Winterthur Museum

Department of Conservation

Conservation Report

Accession #: 2003.0032
Object: Clock face and movement
Object Date: 1755-1775
Artist/Author: Benjamin Chandlee, Jr.
Materials: brass, iron, lead, wood
Measurements: Height: 17”
Width: 12 ¾”
Depth (including movement): 5 ½”
Current Location: Objects conservation lab, Winterthur Museum
Reason for Treatment: To return clock face to correct aesthetic appearance, one that resembles its original artistic intent
Examined by: Jessica Arista and Lauren Fair
Consulted: Bruno P. Pouliot, Mark Anderson, Margaret Little, Jennifer Mass, Terry Drayman-Weisser
Treated by: Jessica Arista and Lauren Fair
Report Date: December 2008

<u>Description</u>:
This clock face and attached movement are part of a complete tall case clock that was purchased from Barton B. McCauley of Wilmington, Delaware, by Winterthur Museum in 2003. Philadelphia clockmaker Benjamin Chandlee, Jr., is credited with the design of the clock face and the movement. The clock is what is known as an eight-day clock, which means that the clock had to be wound only once a week.

Clock face, 2003.0032

Back of clock face with movement, 2003.0032

The Chandlee clock face consists of a wrought brass faceplate that is roughly 12 ¾” square with an arched top, or lunette, that extends 5” above the square portion of the faceplate. Attached to the faceplate are the following: a curved circular nameplate in the lunette; cast brass ornaments located in the spandrels of the lunette and faceplate; a large chapter ring that registers the hours and minutes; and a stippled central plate that contains a seconds ring, a date aperture for the calendar ring, two winding holes, and the hands (see Figure 1 below). These elements appear to be made from a copper alloy, with the exception of the hands, which are most likely steel.

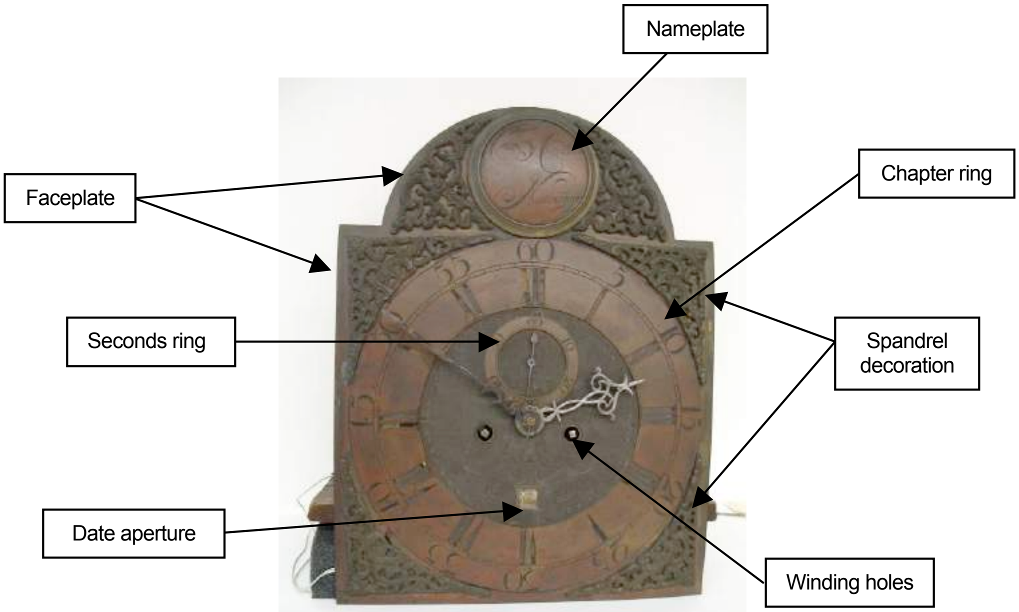

Figure 1. Chandlee clock face, 2003.0032

The convex circular nameplate, engraved “B. Chandlee Nottingham,” is located in the center of the lunette. It is attached to the faceplate via a single, central drive pin. Cast rococo ornaments flank the nameplate in the lunette and also adorn the spandrels. These ornaments are attached to the faceplate with 5 brass and 2 ferrous screws. On the chapter ring are Roman hour numerals and Arabic minute numerals - between these is a ring with minute gradations. The chapter ring is secured to both the faceplate, and the clock movement by a mounting plate (see Appendix for further discussion of the clock movement and construction). The stippled central plate, contained within the chapter ring, is decorated with punching and engraving. This central area also contains the seconds ring, the date aperture showing the calendar ring, and two winding holes used to adjust the time with a gear crank. Also attached to this central plate, are the three hands - one each to register the hours, minutes, and seconds. The seconds hand is attached to the center of the seconds ring, and appears to be blued steel (see Materials and Techniques section for further discussion of the bluing process). All hands are made of a ferrous metal; the minute hand is coated with a black paint, while the hour hand is not coated and is a shiny silver color. All engravings on the nameplate, chapter ring and seconds ring are filled with a black material.

The movement rests on a wooden seatboard and is attached to the back of the clock face via an iron mounting plate. The movement consists of many gears, as well as a striking mechanism, a winding crank, a pendulum, and two lead weights that operate the pulley system. The major components of the movement are made of copper alloy, most likely brass, while minor parts, including nails, fasteners, rods, etc., are made of a ferrous metal (see Appendix for images and diagram of movement parts).

<u>Historical Background:</u>

The Clockmaker

The Winterthur clock, 2003.0032, was made by Benjamin Chandlee, Jr. (1723-1791), around the year 1758 for Roland Rogers of East Nottingham. Some time before the year 1816, John Price acquired the Rogers property in Cecil County, Maryland, which included the clock. Correspondence between the Price and Chandlee families indicates that the two lineages are related. The clock was kept with the Price family until 1849 when Melicent R. Price married Judge James McCauley of Cecil County, Maryland. Since this date, the clock has remained in the McCauley family until the Winterthur Museum purchase in 2003.

Benjamin Chandlee, Jr., was born January 22, 1723. He was the son of Benjamin Chandlee, Sr., and grandson of Abel Cottey, both of whom were also clockmakers. Abel Cottey is believed to have made the earliest dated clock in Colonial America around the year 1680. In 1741 Benjamin Chandlee, Jr., moved with his father and two brothers, Cottey and William, to an area known as Nottingham, which was at that time in Maryland, but today is in Chester County, Pennsylvania. There, all three brothers assisted their father in making clocks, setting up the firm of *Chandlee and Sons* and making many objects out of iron and brass. Of the brothers, Benjamin, Jr., was the most interested in the business, and the most talented, and he went on to become an expert craftsman, making more clocks than any in the family. In 1749 Benjamin, Jr., married his wife Mary Folwell, and in 1752 he purchased land from his father-in-law in Wilmington, Delaware. He also acquired land in a few counties in Pennsylvania and Maryland, where he conducted his business, making and selling clocks with the firm *Chandlee & Sons*, which later changed its name to *Ellis Chandlee & Brothers*.

