Winterthur/University of Delaware Program in Art Conservation

Conservation Examination Report and Treatment Proposal

Owner: Winterthur Museum, Garden & Library
Accession #: 2003.0057
Object: Surveying Compass

Artist/Maker: John & Alexander Walker
Location: Liverpool, United Kingdom

Object Date: 1823-1859
Materials: Copper alloy (brass?), ferrous metal, glass
Dimensions: 11.9 x 5.25 x 5.5 inches, 30.3 x 13.3 x 14 cm (L x W x H, maximum)

Distinguishing Marks: "Walker Liverpool" engraved on face, below "N."

Reason for Treatment: Stabilize the object and reduce aesthetically distracting corrosion.

Examined By: Daisy Diamond (Graduate Fellow, Winterthur/University of Delaware Program in Art Conservation [WUDPAC], Class of 2026)
Consulted: Lauren Fair (Conservator and Lab Head for Objects Conservation, Assistant Director of Conservation, Affiliated Associate Professor; WUDPAC)
Ann Wagner (Curator of Decorative Arts; Winterthur Museum, Garden & Library)
Scott Kip (Clockmaker, Philadelphia Clock and Metronome)
Martin Brückner (English Professor and the Director of the Winterthur Program in American Material Culture [WPAMC])

Proposal Date: November 11th, 2024

Description

This surveying compass consists of a pale-yellow (copper alloy, est. brass) compass dial enclosed in a dark warm yellow metal enclosure (also copper alloy, est. brass) with a cover glass, two instrument attachment arms located at the north and south axes, and a mount on the underside (figs. 1-2). The needle is missing from the instrument.

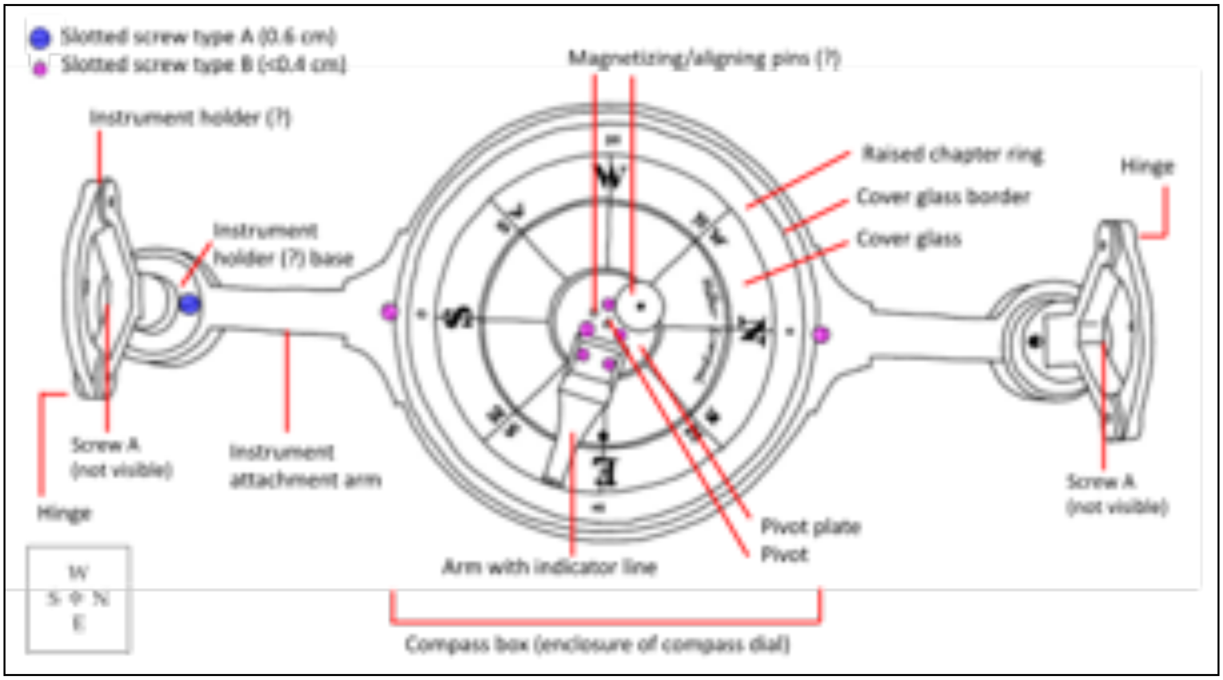


Figure 1. Surveying compass diagram, overall top.[1] Illustration by D. Diamond, 2024.

