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RESTORING THE *M.R. 1750* PUBLIC CLOCK: HISTORY, ANALYSIS, EXPERIMENTAION AND RE-CREATION

Steven W. Dykstra, Donald Saff and Lee W. Badger

Abstract

When the *M.R. 1750* tower clock mechanism was acquired for a specialized private collection, examination revealed that it had alterations and adaptations that left it in barely in working order. The problems included a shortened pendulum and missing parts for hour strike and quarter-hour strike operation. Restoring the clock to full and complete working order required horological analysis and the skills of an artist-blacksmith.

The authors present a brief history of timekeeping machines of this type, providing contexts and precedents that determined and informed the clock's restoration. They explain detection and correction of the clock's operational deficiencies including the pendulum modification and calculation of the correct pendulum length. Prototype replacement parts were created to adjust and test mechanical details of the missing pieces. To avoid anachronistic appearances in the functional restoration, modern materials, methods and techniques were used to imitate the style and patination of the existing 18th c. work. The authors also address differences between stringent conservation and preservation treatment goals and those that primarily seek to restore a mechanical object to operating functionality.

1. Contexts of the Restoration

1.1 The Saff Horological Collection

A clock is a mechanical apparatus to segment time. It evolved in an effort to regulate, indeed control, public routines. Municipal and church tower clocks, with their large dials, bells, and occasional astronomical displays, most effectively facilitated this mission. The Saff Collection of tower clocks in Oxford, Maryland, began from a small private collection in 1970 and was organized to demonstrate the technical innovations in public timekeeping from the 15th century to the present day.

A clock escapement is a mechanical device that releases the latent power of suspended weights incrementally. Over many centuries, clockmakers have endeavored to improve the accuracy of clocks by means of new and more precise escapements. The pendulum determines the duration of the increments of the escapement's motion. It too had numerous iterations of refinement in efforts to reduce the effects of temperature and humidity on pendulum length. The Saff Collection comprehensively represents applications of wrought iron, cast iron, iron alloys and brass, to ever more efficient gearing, escapement and pendulum design.

1.2 Context of the *M.R. 1750* Clock in the Saff Collection

The earliest church clock in the Saff Collection was produced by Laurentius Liechti of Winterthur, Switzerland in 1541 (Fig. 1). The time and strike mechanism of this clock is controlled by the first known type of mechanical escapement. Comprised of a crown wheel, verge, and foliot (a pivoting horizontal bar with moveable weights on both ends), it was developed in 12th Century monasteries and applied to clock mechanisms for approximately 500 years.

Figure 1. The Saff Collection's Laurentius Liechti 1541 clock with a verge and foliot escapement.

With the application of the pendulum to timekeeping in the 17th century, theoretically conceived and attempted by Galileo and brought to mechanical success by Christiaan Huygens in the 17th century, accuracy improved from fifteen minutes per day to two minutes per day. The new system, replacing the foliot, merged the verge and crown wheel with the pendulum. A Dutch clock which dates to about 1670 in the Saff Collection is an example of this short-lived hybrid system (Fig. 2).

In about 1670, Joseph Knibb and/or William Clement invented the recoil (anchor) escapement. This innovation in escapement design allowed time keeping accuracy to leap to about two minutes per week. In the 18th c., this dramatic improvement spurred widespread conversion of earlier clocks from the use of foliot escapements to the anchor and pendulum. Few clocks were spared this conversion, which accounts for the rarity of the foliot in surviving clocks of the period. The German–made clock monogrammed "M.R. 1750" is representative of an early foliot clock, with a back-to-back gear train layout, that was converted to a recoil escapement (Fig. 3). Although it is a matter of speculation precisely when this clock was originally constructed, it was probably made during the 16th Century and it is the conversion to the anchor type recoil escapement with pendulum that accounts for the 1750 date.

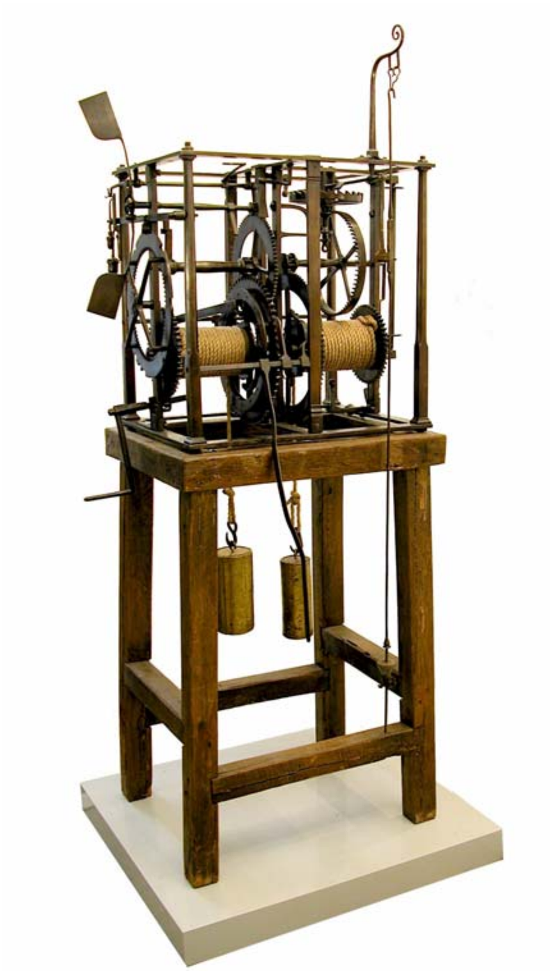

Figure 2. The Saff Collection's Dutch 1670 clock with a crown wheel escapement.