Clockmaking

The history of clockmaking can be dated back to around 1700 B.C. when the sundial emerged as the timepiece. Around 200 B.C. there is first evidence of a Clepsydra, or water clock, which operates on a continuous flow of liquid. It is not until the 14^{th} century A.D. that man produces the first mechanical clock. The workings of the early clocks that were perfected upon over the years by their makers are largely based upon models of windmills and water-powered wheels – techniques already in place for other purposes. These led to the creation of a weight-driven mechanism instead of wind or water that could be regulated by a rocking device.[1]

The first written evidence including an illustration of a clock mechanism exists in a 14^{th} century manuscript. The clock was designed by an astronomy professor in Padua, Giovanni de' Dondi, in 1364. The clock consisted of complicated dials that showed all the planets and the calendar in addition to telling time. Clockmakers

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[1] Battison, Edwin, A., and Patricia E. Kane. *The American Clock: 1725-1865: The Mabel Brady Garvan and Other Collections at Yale University.* (Greenwich, CT: The New York Graphic Society Ltd, 1973) p. 11.

continued to experiment with different devices and make improvements to their designs. During the Renaissance, a form of a spring-driven mechanism was developed which made possible the creation of smaller sized clocks and eventually the pocket watch.[2] By the 18th century and the Industrial Revolution, advances in science and technology, along with a greater need for an accurate time-telling device, drove clock manufacture forward. The pendulum was invented in 1658 by Dutch scientist Christiaan Huygens. This invention, along with others, produced clocks that were superbly accurate.

During the 18th century, England became the center of clockmaking, and it was from England and Europe that clocks were first imported into the American Colonies. The first clocks that were imported were most likely tower clocks, and the first tower clock constructed in the Colonies was made by Benjamin Bagnall of Boston in 1717.[3] Clockmaking in early America first developed in Massachusetts and Pennsylvania, and then later in Connecticut. For clockmakers such as the Chandlee family, Philadelphia proved to be a profitable place for a clockmaker in early Colonial America.

The Tall Case Clock
The tall case clock first made its appearance in the later part of the seventeenth century in England, and by 1700, it had become the most dominant clock form in the home. Originally, tall case clocks hung on the wall, with the pendulum and weights hanging down, exposed. Around 1670-1700 in England, the transition was made to include a hood that protected the movement from dust and dirt. The design then progressed to the development of a tall and impressive case to house the movement and pendulum.[4] The tall case clock, or longcase clock came to be known as the Granfather Clock soon after the 1876 publication of the song *My Grandfather's Clock*, by Henry Clay.

Materials and Techniques:

Clock production in early America was a collaborative effort from many contributing craftsmen. The brass founder, the wheel and pinion cutter, the bell founder, the silversmith, the gilder, the glazier, and the cabinetmaker, could all have had a hand in the production of a tall case clock.[5] Having been trained in Europe, early American clockmakers had to integrate their work with Colonial craftsmen. Their models sometimes had to be adjusted or simplified for this reason.[6]

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[2] Website.
[3] Distin, William H., and Robert Bishop. *The American Clock.* (New York: E.P. Dutton & Co., Inc., 1976) p. 15.
[4] Battison and Kane, 16.
[5] James, Arthur E. *Chester County Clocks and Their Makers.* (Exton, PA: Schiffer Publishing, Ltd., 1947 and 1967) p. 21.
[6] Battison and Kane, 16.

Faceplates
Early faceplates before 1770 were made of brass, and they were usually square in shape, or square with an arched top, or lunette, measuring about 10 ½" on one side. In the following decade, the plates were sometimes larger, measuring 12 ½" on one side, and there could be an aperture added that registered the days of the month via a calendar ring. The Winterthur clock face is most likely brass, and it measures roughly 12 ½" square (excluding the lunette). Although it has been suggested the clock was made around 1758, the size of its faceplate suggests a later date of manufacture. In the last quarter of the 18th century, faceplates began to be constructed of painted or enameled iron, and usually measured about 13" wide. The plates were made by hammering, scraping and polishing the metal into refined sheets.

The arched top or lunette of the faceplate often contained spandrel decoration in cast brass or lead.[7] These embellishments could be rococo designs including cherubs, arabesques, foliage, or dolphins, and the same decorations of the lunette would also be found in the corners of the faceplate. This is the case on the Winterthur faceplate: the decoration in the lunette and the spandrels are cast metal ornaments, probably brass, in the form of rococo scrolls.

In 1777 it became British law that English clockmakers were obligated to engrave their names and place of manufacture on the clock faces. Although not always practiced by American clockmakers, when it was present, the signed name usually belonged to the artisan who assembled the clock works, and it was stenciled or painted and included the township in which they lived. The name could be found in several locations: in the lunette, in a large circle within the center of the face, or on a curved brass nameplate riveted to the face above or beneath the date aperture. The Winterthur clock face has a curved circular nameplate, probably brass, located in the center of the lunette. The clockmaker's name and location is engraved into the surface, and the engraving was most likely filled with a black waxy or resinous material.

Dials
Attached to the faceplate with steel tapered pins was the dial, or chapter ring, which included the hours and minutes. The dial could be made from polished brass, pewter, or silver. It was customary to indicate the hours with Roman numerals and the minutes and seconds with Arabic numbers. The hours and minutes were deeply engraved onto the chapter ring and usually filled with a hard black wax. Oftentimes, the chapter ring would be chemically silvered for greater contrast and emphasis of the numbers. The Winterthur clock dial is most likely made of brass, and the hours are demarcated by Roman numerals, while the minutes and seconds are Arabic numbers. It is not clear, given visual examination alone, whether the Winterthur clock dial was silvered at one time or not. A silver layer from the process of silvering an object would result in an extremely thin layer, thus making it susceptible to

[7] James, 25.

damage from any polishing. This might explain the apparent lack of any silver on the surface presently.[8]

The Winterthur clock is what is known as an eight-day clock, which means that the clock had to be wound only once a week; as opposed to a thirty-hour clock, which had to be wound once a day. Eight-day clock dials were usually adorned with silvered brass chapter rings as well as a smaller silvered brass ring that registered the seconds in Arabic numbers. This smaller ring was usually located just below the Roman numeral for hour XII, and was equipped with a small steel hand.