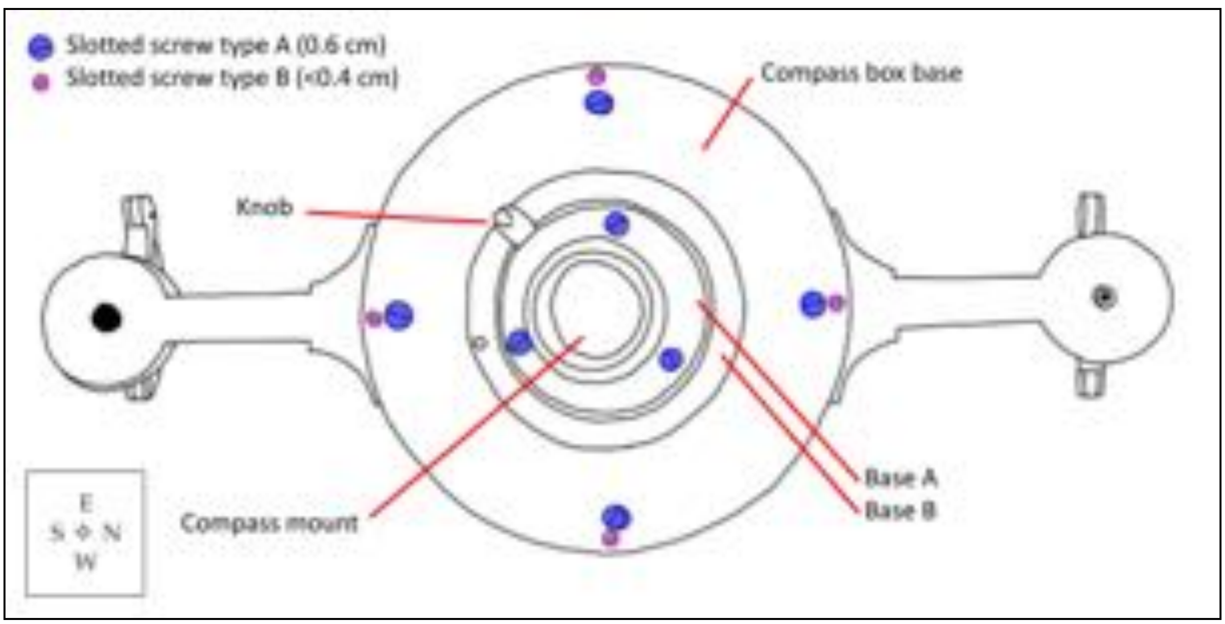


Figure 2. Surveying compass diagram, overall bottom. Illustration by D. Diamond, 2024.

[1] Terminology for scientific instruments has a degree of inconsistency dependent on the period and context of the instrument (Bryden 1993, 365). The terminology used here is based on Gillespie (1885), personal communication with clockmaker Scott Kip (November 11th, 2024), and personal communication with Objects Conservator Lauren Fair (November 12th, 2024). Less certain terminology is noted in the diagram with "(?)," but referred to without the question mark throughout this report. Variation in terminology is beyond the scope of this report.

Oriented in the center of the compass on top of a shallow brass **pivot plate**, the **pivot** is composed of a magnetic, pointed wire fixed horizontally with an upwards-facing tip. Also present on the pivot plate are two components which potentially function as **magnetizing or aligning pins**: a darker circle of a smaller radius in plane with the pivot plate and a mounted cylindrical form approximately 1.4 cm in diameter with a drilled central hole. The mounted cylindrical form could also potentially be used to arrest the needle when taking measurements (Martin Brückner, personal communication, November 13th, 2024). The cylindrical form is asymmetrically mounted on a pin and with the ability to move freely up and down the pin. The pivot plate is attached to the compass dial by three **slotted screws (type B)**. Additionally, an **arm with an indicator line** is mechanically attached to the pivot plate by two slotted screws (type B) and extends to the **raised chapter ring**. The compass dial has engraved serif block initials that are inlaid with a black pigment in binder for “N,” “NE,” “E,” “SE,” “S,” “SW,” “W,” and “NW.” The principal cardinal directions are in a larger font. The face is also engraved and inlaid with eight radiating lines that bisect each labeled compass direction as well as two decorative circles approximately ⅔ of the distance between the pivot and the raised chapter ring. Inside the narrowest engraved circle and below the engraved “N,” “Walker Liverpool” is similarly inscribed. A hole of approximately 0.2 cm in diameter is drilled on the radial line below the engraved “E.”