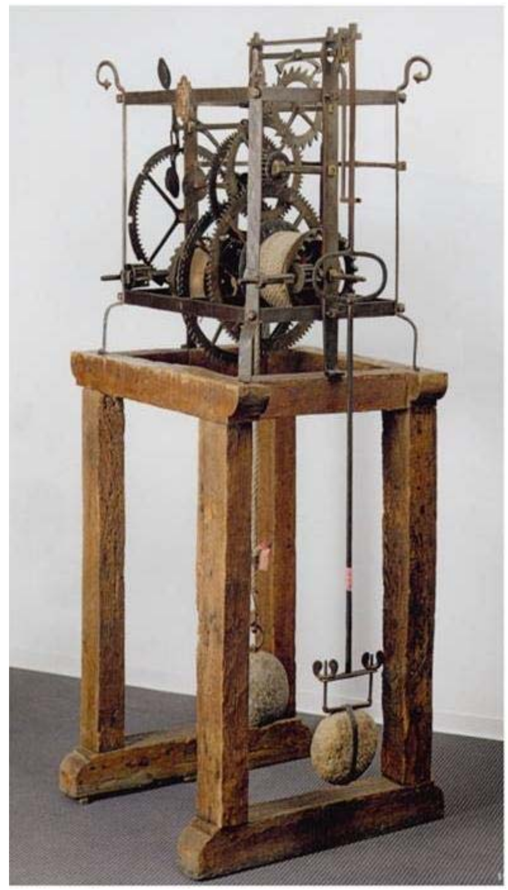

Figure 3. The *M.R. 1750* clock before treatment, as it appeared at the time of its acquisition.

2. Analysis of the *M.R.1750* Clock

After the acquisition of the *M.R. 1750* clock, it became obvious that crucial parts were either missing or altered, and experimental test operation of the clock revealed gross time-keeping dysfunction. Missing parts included an hour strike release arm, the entire quarter-hour strike assembly, a weight to drive the strike train and several less functionally critical fittings; a winding crank, a frame brace and several spacers and washers. Horological analysis of the clock's operation included direct observation of its mechanical operation and the introduction of experimental prototype pieces to determine the functional form and configuration of missing pieces. Most of the analytical observations and the development of prototype replacement pieces revolved around fundamental observations leading to the conclusion that the time train barrel on which the time keeping weight is wound and its integrated great wheel were intended to rotate exactly once each hour. Analysis of the clock's functioning revealed two highly compromising alterations; shortening of both the pendulum rod and the hour lift pin on the time barrel great wheel.

2.1 The Strike Train

2.1.1 The Hour Strike Release Arm

The hour strike release arm was missing from the existing hour strike release arbor. In full operation, this arm would be lifted each hour, rotating the arbor to release the hour counting and striking portion of the clock. A hole in this arbor indicated the location of this arm whose alignment demonstrated that it should be lifted by a pin on the time barrel great wheel.

Unlike most striking clocks in the 18th C., the *M.R. 1750* hour strike system did not incorporate a "warning" feature. A strike train with a warning system strikes a warning bell prior to releasing the hour strikes. It also partially unlocks the strike train and remains poised to allow the correct strike count to begin exactly on the hour. The warning feature was intended to alert listeners to the upcoming hour strikes, allowing them to count them accurately with full attention. In the *M.R. 1750* clock, the warning function would be accommodated more simply by a quarter-hour strike tolling just before the hour count.

The absence of a separate warning strike and hour count release system in the *M.R. 1750* clock required an hour strike release arm that would not dwell on the down (waning) side of the hour lift pin after reaching its apogee. If the arm remained elevated in the release position, the hour count wheel would continue to allow the counting of subsequent hours beyond the one marked at the apogee of the hour lift pin. To obviate this problem, the hour strike release arm would need an articulated foot. This drop-foot device is occasionally found in Dutch striking clocks and is called a "goat's foot," or "nag's head." Once the lever reaches the highpoint of the pin, the goat's foot drops and the lever immediately falls rather than remaining elevated in the release position while riding down the backside of the pin. All lengths and angles of the missing arm were determined by extensive prototyping and testing, resulting in the development of a precisely functional prototype hour strike release arm (Fig.4).

Figure 4. The prototype hour strike release arm.

2.1.2 The Quarter-Hour Strike Lever

The rim of the clock's time-barrel great wheel carried four evenly spaced lifting pins ostensibly for accommodating a quarter-hour passing strike. However, the quarter-hour strike lever, arbor, hammer pull, and bearing brackets were missing. The original location of the bearing bracket tenons was marked by holes present in the vertical angled corners of the clock's frame. These bracket tenon holes located the missing quarter-hour strike assembly just above the hour strike assembly. The existing hour strike assembly, consisting of a pair of bearing brackets, an arbor and a lift lever/hammer pull arm would serve as an example for developing the form and configuration for the missing quarter-hour strike assembly.

The quarter-hour strike lever was the most complicated piece missing from the clock. It needed to be lifted by a pin on the great wheel in the time train portion of the clock, rotate on an arbor mounted above the hour strike assembly on the strike train portion of the clock and incorporate a quarter-strike hammer pull. In addition, it would need a feature to prevent it from falling too far into the time train where it could miss being lifted by pins on the great wheel on their upward arc.