Hands

The early clock dials had one or two hands. Later clocks sometimes had a third hand that registered seconds, in addition to the hours and minutes. The hands were finely wrought steel and were cut out and filed. After about 1825, clock hands were much thinner and often stamped from sheet metal. The hands on the Winterthur clock dial are most likely made by cutting and filing steel. Often the hands were made of blued steel. The process of bluing steel involves creating an electrochemical conversion coating of iron oxides in the form of magnetite (Fe_3O_4) on the surface of the steel. These oxides provide minimal protection against corrosion. It appears that the seconds hand is blued steel, but it is not clear the other hands were processed in this way. The minute hand appears to have been coated with a black paint. One clockmaker from Berks County, Pennsylvania, manufactured clock dials that had hands made from different materials each for hours, minutes and seconds: brass, silvered brass, and blued steel.[9] In the days before electricity, this detail served the purpose of a clock owner being able to tell the exact time at night by light from a candle only.

Movement

In earlier clocks, the movement, or works, was mostly made of cast brass, and the supplemental parts were of iron and steel. The movement consists of many plates and gears that allow for the weight-and-pulley system to operate. The parts of the movement would be made by another craftsman and ordered by the clockmaker or assembler, and oftentimes the clockmaker would have to file and finish these parts before assemblage.[10] As mentioned earlier, the works of an eight-day clock had to be wound once every eight days. Winding the clock required that one pull a chain that would draw up one of the lead weights.

The clock works could be very simple or incredibly complex. Some clocks were equipped with striking mechanisms, calendar dials, and moon wheels. The Winterthur clock has a striking mechanism, a calendar dial, and a mechanism to register seconds.

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[8] Breslin, Debra. Conservation Report of the clock dial plate and hands, ACP1234, from a John Turnbull clock. (Winterthur/University of Delaware Program in Art Conservation, 2007) p. 5.

[9] Machmer, Richard S. and Rosemarie B. *Berks County Tall-Case Clocks, 1750 to 1850.* (Reading, PA: The Historical Society Press of Berks County, Pennsylvania, 1995) p. 32.

[10] James, 26.

As a result of the Industrial Revolution and the appearance of power-driven machinery, many clock works and other parts were made of wood instead of brass, iron, and steel. Machining clock parts with wood was cheaper and faster, while metals were more expensive and of limited supply.[11] Clock historian Edwin A. Battison explains that wooden clockmaking, while it made clocks more affordable and thus more accessible to customers, also lowered the standards of the craft and resulted in a "decline in the quality of workmanship."[12]

The case of the Winterthur clock will not be addressed in detail in this examination and treatment report, as Winterthur Museum furniture conservators, Mark Anderson and Ridgely Kelly, performed conservation treatment on the case in 1991.[13]

<u>Condition</u>:

The clock face is in fair condition and does not appear to have undergone previous treatment. Based on visual observation no elements of the clock face appear to be missing. The most serious condition issues include damages to the metal surface, including surface grime, extensive corrosion/tarnishing of the metal elements, possible loss of silvering, and loss of black fill material in the incised numbers, resulting in an appearance quite different from the original. While the clock face and attached movement function and appear to be structurally sound there are minor cracks in the faceplate and spandrel decoration. The rivets and drive pins which hold the elements of the clock face together are functional, even though they are slightly corroded.

On the front of the clock face, all brass elements (faceplate, spandrel decoration, stippled central plate, chapter ring, nameplate, and seconds ring) suffer from corrosion. On the faceplate there is red, brown, and light green corrosion around the edges. The spandrel decoration and the stippled central plate have a dark brownish-green patina. In the crevices of the spandrel decoration and around the edges where the decoration meets the faceplate are tiny amounts of light green powdery corrosion. The chapter ring, seconds ring, and the nameplate currently are similar in appearance and are reddish in color, possibly a result of dezincification of the brass. These three elements would have most likely been silvered, but there is no visible sign of any silver at this time. Loss of silvering could have occurred as a result of chemical or physical cleaning of the thin, silvered surface. Dezincification could have occurred if highly alkaline or acidic solutions were subsequently used to clean the exposed brass. The calendar ring is less corroded on the front than other elements, but it is scratched.

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[11] Battison and Kane, 17.
[12] *Ibid,* 17.
[13] Anderson, Mark, and Ridgely Kelly. Conservation report of wooden clock case, L89.1310, from Benjamin Chandlee, Jr., clock. (Winterthur, Delaware: Winterthur Museum, 1991) p. 1-10.

Figure 2. Detail of Chandlee clock

The steel hour, minute and second hands all have minor brown corrosion (rust) and there is significant loss to the black paint on the minute hand. The minute hand is slightly bent away from the face. In comparison with other hands on Benjamin Chandlee, Jr., clock faces, the shape and thickness of this minute hand give rise to the suspicion that it is a later addition to the Chandlee clock face or that it has been altered (see Appendix for examples of other Chandlee clock faces). It is possible that the minute hand is original but has been flattened in response to previous damage.[14] Technical analysis will aim to elucidate this. There is no evidence of paint on either the hour or the second hands.

On the back of the faceplate, the surface has fairly uniform dark brownish-green corrosion, with minor areas of spotty, light green corrosion which appear to correspond to tool marks. The iron mounting plate has reddish-orange corrosion (iron sulfates and oxides) and the steel drive pins are in good condition.

There is extensive loss of the black fill material in the engraved designs on the clock face. The most severe areas of loss are in the engraved Roman numerals (see figure 3). Minor pitting, abrasion, and surface grime are present on the fill material in the engraved Arabic numerals (on the chapter ring and seconds ring) and also in the script of the nameplate.

Figure 3. Detail of loss to black fill material and broken spandrel

The proper right spandrel ornament in the upper corner of the faceplate is broken into two pieces, but both remain attached to the faceplate with steel pins and screws that appear to be historic repairs to the spandrel. The break is located above minute "55" on the chapter ring.

There are 3 cracks present on the faceplate. The largest crack, which has resulted in a loss, is behind the center of the lower proper right spandrel decoration. This loss measures approximately 4 mm by 20 mm, but is mostly covered by the spandrel decoration. Two hairline cracks extend into the faceplate perpendicularly from the bottom edge. One is 3.1 cm in from the proper left edge and is 1 cm long, and the other is 4 mm in from the proper right edge and measures 1.5 cm long. While these cracks should continue to be monitored, they do not present a structural weakness to the faceplate at this time.

