are undisputed in the history of the past seven centuries. Those of us carrying on the venerable trade today, with our files and burnishers, and lathes, are proud to be a part of that history.