Furthermore, the combined quarter-strike and hour warning function would require the lift-arm portion of the lever to be released from the lift pin precisely for accurately timed striking by the hammer pull. This would be accomplished by the traditional method of forming the ends of lift arms with reverse bevels, providing a sharp and sharpenable point at its critical tip. Again, the lengths, bends, shapes and angles of the missing arm were determined by extensive prototyping and testing, resulting in the development of a precisely functional prototype quarter-hour strike release arm (Fig. 5).

Figure 5. The prototype quarter-hour strike lever.

2.1.3 Great Wheel Quarter-Hour and Hour Strike Pins

As previously noted, the rim of the existing great wheel carried four evenly spaced lifting pins for activating quarter-hour strikes. A full rotation of the great wheel each hour would also be required to lift the hour-strike release arm once each hour, therefore one of the four pins on the great wheel would also have to act as an hour lift pin. An important part of the hour-lift pin's function, as worked out with the prototype replacement pieces, is for both the hour strike release arm and the quarter-hour strike arm to be lifted together on the same pin each hour. This would have to be accomplished by one pin long enough to lift both arms at the same time. However, all four pins on the great wheel were the same length. Possible reasons for this alteration are unknown.

Close inspection of the great wheel and its four pins revealed that the back of one pin, where it was peened over its point of insertion through wheel, was somewhat larger and rounder than the others, and more significantly, marked with a small dimpled punch mark (Fig. 6). These differences in this pin were taken to identify it as the original hour lift pin to be extended to functional length.

2.2 The Pendulum

Observation of the mechanical features, configuration and operation of the clock's time train indicated that the time barrel and great wheel needed to travel one revolution per hour. On test, it traveled at a rate of almost two revolutions per hour. The error proved to be the product of a pendulum that had been significantly reduced in length. Although some similar clocks may have been casually displayed without their awkwardly long pendulums, the *M.R. 1750* clock has a stone pendulum weight, unique and unusual in its shape, support and method of attachment to the pendulum rod (Fig. 7). When the clock was removed from service, it was likely placed in a home as a display artifact requiring a pendulum length that did not exceed the height of the clock and its stand.

Figure 6. The back of one of four pins on the hour wheel showing a punch mark indicating it as the likely hour lift pin.

Figure 7. Detail of the weight end of the existing shortened pendulum showing the unique weight stone and wing nut assembly for fine adjustment of pendulum length.

A contemporary weld in the pendulum rod was readily discernable, indicating the location where a length of original rod was removed and the pieces rejoined in a convenient shortening. The operationally functional pendulum length was calculated by multiplying the wheel teeth and dividing by the number of pinion trundles using the principles and the mathematical formula relating the period of a pendulum to its length and the acceleration of gravity, as applied by Huygens in the 17th c (Rawlings 1948). The amount of time it takes for a pendulum to go back and forth once, its period, is related only to the length of the pendulum and the acceleration of gravity. Since gravity is considered to be constant at any given spot on the planet, the length of the pendulum is the only thing that affects its period. Neither the weight of the pendulum nor the length of its arc of swing have any consequence in this calculation. The re-computed pendulum length was tested by attaching temporary improvised extensions to the pendulum rod. After the clock was made to keep accurate time by these provisional methods, a clear specification could be made for correcting the length of the shortened pendulum rod.

2.3 The Time Weight, Stand and Miscellaneous Fittings

Several other features would be necessary to return the *M.R. 1750* clock to timekeeping operation. The mass of the missing strike weight was determined by incrementally increasing experimental weights until the least necessary weight was determined for insuring dependable train motion. The wood stand, though historically correct in its outward appearances, was too short unless the clock was originally installed with its pendulum swinging through an opening in the floor below. Alternately, the original clock stand may have been a supporting frame which was integrated into the clock's host structure, with a ladder-like arrangement of beams, shelves and platforms to facilitate access and maintenance. The existing iron frame of the clock includes a center support with an attachment foot, but the existing stand acquired with the clock provided no cross brace or other support for the iron foot. Additionally, the clock lacked a winding crank to enable re-winding the time and strike train weights as well as several bearing washers necessary to hold moving parts in optimum working alignment.

3. Development of Treatment Goals

3.1 Functional Purpose

The primary consideration in developing treatment goals for the *M.R. 1750* clock was operational functionality. A fundamental purpose of the clock's host collection is the demonstration of innovation and advance in horological technology. With few exceptions, the principal property of clocks in this collection is their demonstrable ability to keep time within the constraints of their particular technology. Especially for this clock and the related 1541 and 1670 public clocks that give it context, there was no other original function or purpose outside of timekeeping operation; they were not originally valued for any other reasons, artistic, aesthetic or material.

As historical objects, some public clocks are valued as representatives of the work of a specific clock maker (such as the previously mentioned Laurentius Liechti 1541 clock), as accessories specific to a particular structure or location (such as the Salisbury Cathedral clock discussed in Section 3.3, below), or as individually distinguished standard-setting timepieces. However, the *M.R. 1750* clock enjoys no such historical celebrity.

The clock also lacks unique or unusual significance in the methods or materials employed in the construction or in any aspects of its condition or state of preservation. Furthermore, the clock's existing materials exhibit no signs of destructive corrosion, active deterioration or inherent vice. Consequently, the present treatment was not conceived as a comprehensive conservation effort addressing all aspects of the object's condition and preservation as a historic artifact. Immediate treatment goals were oriented only toward the restoration of full and historically accurate timekeeping functionality.

3.2 Historical Consistency

A functional object can experience a working history of modifications that defy pinning it to a single specific date. The object's users may make repairs and modifications to maintain or enhance its functionality whenever convenient or necessary, and often without documentation. Any particular date in the lifetime of a functional object may not accurately reflect its past or future form or configuration. This is especially true of technological objects - those objects whose practical use can be improved through successive alterations and modifications.