[14] Wagner, Ann. Personal communication. (Winterthur Museum, 2008).

Analysis:

The Winterthur Museum's Chandlee clock face is the subject of a technical study that will be conducted by Lauren Fair during the Spring of 2009 under the supervision of Winterthur scientists Dr. Jennifer Mass and Dr. Joseph Weber.[15] As part of the research carried out in this study, the following analytical techniques and instruments will be used in order to characterize the materials present on the clock face and inform the proper aesthetic treatment:

1. Energy-dispersive X-ray fluorescence (XRF)
   Use of this analytical technique aims to identify the alloy compositions of all metal components on the clock face.
2. Energy-dispersive scanning electron microscopy with X-ray microanalysis (SEM-EDS)
   SEM-EDS will be carried out to gain surface information about methods of manufacture as well as characterization of corrosion products.
3. Fourier-transform infrared spectroscopy (FTIR)
   Samples of corrosion products on the clock face, black fill material in the engraved numerals, and black paint on one of the hands will be taken and prepared for qualitative analysis with FTIR.
4. Dispersive Raman Microanalysis (Raman)
   Raman will also be used for qualitative analysis of samples of corrosion products on the clock face, black fill material in the engraved numerals, and black paint on one of the hands.
5. Gas chromatography-mass spectrometry (GC-MS)
   GC-MS will be used for material characterization of the black fill material in the engraved numerals and the black paint on one of the hands.

Purpose of treatment:

The purpose of this treatment is to improve the appearance of the clock face and hands and allow for correct aesthetic interpretation, and to stabilize the materials and aid in the prevention of further corrosion.

[15] Fair, Lauren. Technical Study Proposal: "Technical Analysis of a Benjamin Chandlee Tall Case Clock in the Winterthur Museum Collection". (Winterthur, Delaware: Winterthur/University of Delaware Program in Art Conservation, 2008) p. 1-25.

Treatment Proposal:

Clock Face:

1. Disassemble the parts of the clock face (what can be done safely): hands, spandrel decoration, chapter ring, nameplate, etc.
2. Surface clean entire clock face and parts of movement using a vacuum cleaner equipped with a HEPA filter and a soft bristle brush. Additional surface cleaning can be carried out using cotton pads with Stoddard solvent and/or de-ionized water with a small amount of surfactant such as Triton XL-80N.
3. Remove corrosion on all elements of clock face after testing various methods. Conduct a series of solvent tests to determine the most appropriate method of corrosion removal. Possible solvents include ethanol, ethanol/water, toluene, acetone, isopropanol, Stoddard solvent, etc. Mechanical methods for corrosion removal will also be tested.
4. Finally clean and polish surfaces to a level deemed appropriate by the curator.
5. Given the results of analysis conducted during treatment, chapter ring, seconds ring, and nameplate may require the addition aesthetic treatment of “re-silvering.” The method for this treatment step will be discussed further with the curator, and may include the use of silver leaf, or toning with paints and mica pigments.
6. Apply a final coating to the metal elements of clock face. The purpose of this coating will be to protect elements from further corrosion and may also provide visual integration of the now polished surfaces. Possibilities will be discussed with the curator and tested for visual qualities.

Hands:

1. Conduct solubility test of black paint on minute hand and carry out surface cleaning with appropriate solvent on all hands. Possible solvents include Stoddard solvent, acetone, ethanol, isopropanol, toluene.
2. Remove corrosion using mechanical methods such as 0000 grade steel wool, glass bristle brushes, or a bamboo skewer. Care will be taken to avoid areas where bluing remains.
3. Discuss treatment of the minute hand with the curator, pending results of analysis of the alloy and coating. A re-forming or replacement of the inaccurate portion of the hand will be considered.

Student Conservator: ______________________ **Date:** ______________

Jessica Arista

Student Conservator: ______________________ **Date:** ______________

Lauren Fair

Supervising Conservator: ______________________ **Date:** ______________

Bruno P. Pouliot, Winterthur/University of Delaware

Curator: ______________________ **Date:** ______________

Ann Wagner, Curator, Winterthur Museum

Treatment Report

The treatment proceeded as proposed and each step of the treatment was guided by significant discussions between the conservators and the curators on the final appearance of the clock face, versus the intention to preserve a patina of age. This clock is very significant to the Winterthur Museum, and we were trying to avoid a full “stripping” of the corrosion/oxidation layers on the different metals. To achieve this goal, we constantly discussed and reevaluated our methods/techniques and the results throughout the treatment. Please see the Appendix for a more in depth discussion of the treatment rationale.

This object was also the subject of an in depth Technical Study by Lauren Fair for ARTC 673 Advanced Analytical Methods, in Spring 2009. The findings from her analysis greatly informed its treatment. With XRF, the metal components of the faceplate (spandrels, faceplate, central field, chapter rings, nameplate, calendar ring) were found to be copper-zinc alloys, most likely brass, and the hands were found to be ferrous. Silver was detected on the calendar ring using XRF, confirming that this brass element is silvered. With SEM-EDS analysis of corrosion on the outside edge of the nameplate, silver was detected; this strongly suggests that the nameplate was silvered originally, and it is also highly likely that the chapter ring and seconds ring were as well. With Raman spectroscopy, magnetite was found on the surface of the seconds hand, confirming this hand is blued. The material in the engravings of the chapter ring, seconds ring, and nameplate were found to be a mixture of pine resin and beeswax with FTIR and GC-MS. A pine resin coating was found on the spandrel ornaments with FTIR and GC-MS, and carnauba wax was identified as a coating on the faceplate with GC-MS. A copy of the full report is included in the Conservation file.

The Chandlee clock face before and after treatment.

1. Pre-treatment digital photographs were taken of the clock face using a Nikon D200 digital camera.

2. The clock face was disassembled in order to gain better access to each component. Stoddard solvent was used to lubricate the drive pins and screws which held the components together. The faceplate was removed from the movement and the following components were removed from the faceplate: the hour and seconds hands, seconds ring, chapter ring, nameplate, nameplate ring, and spandrel decorations. Still attached to the faceplate were the stippled central plate and the calendar ring. A small piece of the upper proper right spandrel decoration that was detached from the rest of the spandrel and pinned (possibly soldered, too) to the faceplate, also remained attached to the faceplate and could not be removed. The method of disassembly, locations of screws, and orientation of drive pins that connect various elements was documented to facilitate the reassembly after treatment.


Detail of faceplate after the upper proper right spandrel decoration has been removed. Note the piece of the spandrel decoration that remains attached.