The raised chapter ring frames the compass dial and consists of four 90° quadrants labeled in 10° increments along the circumference, which is a labeling method consistent with surveying compasses. This ring is fixed in place. The cover glass is transparent and colorless. It is held in place by a copper alloy cover glass border of a darker and more brown appearance than the rest of the compass. This ring is secured in place with two screws (type B) at the north and south edges. The cylindrical compass box has a depth of 1.5 cm, and a compass box base of similar diameter and depth of 0.2 cm is attached at the bottom.

The **instrument attachment arms** of the compass box extend outward approximately 9 cm each and are level with the height of the compass box. At the end of each arm, a vertical component is mounted that serves to hold another instrument parallel to the compass. Each instrument holder is trapezoidal in shape with a hinging top arm that opens to allow for placement of said instrument. The southern hinging arm features a 0.4 cm square brown pad (leather or textile, est.) attached to the underside with a screw for padding. The northern hinging arm just has a screw with no padding.

Although this portion of the compass is symmetrical on both sides, there are slight differences between the two ends. The **instrument holder** at the south end has a separately manufactured top, cylindrical vertical component with a 1-cm shelf facing the compass box, and is soldered to the **instrument holder base**. In contrast, the instrument holder at the south end was manufactured in one piece, has a rectangular vertical component with a 2-cm shelf facing the compass box, and is mechanically joined to the instrument attachment arm by two screws (**type A**). The **hinge** of each instrument holder consists of a single pin, although both sides of the holders have aligned holes which could fit a pin. The southern instrument holder has a pin on the eastern side, and the northern instrument holder has a pin on the western side. On the underside of the southern instrument attachment arm, a 0.7-cm diameter hole contains a square peg which extends from the hole by 1 cm in length. The northern instrument attachment arm contains no peg, and threading is visible deeper within the hole.

The **compass box base** is attached with eight screws (four type A, four type B). The **compass mount** in the center of the box base has an outer lip of 3 cm and inner diameter of 2.5 cm with an approximately 0.5-cm threaded hole visible on the compass box base through the opening of the mount. The mount is attached **base A** (5.75 diameter), which is attached by three slotted screws to **base B** (6 cm diameter). A 1-cm tab with a **knob** is held between these two bases. The mechanism that attaches the mount unit (mount, base A, base B, knob) to the compass box base is unknown. When the knob is rotated, the entire mount unit rotates, and the arm with the indicator line simultaneously rotates in the opposite direction. The indicator line on the arm can thus be rotated by the user to align with the desired direction and degree on the raised chapter ring. The internal mechanism that allows the arm with the indicator line to rotate in the opposite direction the knob is turned cannot be visibly deduced.

Significance and Cultural Context

Surveying compasses are broadly used for identifying the relative positions of given points on land or sea (fig. 3). As described by Martin Brükner, scholar of American maps, each township during the mid-19th century typically had a surveyor who assisted with the sale of land, and they would travel by foot or horseback with their surveying equipment (personal communication, November 13th, 2024). When used for nautical purposes, the surveying compass is divided into 32 directions, rather than the four or eight used for land, confirming that this instrument was used on land (Gillespie 1855, 130). Although imperfect and not as direct as other surveying methods,[2] the surveying compass was a rapid and affordable tool commonly used.