In order to avoid creating a misleading combination of features from various and unconnected parts of the object's history, the restoration of a technological object requires specific understanding of the particular object as well as the history of the technologies it demonstrates. Specifically, it is necessary to analyze the historical sequence of repairs and modifications the object received, and to understand the character and function of parts and pieces that may have been replaced or discarded in the alterations. Any accurate restoration must attempt to represent a particular time period in the history of the object, and it may often require the introduction of appropriate facsimile or re-created pieces.

Like other clocks in its category, the *M.R. 1750* public clock is a clear example of a technological object that was repeatedly subject to repairs and significant functional modifications. This clock's role and context in its host collection identifies it with the utilization of recoil escapements from the late 17th century through the mid 18th century. Therefore, in order to maintain historical consistency and avoid anachronistic representation, the goal of restoration treatment was to recreate functionality and appearance compatible with the clock's likely configuration circa 1750. This treatment goal would require the reversal of some alterations and the recreation of several missing pieces.

3.3 Treatment Precedents

The Salisbury Cathedral clock is the oldest functional clock in Great Britain. As is common with public clocks, the clock's keepers occasionally replaced worn pieces and implemented technological improvements as they became available. The earliest records of the clock's use are dated to 1386, and it continued in operation through three or four centuries before it was taken out of service. By the time it was retired in the later 18th c. it had been fitted with a contemporary escapement and updated with a number of other functional adaptations.

When this clock was restored to functionality in 1956, the national authority responsible for the project removed and replaced several crucial parts of the mechanism and pursued other alterations in order to achieve a representation of how the clock looked and worked in its first decades of operation. Before and after treatment photographs illustrate the extent to which the existing clock was altered to represent its late 14th century configuration (Fig. 8). Although this may be an extreme example of the degree of re-creation necessary to represent a functional object at a particular date in its history, this treatment was considered as an important precedent because the Salisbury Cathedral clock and the *M.R. 1750* clock have many categorical similarities. Additionally, in the field of horological repair and restoration, critically worn, broken or lost parts and pieces are commonly replaced with replicas, either exact facsimiles or simply functional copies.

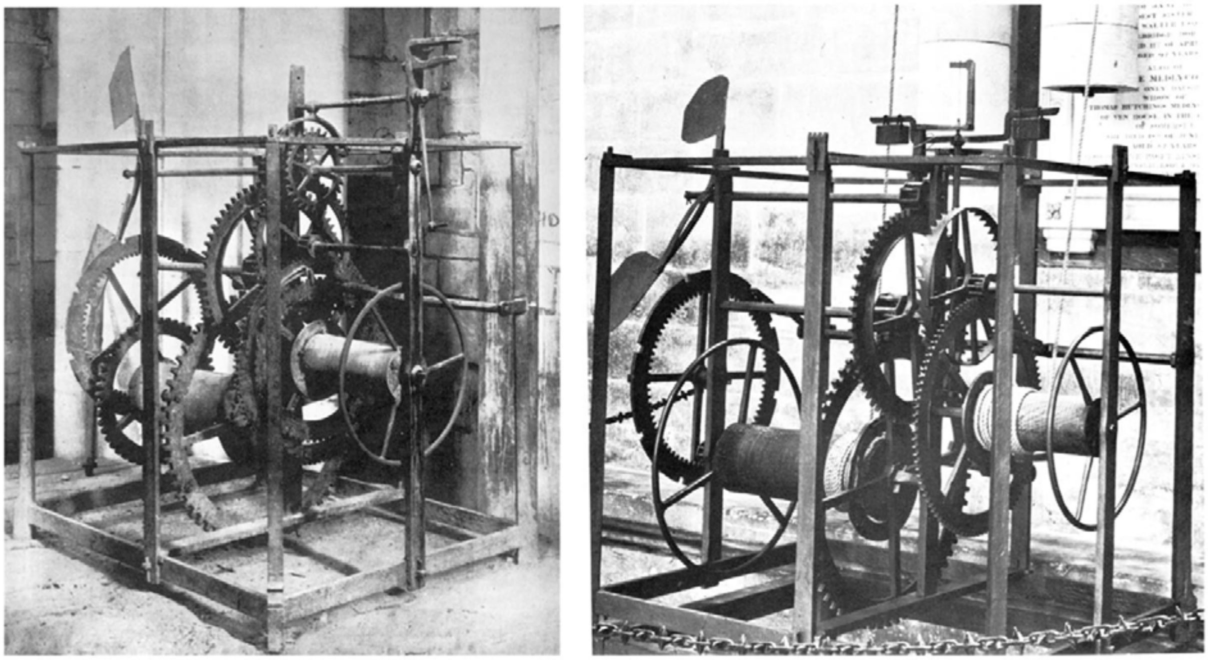

Figure 8. Before (left) and after (right) treatment photographs of the Salisbury Cathedral clock. The arrows indicate the old 18th c. escapement on the left, and the new reproduction 14th c. escapement on the right.

4. Restoration, Re-creation and Patination of Parts

Because the treatment goals were focused on restoration of operable functionality and historical consistency in both functional configuration and appearance, treatment required the services of an artist-blacksmith with knowledge, experience and sensitivity in the preservation and restoration of historic iron objects. The blacksmith selected for this project also had references and experience in historic horological projects in addition to appropriate training, skills and credentials in historic and reproduction iron work. The *M.R. 1750* clock was removed from its stand and placed on temporary supporting skids and moved to this blacksmith's studio and workshop to facilitate the necessary work.