The clock face disassembled into its various components. Note that the seconds ring is still attached, but was later removed.

3. Surface cleaning was carried out an all faceplate components and the clock movement. First, vacuuming was done using a vacuum equipped with a HEPA filter and soft bristle brush. Wet cleaning was done by first using Stoddard solvent delivered via cotton swabs, then a 1:3 Stoddard solvent/deionized water mixture with one drop of Triton XL80N, which was cleared with deionized water on cotton swabs. The hands and the movement were cleaned with Stoddard solvent only.


Vacuuming and surface cleaning the clock face post disassembly.

4. In preparation for corrosion removal, the faceplate, central stippled field, and spandrel ornaments were additionally surface cleaned using 1-methyl-2-pyrrolidinone and acetone. With GC-MS analysis, the corrosion on the faceplate was found to be embedded in layers of carnauba wax. It had been found through FTIR and GC-MS analysis that the spandrel decorations were coated with an untinted pine resin coating. The pine resin coating on the spandrel ornaments was removed during this step, because in order to remove the corrosion from the spandrels, this coating, now embedded with corrosion, had to be removed. Remnants of coatings and corrosion were left on a small area on the broken segment of the upper proper right spandrel decoration.

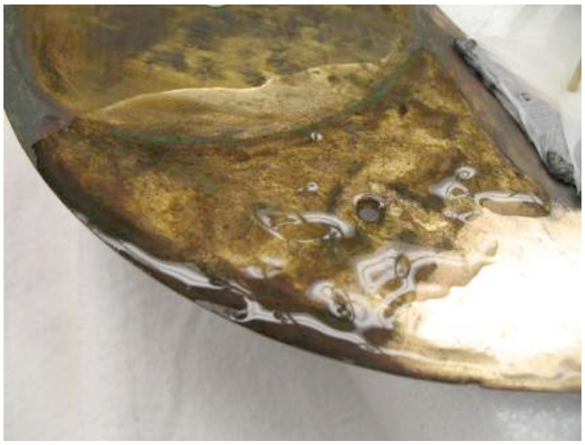
5. On the faceplate, central stippled field, nameplate ring, and spandrel ornaments, all of which are made of brass, mechanical and chemical corrosion removal techniques were tested to determine the method which could best provide the desired aesthetic results and gradually remove corrosion without undercutting the metal on these elements (see Appendix for detailed discussion of corrosion removal rationale).

On the spandrel ornaments and the nameplate ring, mechanical methods alone were found to be effective; a slurry of Buehler Alumina 1 micron alumina micropolish in ethanol/deionized water (1:1) was used to remove corrosion on these elements. The polish residues were removed using ethanol/deionized water (1:1), 1-methyl-2-pyrrolidinone and acetone. These solvents were used to degrease the surfaces and remove all remnants of polish residues and possible remaining coatings.

For corrosion removal on the faceplate and central stippled plate, mechanical methods alone did not reduce the corrosion. Upon consultation and testing with Richard Wolbers, a 2% citric acid gel (pH=3, pH raised using triethanolamine) was found to most effectively remove the corrosion. The gel was applied to a small area, left for a few minutes, removed with a cotton swab, and the area was cleaned used

1-methyl-2-pyrrolidinone, followed by acetone. This process was repeated until the corrosion had been reduced to a thin, pink-colored layer. It was thought that this pink layer was a remnant of the red corrosion (cuprite, Cu_2O) present on the faceplate. Please see Appendix for a discussion about acid cleaning and possible dezincification or redeposition of copper.

Following the chemical treatment, the faceplate and central stippled field were mechanically polished with Buehler Alumina 1 micron alumina micropolish in a slurry of ethanol/deionized water (1:1) to reduce the pink appearance of the metal and any remaining corrosion. The polish was cleared using ethanol/deionized water (1:1), 1-methyl-2-pyrrolidinone, and acetone.



Left: Lunette of faceplate with citrate gel in place. Corrosion has been removed in the bright area at the far right.
Right: Lunette of faceplate after half has been cleaned with citrate gel.

The central stippled field underwent additional treatment using Autosol Metal Polish® (aluminum oxide powder dispersed in an aqueous soap solution) and Nevr-Dull® (aluminum oxide and calcium carbonate dispersed in mineral spirits) wadding polish to help reveal the brass and reduce the pink appearance of the metal. These materials were used as a last resort when no other methods reduced the “pink” layers to a satisfactory appearance.

Left: Removing corrosion from the central stippled field.
Right: Stippled central field during treatment.

6. The hour and minute hands were surface cleaned with Stoddard solvent on cotton swabs, after testing the solubility of the black paint. Corrosion on the hour and minute hands was softened with Stoddard solvent and removed using glass bristle brushes and Grade 0000 steel wool. The hour and minute hands were brush coated with Renaissance microcrystalline wax (a mixture of Cosmolloid 80 hard and BASF A waxes). The seconds hand was not cleaned, as it was found to be blued steel via Raman analysis. While it is not known whether the hour and minute hands were blued originally, no evidence of bluing currently exists on these elements.

Through XRF analysis it was determined that the minute hand, originally thought to have been restored, was in fact uniform in elemental composition. Therefore, no treatment beyond surface cleaning was carried out.

7. Through FTIR and GC-MS analysis the black fill material in the numerals on the chapter ring, seconds ring, and nameplate was found to be a mixture of carbon black, pine resin and beeswax. Solubility testing determined that the black material softened in acetone, ethanol, Shell Sol, and toluene. The black fill material was found to be least immediately soluble in water and mineral spirits.

The black fill material of the incised decoration on the chapter ring, seconds ring, and nameplate, was consolidated with two brush applications of 5% Aquazol® (poly(2-ethyl-2-oxazoline) in deionized water. 5% Aquazol® in water was also applied over the black decoration and in the areas of loss as a barrier layer for inpainting. The areas of loss in the Roman numerals of the chapter ring, and the "30" on the seconds ring were inpainted using Golden mineral spirit acrylic paints with xylene/shellsol D38 (60:40) as a diluent.

8. Typically, the chapter ring, seconds ring, and nameplate of a clock face would have originally been silvered. Through SEM-EDS traces of silver were found on the nameplate. XRF analysis also found silver present on the calendar ring. The results of this analysis strongly suggest that the chapter ring, seconds ring, and nameplate were silvered originally.

Various methods for re-creating a silvered appearance on these elements were explored on mockups and included testing of Golden's acrylic silver paint, mica pigments suspended in Regalrez, Agateen, and MSA varnish, and various types of silver leaf (white gold, palladium, silver, pewter-colored silver leaf).