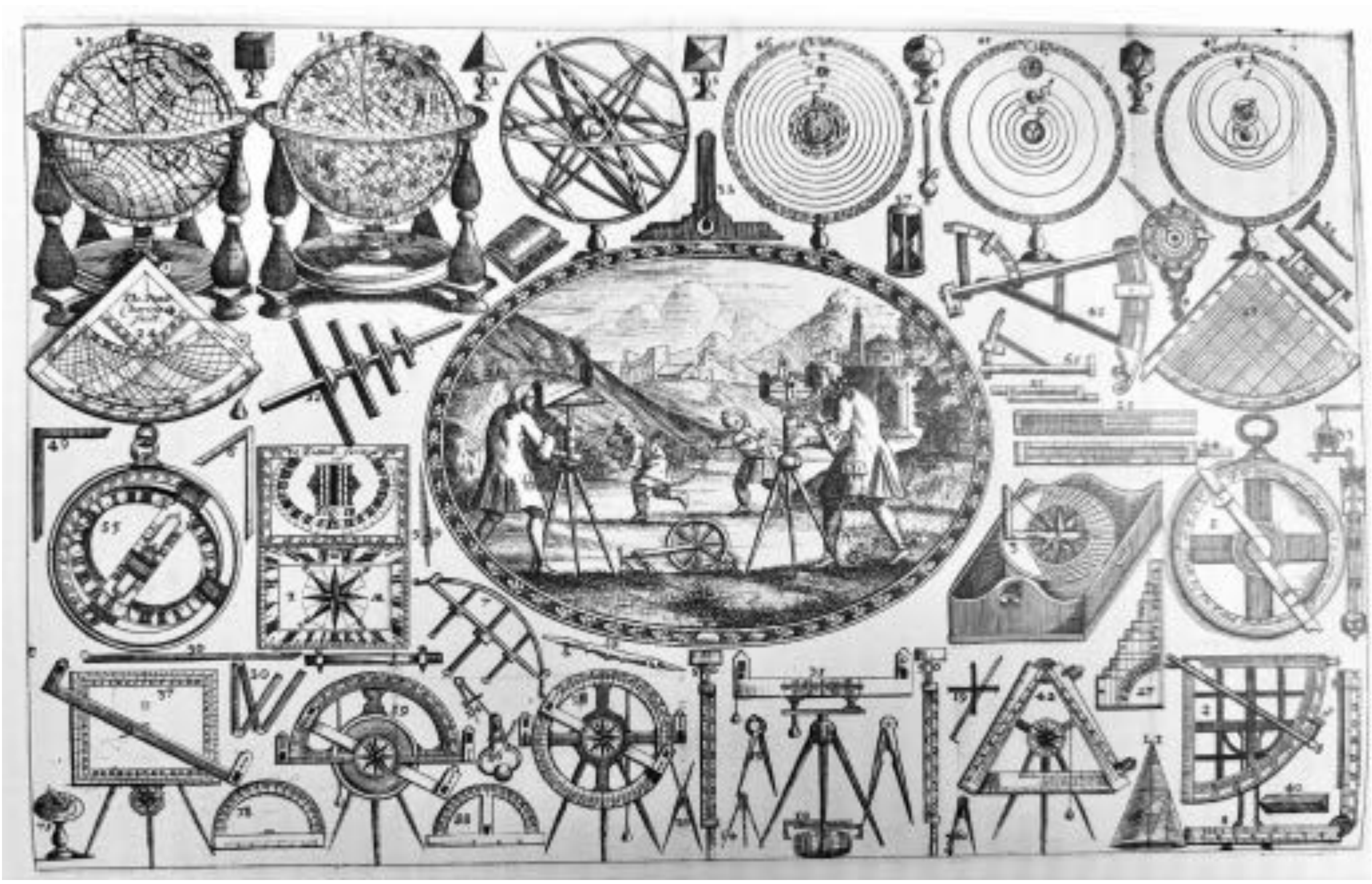


Figure 3. Early 1700s illustration of surveying technology with a central depiction of surveyors at work used for advertising (*The Description and Explanation of Mathematical Instruments*, Moxon and Tuttel, Cambridge University Library; Bryden 1993, 372).