According to the established treatment goals, all altered and re-created pieces would be required to match in appearance both the historic craftsmanship and current patina and condition apparent in the existing clock. However, treatment was not intended to create false authenticity that would tend to obscure or deny the restorations. Therefore, modern methods and materials would be used to imitate historic appearances - no historically genuine production processes or iron alloys would be used in the restoration. In this way, if treatment documentation should ever become lost or separated from the clock, simple and direct material analysis would allow the restored and re-created parts and pieces to be distinguished from their historic counterparts.

In addition to re-creating pieces in a metalwork style harmonious with the 17th and 18th century craftsmanship evident in the existing clock, the project blacksmith was also responsible for patination of the new pieces to match existing parts. He recognized that the existing surface texture was due primarily to traditional hand forging, hammering and filing and the existing patina could be matched subsequently with commonly available modern products. Historically traditional methods would need to be combined with modern methods and materials to achieve the desired result.

All re-created parts were made from standard and commonly available mild steel cut from stock mill sizes, roughly formed and shaped by grinding and filing, then heated to working temperature in a propane forge and hot hammered and filed further in successive approximations until the finished form with matching surface texture was achieved. A proprietary 40% hydrogen peroxide solution was used to remove scale and establish a uniform, finely etched and oxidized surface to prepare the finished steel pieces for final patination. Interestingly, this oxidizing solution is marketed for the hair salon industry, but it has been adopted by taxidermists and metal smiths who favor its additional phosphate rinsing agents and extended shelf life. The project blacksmith used this solution with cotton rag poultices, repeatedly wet with the solution until achieving the desired degree of oxidized etch. Following a thorough water rinse and drying, proprietary solutions for gun bluing and "plum brown" gun barrel finish were mixed a drop or two at a time and applied with a small folded pad of clean cotton rag to achieve the desired color effect on the prepared steel. Then, after additional rinsing and drying, a proprietary paste wax provided a traditional and appropriate final protective finish and sheen.

4.1 Restoration of the Hour Lift Pin

The first step in restoring the *M.R. 1750* clock was to add the length to the hour-lift pin that was removed in the past, as described in section 2.1.3, above. The length and diameter of the pin extension was determined by measurements taken in-situ from the prototype lever arms and the existing pin, and a piece of mild steel was cut and ground to the appropriate dimensions. The extension piece was welded to the existing pin using a MIG welder.

Contemporary metal-inert gas (MIG) welding uses an electric arc to apply and fuse metal alloy to conductive substrates within an envelope of inert gas. Control of the electrical current determines the length and heat of the arc. Feed controls vary the speed at which wire alloy is introduced into the arc as the positive electrode. Inert shielding gases protect the welding area from nitrogen and oxygen, which can cause fusion defects if they come in contact with the electrode, the arc, or the substrate metal. Control of these variables and selection of these materials determine the nature and quality of the weld in various applications. (Cary and Helzer, 2005). The project blacksmith selected Stargon CS, a widely available commercial blend of argon and carbon dioxide gas and .035" (0.9mm) diameter welding wire conforming to ASME SFA-5.18 for compatibility with both wrought iron and mild steel. Electrical current and wire feed settings were adjusted to achieve a small quick weld of minimum size and heat. After filing the weld smooth to match the diameter of the pin, it was tested successfully with the prototype levers and patinated to match the great wheel and existing pins.

4.2 Re-creation of the Quarter-hour Strike Lever and the Hour Strike Release Arm

Restoration treatment required re-creation of the entire quarter hour strike assembly including bearing brackets for attachment to the clock frame, an arbor bar and lever arms. The prototype quarter hour strike assembly provided a model for dimensions and configuration while the existing hour strike assembly (Fig. 9) served as an example to illustrate the characteristics of materials and manufacture necessary to avoid a mismatched or anachronistic appearance**.**

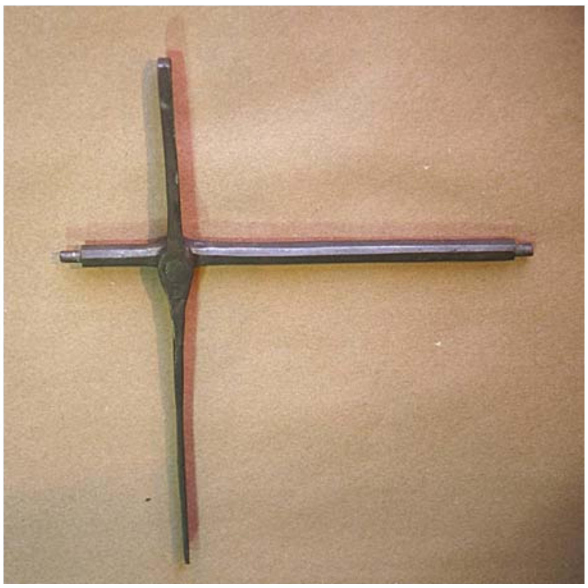

Figure 9. The existing hour strike lever showing characteristics of form and manufacture to be matched in a re-created quarter-hour strike lever.