Through discussions with curators Ann Wagner and Wendy Cooper, it was decided to recreate the silvered appearance on the chapter ring, seconds ring, and nameplate by gilding with palladium leaf. The palladium leaf was chosen because: it is darker in appearance compared to silver leaf, and thus more closely resembles other clocks in the Winterthur collection; in the future, palladium will not be confused as an original material; and palladium is a more stable metal than silver, and it will be less likely to corrode or tarnish. Rolco Aquasize, (a water soluble acrylic emulsion composed of an acrylic copolymer (45%), drying additives (0.2%), flow and foam additives (2.8%), and water (52%), was used as a sizing medium for the palladium leaf. The sizing medium came to tack within one hour. The leaf was applied to the chapter ring, seconds ring, and nameplate using a gilder's tip.

These elements were not polished before gilding, because, while covered with a layer of cuprite, they appear stable, have very smooth surfaces, and polishing would put the incised black decoration at high risk of damage. A water-soluble size for the gilding was chosen so that its application and possible removal in the future would not harm the black incised decoration.

Left: The chapter ring after gilding with palladium leaf
Right: The nameplate after gilding with palladium leaf, before the leaf has been wiped away in the letters.

9. Corrosion on the iron mounting plate was first softened using Stoddard solvent and reduced using 0000 grade steel wool as swabs. This method was not effective at removing corrosion, so glass bristle brushes were subsequently used for the majority of corrosion reduction. Renaissance microcrystalline wax (a mixture of Cosmolloid 80 hard and BASF A waxes) was applied to the mounting plate for protection as follows: the iron elements were heated with a heat gun and the Renaissance microcrystalline wax was applied by brush.

10. The faceplate, central stippled field, spandrel decorations, and nameplate ring were brush coated with four coats of (1:1) Agateen lacquer #27: Agateen thinner #1 (cellulose nitrate lacquer in a mixture of 4 solvents - meth isobutyl, ketone, toluol, butanol, and amyl acetate) to protect the brass from future oxidation.

Brush coating the clock face elements with Agateen and Regalrez.

The nameplate, seconds ring, and chapter ring were brush coated with one coat of 50% Regalrez® 1094 (hydrogenated oligomer of styrene and alpha-methyl styrene) in Shell Sol D38 to protect the palladium leaf from mechanical damage. Regalrez® 1094 was chosen because it maintains its solubility over time and is soluble in non-polar solvents, meaning that it could be removed later without undermining the protective layer applied over the black numerals.

11. The clock face was reassembled by the student conservators along with Objects Conservator Bruno Pouliot and Curator Ann Wagner.


Reassembly of the clock face with curator Ann Wagner.

Treatment hours (person-hours):

Disassembly: 3 hours (L+J)
Surface cleaning and coating removal: 8 hours (L+J)
Corrosion removal/polishing: 73 hours (L+J)
Gilding and coating tests: 36 hours (L+J)
Gilding: 12 hours (L)
Inpainting: 2 hours (L+J)
Coating: 4 hours (L+J)
Re-assembly: 3 hours (L+J)
Photography (before and after): 6 hours (L+J)

Total: 147 person-hours

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Appendix

Clock Face Construction

The entire clock face is composed of many separate brass and iron elements. The faceplate is one piece of wrought brass sheet. On the back of the faceplate, hammer and file marks are visible, and an iron mounting plate attaches the chapter ring to the clock movement. The mounting plate is fastened to the chapter ring by small, round, brass feet on the chapter ring, drilled with holes and fastened with tapered steel pins, called drive pins. Ferrous rods extend from the mounting plate to the clock movement, connecting the back of the chapter ring to the movement. The mounting plate is also attached to the stippled central plate and the faceplate with ferrous rivets. On the front of the faceplate the rivets are covered by the spandrel decoration.

On the clock face, the convex nameplate is attached to the lunette by a single, central drive pin. The spandrel decorations are attached to the face plate with 5 brass and 2 ferrous screws. The chapter ring, on the back, is secured to both the faceplate, and the clock movement by the mounting plate. Sandwiched between the chapter ring and the mounting plate is the central stippled plate and the calendar ring. From the back of the clock face it can be seen that the seconds dial is attached to the central stippled plate via a single, tiny drive pin and is also attached on the opposite side with a rivet. The hour and minute hands are attached to the movement with a drive-pin-like attachment. The second hand is attached to the clock movement via a rivet.

Figure 1. Clock face with weights, pendulum and crank.