As depicted in Figure 4, the surveying compass could be used to establish the angle of two points when viewed from a third: line AB makes a 30° angle with the line AN, and line AC makes a 75° angle with AN. The difference of these angles, 45°, is the angle which AC makes with AB (Gillespie 1855, 124). A method called Polar Surveying (also known as the Method of Progression or *Cheminement* by the French) consisted of going around a field with the surveying compass, measuring the angle each side makes with its neighbor from the corner, as well as the length of each side. Another system, the Method of Radiation, consisted of setting the instrument at one point, and measuring the direction and distance of each corner of the field (Gillespie 1855, 124-125, 130). They were frequently used on tripods and with a Jacob’s staff, or a pole with measurements that could measure angles to calculate heights and distances (fig. 5). Sometimes surveying compasses also included covers made of brass or other metals. Specialized carrying cases were used for transport and to store removable sights (Chandlee 1943; 137, 212, 221).

[2] Such as a theodolite, an instrument capable of measuring both vertical and horizontal angles.

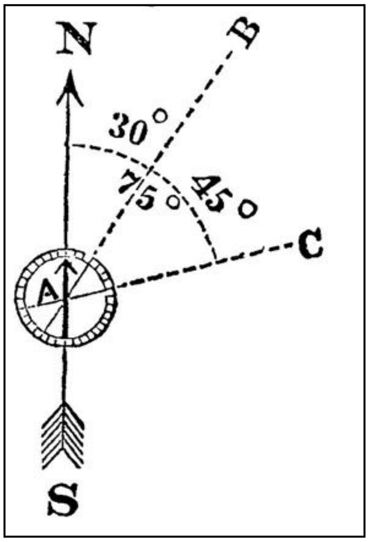


Figure 4. Surveying compass application example (Gillespie 1855, 124).

Figure 5. Surveying compass, tripod, Jacob's staff, saddle bags (Chandlee 1943, 220).

This surveying compass was made in Liverpool by John and Alexander Walker, who may have also been clockmakers. It is believed to have belonged to James McCauley (1809-1897) of Cecil County, Maryland (Surveying compass 2005). It was on loan to Winterthur from McCauley's family beginning in 1993 until its acquisition in 2003. McCauley worked as a surveyor of land alongside engineers for the construction of the Baltimore and Ohio Railroad at Sykesville Maryland in the 1830s. In 1841, he was appointed county surveyor of Cecil County by Governor Pratt. He likely used this instrument in the establishment of private property lines, routes of transportation, and varied state and federal projects. This object is therefore directly connected to the history of land organization and colonization of Indigenous land in the United States, as influenced by European conceptions of private property, ownership, and white supremacy. Winterthur objects from this same acquisition include two surveying compasses including this instrument (2003.0054, fig. 6, and 2003.0057), two tripods (2003.0058 and 2003.0059), a Jacob's staff (2003.0060), and saddle bags (2003.0056). When acquired for the Winterthur collection, the value of these objects was stated to be as "a useful interpretive adjunct to the small collection of surveying equipment presently in the museum's collection" (Fennimore 2003). In comparison to other surveying compasses and theodolites from a similar time period (figs. 6-7), the instrument attachment arms and instrument holder of 2003.0057 are quite unique and potentially indicate a missing component, such as a telescope or level, which would within each instrument holder (fig. 8).

Figure 6. Isaac Chandlee. "Surveying Compass" (1790-1813). Brass, Glass, Iron. Winterthur Museum, Garden and Library, Wilmington DE (2003.0054).

Figure 7. Frederick Augustus Heisely Jr. "Surveying Compass Field Case, Box and compass" (1820-1836). Brass, Glass, Iron. Winterthur Museum, Garden and Library, Wilmington DE (2010.0042.001).

Figure 8. Improved Patent Portable Theodolite, consisting of prismatic compass, telescopic sight and level by C. A. Schmalcalder, 82 Strand, London, England, 1818-1826. Image courtesy Science Museum Group (1911-180).