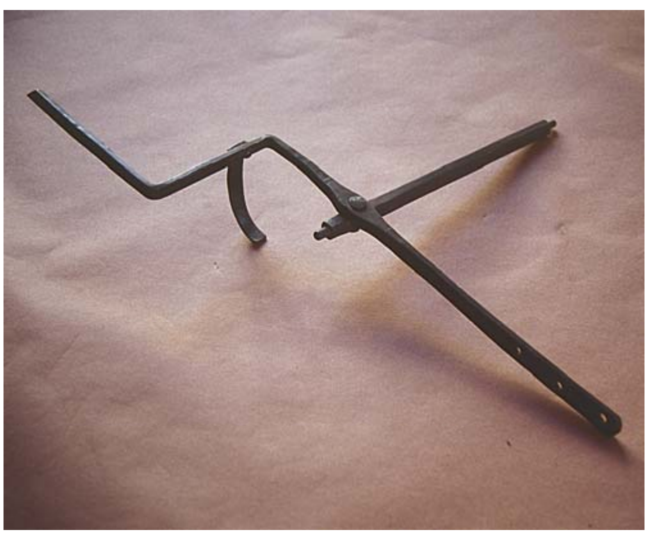

Figure 10. The re-created quarter hour strike lever showing the functional configuration and dimensions of the prototype (Fig. 5).

Existing bracket attachment holes in the clock frame indicated that the original bearing brackets were attached by hot peening cylindrical shafts on the brackets over the backs of the round holes. However, in the process of making and fitting the re-created brackets, it became apparent that a hot peened attachment was not desirable for both brackets. If both brackets were attached by this method, a long and arduous sequence of clock frame disassembly and reassembly would be required for each step in subsequent fittings and adjustments of the remaining pieces for this assembly. An alternative method of attachment was found on existing bearing brackets supporting the hour strike release lever. One of these brackets was attached to the frame through a square hole with a square mortised shaft and a cotter wedge. Because similar mortised wedge attachments also exist throughout the frame of the clock, this method was reproduced for one of the quarter hour strike lever brackets. In this way, a more practical removable bracket was created allowing for easier fitting and adjustment of the entire assembly.

The dimensions and configuration of the prototype hour strike release arm permitted little speculation on the original characteristics of its manufacture. The individual features of the mortised wedge attachment to the existing arbor bar were also easily apparent in wear patterns at the attachment point. The resulting re-created arm was also easy to fit and adjust by simple methods (Fig. 11).

Figure 11. The re-created hour strike release arm.

4.3 The Re-Created Strike Train Drive Weight

The absence of a weight to drive the strike train posed a separate set of problems for restoration treatment. For clocks in this category, stone weights were not uncommon, and matching granite spheres or cylinders were the normal types. However, the force required to drive a strike train commonly differs from the force required by a time train. In the *M.R. 1750* clock the existing time train weight is a granite sphere, and it is likely that the strike train would also have a matching weight of a different size. Horological experimentation described in section 2.3 above indicated the mass necessary to drive the strike train, and the established treatment goals required a re-created weight of the proper mass and appearance. Practical problems in identifying the particular type and source of granite used for the existing weight led to consideration of alternative types of stone. Limestone was chosen to re-create the missing weight because it is easily worked and accepts a wide variety of color and texture finishes. Additionally, an artificially colored and textured limestone weight is in keeping with the treatment goals to avoid falsification or confusion between original and re-created parts. The resulting strike train weight accurately suggests the appearance of an original weight without deceptive imitation (Fig. 12).

Figure 12. The existing granite time train weight (right), and the re-created strike train weight (left), sculpted from limestone, textured and colored to match.

4.4 Restoration of the Pendulum

After determination of the correct pendulum length, described in section 2.2 above, inspection of the pendulum rod showed one forge weld consistent with 17th or 18th century manufacture and one electric arc weld (Fig. 13). Electric arc welding came into practical industrial use in about 1920 and became widely available for common metal fabrication purposes in the 1950's. Therefore, the newer weld marked the location where a section of the original pendulum rod was removed and the cut ends re-joined, sometime in the 20th c.