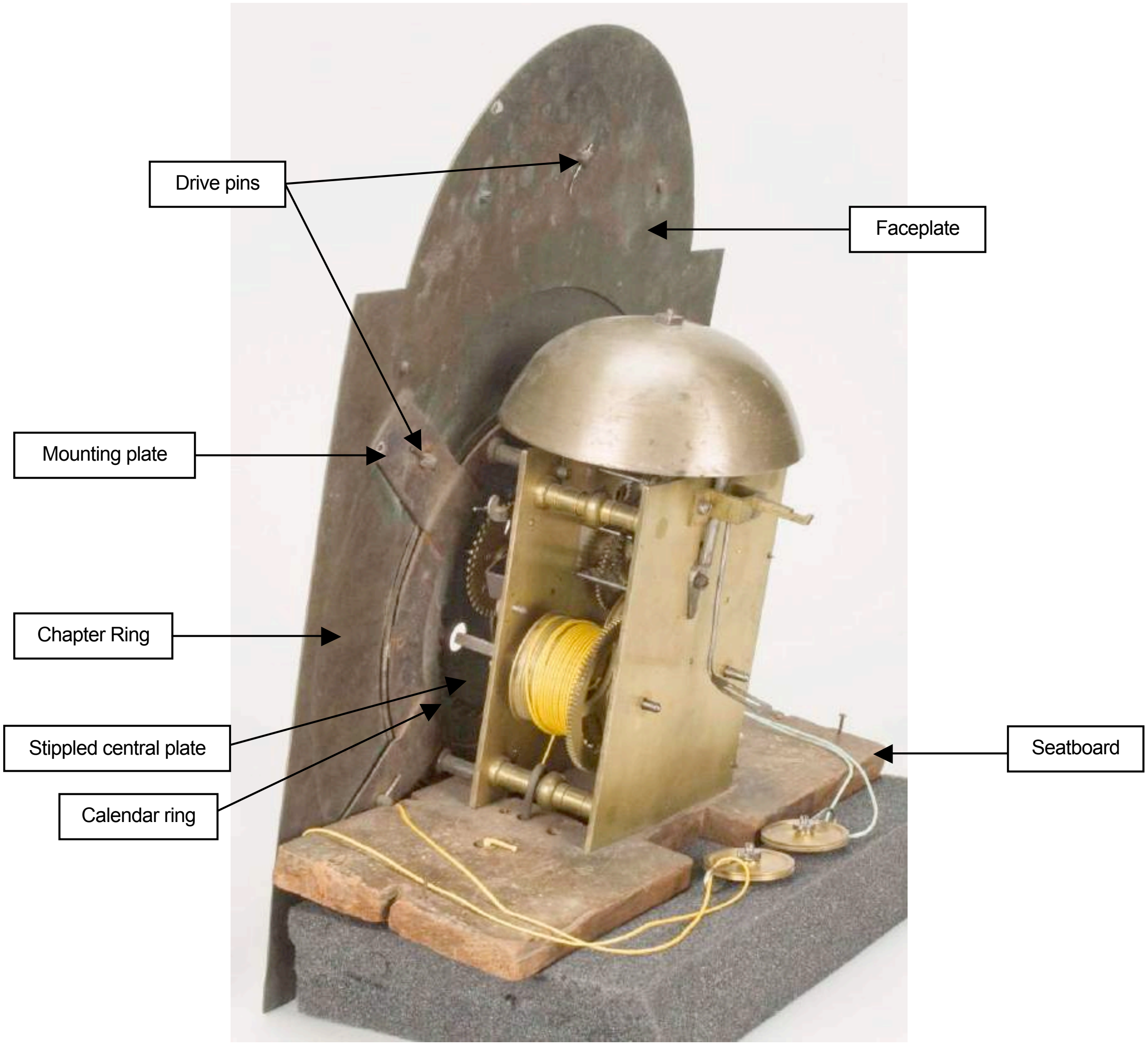

Figure 2. Back of clock face, showing mounting plate, movement, and seatboard

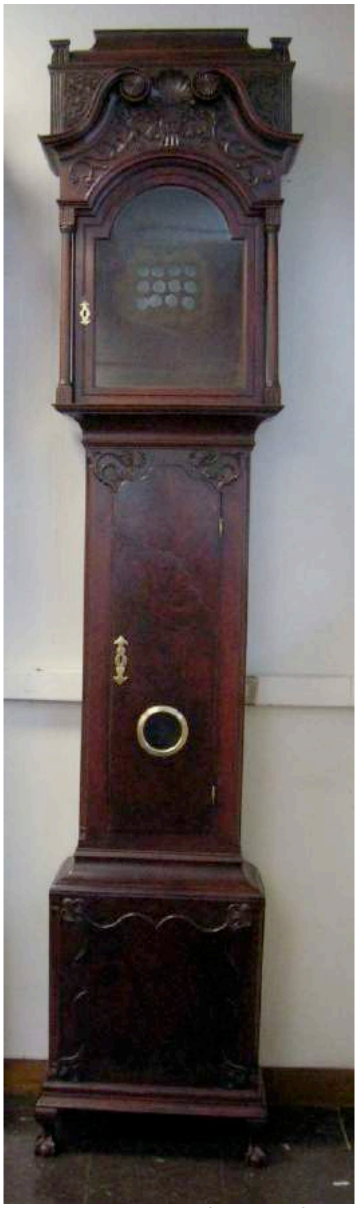

Figure 3. Winterthur's Chandlee Clock (2003.0032) Case

Figure 4. Clock made by Benjamin Chandlee, Jr., 1770, owned by Mr. and Mrs. John H. Ware of Oxford, PA.

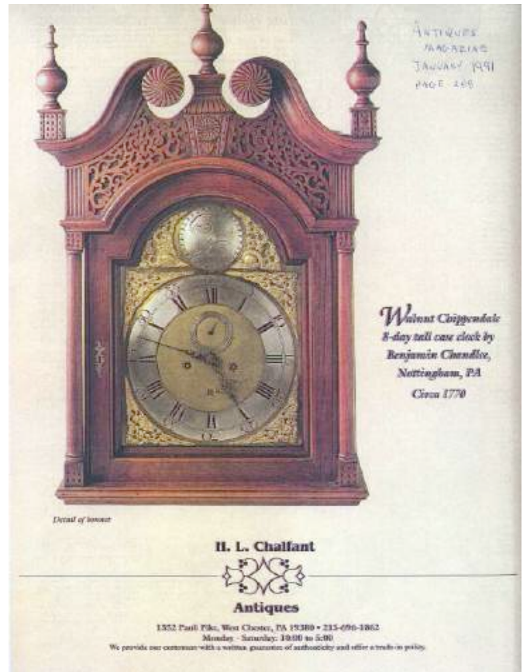

Figure 5. A Benjamin Chandlee, Jr. clock face circa 1770, private collection. Antiques Magazine, January, 1991.

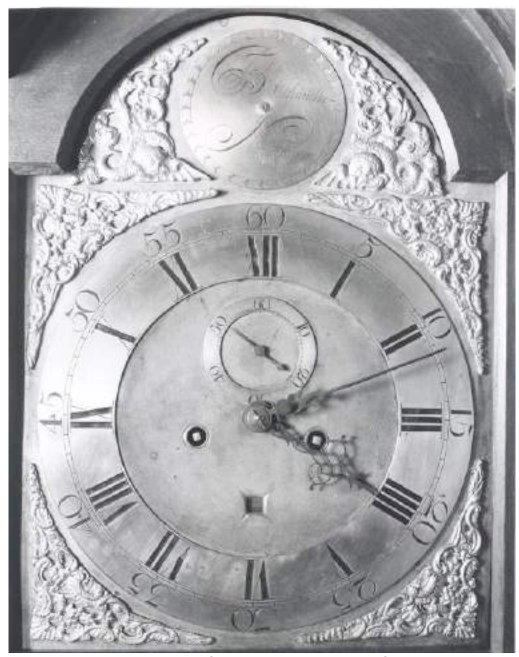

Figure 6. A Benjamin Chandlee, Jr. clock face made circa 1770, private collection.