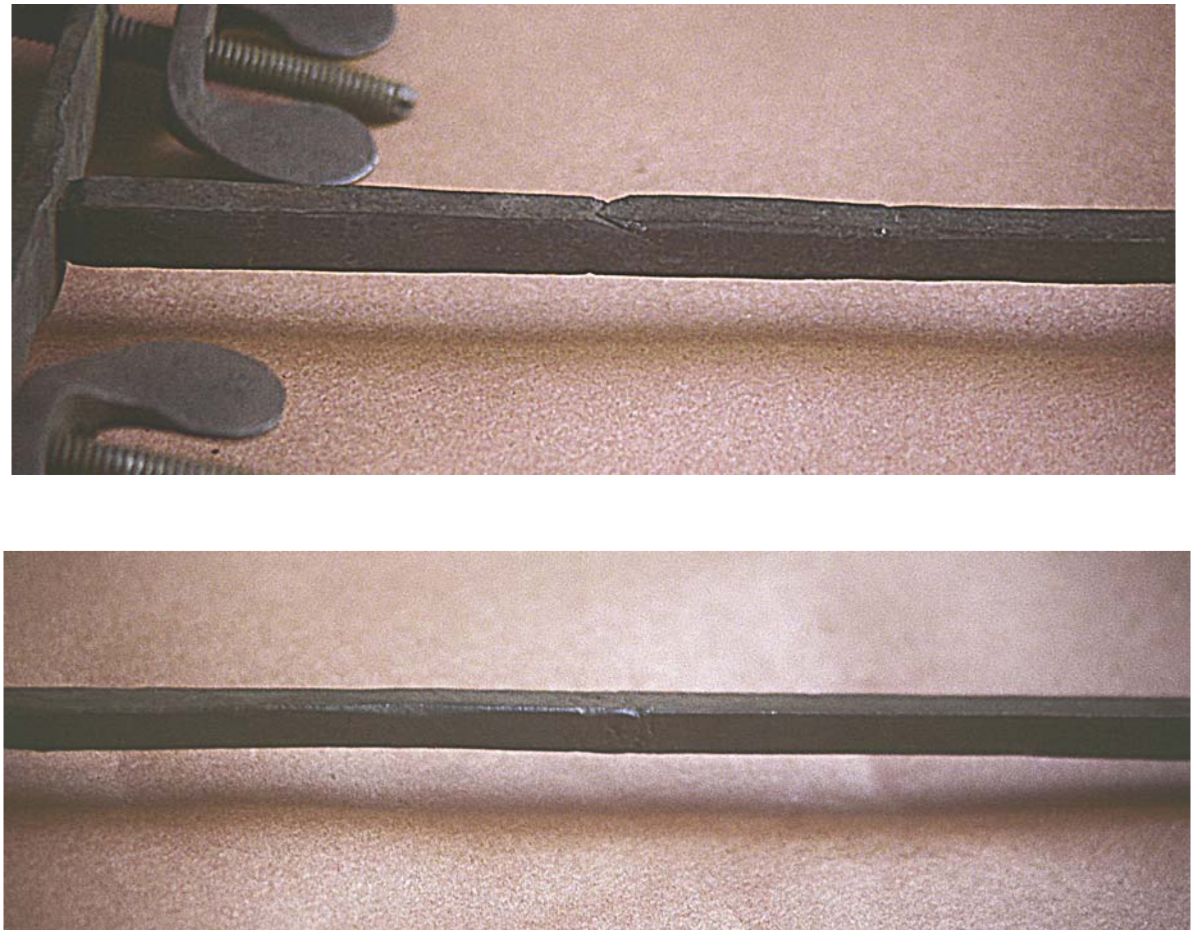

Figure 13. Existing welds on the pendulum rod: An older forge weld (top) and a 20th Century electric arc weld (bottom).

In order to lengthen the rod, a matching extension piece was created and the rod was cut at the newer welded point. The extension piece was inserted at the cut with two new welds. Again, the welds were accomplished using Stargon CS and .035" (0.9mm) diameter MIG welding wire conforming to ASME SFA-5.18, with welder settings adjusted to achieve a small quick weld of minimum size and heat. To create the appearance of a continuous original pendulum rod, the new MIG welds were heated with a propane torch and hammered on an anvil to alter their surface texture and to form them more closely to the dimensions of the existing and replacement sections of the pendulum rod. Additional draw filing by hand was necessary for final adjustment of surface texture before patination. The finishing and patination treatment of the extension welds yielded excellent results, unnoticeable to the casual observer (Fig.14).

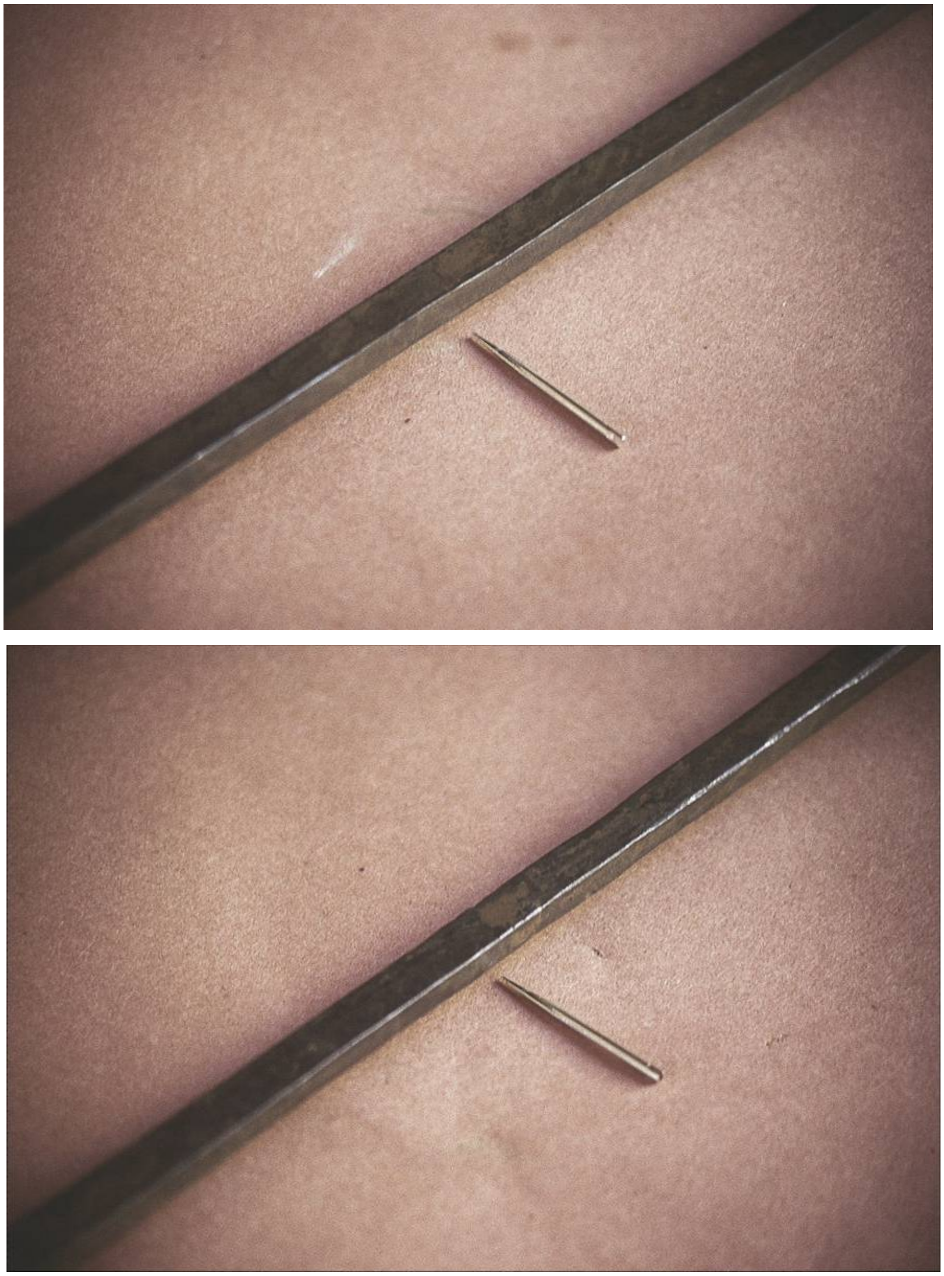

Figure 14. Locations of new welds showing the points where a section of re-created pendulum bar was inserted to restore the pendulum to proper operating length.

4.5 Restoration of the Stand and Provisions for Functional Operation

Because the *M.R. 1750* clock could be installed in a Saff Collection space allowing the pendulum to swing freely over the edge of a split-level floor, the existing stand was modified for re-use by disassembling it and re-fitting its pieces with dowels and lag screws for additional strength and stabilization. The project blacksmith provided a horizontal forged steel cross brace for the stand, fabricated and patinated to match the clock frame's center support and support foot. The Saff Collection space also allowed for overhead pulleys and adequate lengths of rope to be wound on the time and strike barrels providing the necessary drop length for functional operation of the clock's weights. The project blacksmith also designed and fabricated a compatible crank to fit both barrel's rewinding shafts. The terminus of the crank handle was forged to match finials on the clock's frame indicating the dedicated function of the crank as a necessary accessory particular to this specific clock. The functionally restored clock has historically correct operation consistent with its likely configuration in 1750, and its operation is the subject of continued demonstration, adjustment and testing within the representational and research purposes of the Saff Collection (Fig. 15). In periods of operation during the first year of its demonstration in the Saff Collection, *M.R. 1750* has proved to be a reliable and dependable, easily adjusted and maintained clock, never stopping due to friction or design deficiencies, striking accurately without missed or miscounted, premature or delayed strikes, and demonstrating timekeeping accuracy within the 2 min./week expectation for well-functioning clocks of its historical period and type.

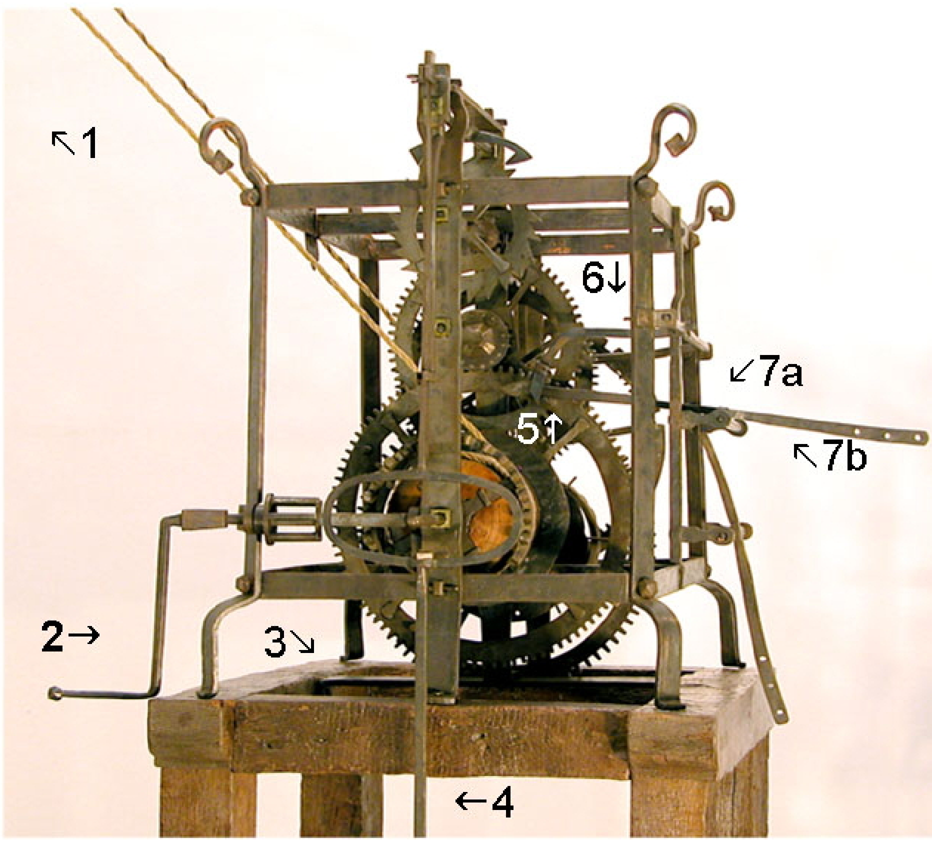

Figure 15. The *M.R. 1750* clock after treatment. Arrows indicate locations of: 1. Re-created strike train weight; 2. Re-created winding crank; 3. Re-created stand brace and center support; 4. Restored pendulum; 5. Restored hour lift pin; 6. Re-created hour strike release arm; 7a. Recreated quarter hour release assembly - brackets and arbor bar; 7b. Recreated quarter hour release assembly - quarter strike lift arm and hammer pull.

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