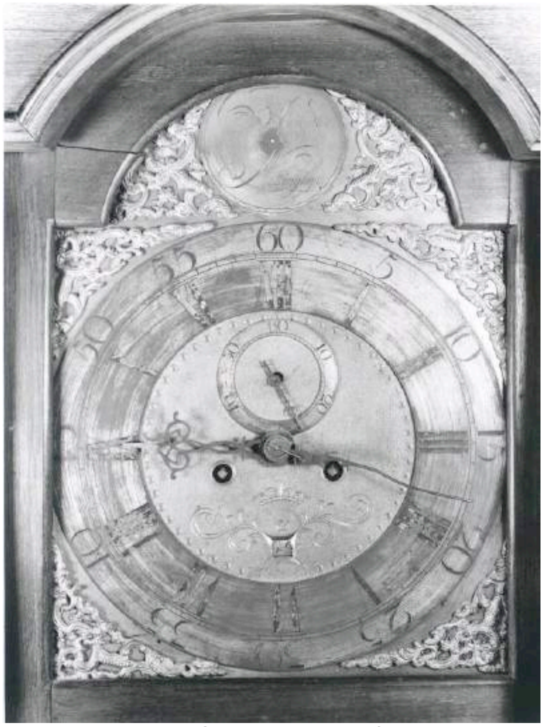

Figure 7. A Benjamin Chandlee, Jr. clock face, made circa 1765, owned by Denton Miller of Baltimore, MD.

Figure 8. A Benjamin Chandlee, Jr. clock face, made circa 1765, owned by Ted Chandlee of Baltimore, MD.

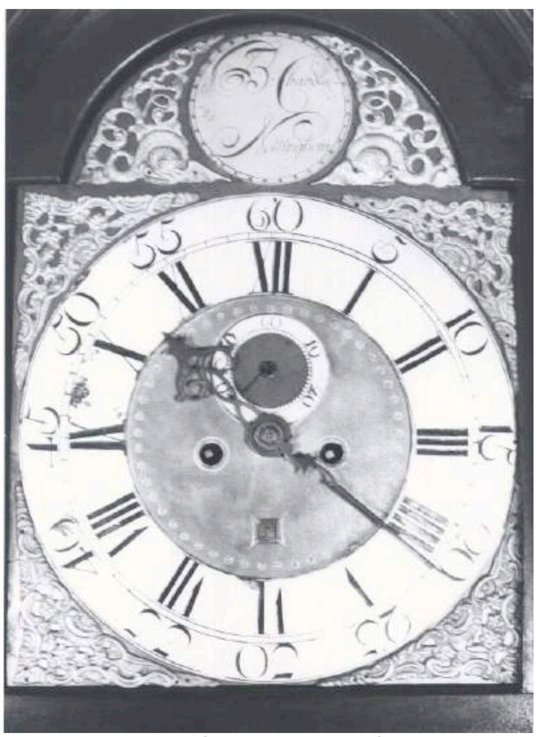

Figure 9. A Benjamin Chandlee, Jr. clock face, made circa 1756, owned by Mr. and Mrs. C Thomas Attix, Wilmington, DE.

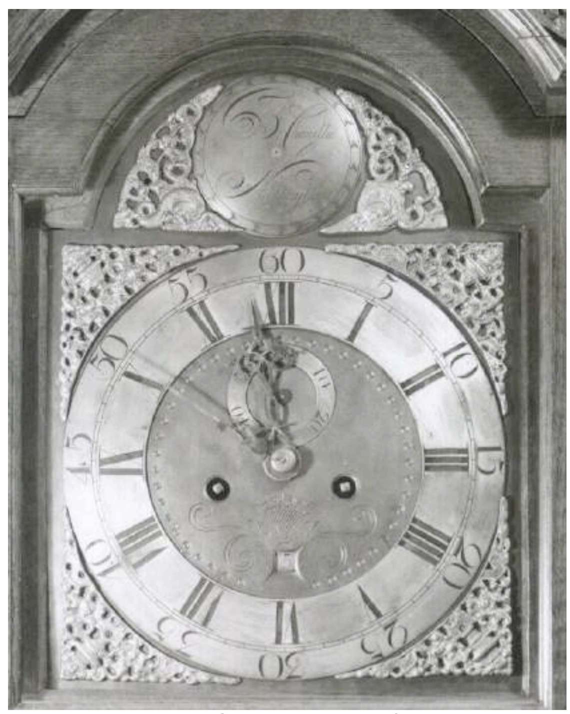

Figure 10. A Benjamin Chandlee, Jr. clock face, made 1750-1755, owned by the Chester County Historical Society, PA.

Corrosion removal rationale:

On the faceplate and central stippled field, our testing of mechanical polishing methods included calcium carbonate and Buehler alumina micropolish (in a slurry with deionized water/ethanol (1:1)). These mechanical methods alone did not successfully remove the thick layers of corrosion. Nevr-Dull® wadding polish was found to easily remove corrosion; however it left the surface too bright, and through communication with the manufacturer this product was found to contain a small quantity of ammonia, which can be detrimental to brass. Selwyn says that ammonia promotes stress corrosion cracking in copper alloys, particularly brass, because the ammonia ions form soluble complexes with copper (I) and copper (II) ions, thus making it vulnerable to continued damage.[16]

Due to the ineffectiveness of the mechanical methods tested, the students consulted Richard Wolbers to discuss chemical cleaning options. Various chemicals were tested: EDTA solution (pH=8.5), EDTA gel (pH=8.5), phytic acid (pH=4), citric acid (pH=3), and citric acid gel (pH=3). The citric acid solution in gel form at a pH of 3 worked the best in reducing corrosion on the faceplate and central stippled field. Chemical methods were used for three main reasons: the mechanical methods tested proved to be ineffective; it was thought the gel could better reduce corrosion in the recesses of the engraved portions of the central stippled field; and lastly, it was thought that through mechanical methods it would be too difficult to control the level of polish obtained.

The student conservators were aware of the risks of using an acid to clean copper alloys. Rivers and Umney state that two mechanisms, dezincification and redeposition, may occur as a result of cleaning copper alloys with acidic solutions.[17] During corrosion removal with the citric acid gel, it was found that a pinkish coppery layer remained on the surface. This layer could have been present prior to the current treatment, as the small traces of polish residue, the complete removal of the silver plating, and finally the generally reddish brown appearance of the brass components prior to treatment, strongly suggest that these components were subjected to acid cleaning in the past. Initially, it was thought that was a thin layer of cuprite left on the surface that was not being removed by the citric acid gel. As treatment progressed, it became clear that either redeposition of copper or dezincification was taking place. In order to avoid further dezincification or redeposition during corrosion removal of the brass components, the treatment course was changed so that only mechanical and abrasive methods were used. The spandrel ornaments, which were treated last, for instance were only cleaned mechanically.

[16] Selwyn, Lyndsie. *Metals and Corrosion: A Handbook for the Conservation Professional.* (CCI, 2004) p. 69.
[17] Rivers, Shane, and Nick Umney. *Conservation of Furniture.* (Oxford, 2003) p. 694.