When considering the importance of no-longer-functioning objects, a decision must be made: should elements be reconstructed to reinstate functionality, or should the unaltered object be preserved with minimal intervention? This question is essential to understanding the significance of this surveying compass and evaluating the appropriateness of re-introducing a magnetized compass needle. Stewardship by amateur enthusiasts has resulted in only a small number of unaltered historic scientific instruments, which impacts the availability of information about original materials or construction techniques (Appelbaum 2007, 144). Scientific instruments are an invaluable source of direct, original evidence about past processes of invention, meaning-making, discovery, and cultural values (Keene 2000, 57). However, conservation ethics has expanded in the recent past to acknowledge the value of objects in enhancing meaning through use or function rather than arrested change, particularly as influenced by conservators supporting the preservation of Indigenous belongings (Henderson 2024). Martin Brückner expressed that a needle would be very useful for the curatorial interpretation of the object, but that the broken cover glass was historically consistent as these frequently cracked during transit and use (personal communication, November 13th, 2024). There is no objectively right or wrong answer regarding the re-introduction of a magnetized compass needle, so long as the decision is made with appropriate stakeholders and the reproduction needle does not have a detrimental material impact on the compass, is documented, and is reversible.

Materials and Manufacture

The enclosure for this compass was likely cast then finished on a metal lathe, as evidenced by pitting consistent with casting processes and concentric curvilinear marks on the mount, compass box base, compass box, and compass dial (fig. 9). The extensions were likely cast in one piece and further finished by hand cutting. Single cast components are stronger than mechanical or solder joints (Lauren Fair, personal communication, November 12th, 2024).

Figure 9. Pitting and concentric curvilinear lines. Compass dial near pivot plate, SE-5.

A clock maker may have made the face of the compass with an inlaid black colorant, commonly in shellac, pine resin, gum arabic, or pitch (typically bitumen) (Scott Kip, personal communication, November 11th, 2024; Lauren Fair, personal communication, November 12th, 2024). The variation in coloring between the compass dial and raised chapter ring in comparison to the rest of the compass may be attributed to differences in coating, oiling, cleaning, or exposure, rather than distinct alloy compositions or a silvered dial. However, the compass dial may also be silvered (Ann Wagner, personal communication, December 17, 2024). The screws on this compass are mass produced and more crudely joined than expensive surveying compass models, which would have screws set in flush with the surface (Martin Brückner, personal communication, November 13th, 2024). It is worth nothing that manuals for the use of surveying equipment do include chapters about varnishing instruments (Martin Brückner, personal communication, November 13th, 2024). The historic cover glass also has three 0.2-cm air bubbles and fine lines consistent with hand manufacturing.

Although absent in this example, the magnetized ferrous needle is the most essential component of a functional compass. The needle is a slender bar of steel, usually five or six inches long, strongly magnetized, and balanced on a pivot so it may turn freely and continue pointing to the magnetic meridian. Typically, the north end is more ornamental for the sake of distinction. The center of the needle typically has a cap of agate, ruby, or other hard material which rests on the pivot. The needle must move with minimal friction, so the pivot is made from the hardest steel or iridium ground to a very sharp point (Gillespie 1855, 127).

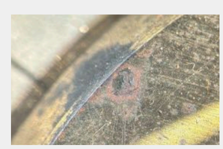
Condition

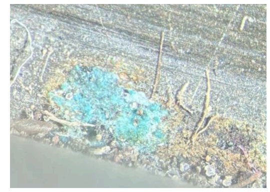
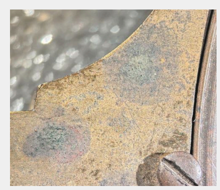
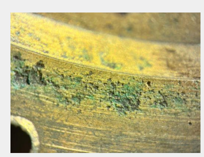
This surveying compass is stable and in fair structural and aesthetic condition with a loose component, assorted variegated corrosion products, and a missing compass needle.

The northern instrument holder and base are missing one screw (type A), which contributes to its unintentional ability to swivel on the attachment arm. The one intact screw is slightly raised and does not create sufficient structural support to hold the components in line with friction and pressure.

The surface corrosion includes red, black, brown, bright green, pale green, and white corrosion products as well as varied textures, dimensions, and distributions (table 1). Copper (I) compounds and complexes are typically colorless, except for cuprite (red) and chalcocite (black). Most copper (II) compounds are green or blue (Selwyn 2000, 59). Some of the dimensional, powdery, pale-green corrosion on the compass dial may be consistent with localized bronze disease caused by salts deposited during handling. The corrosion on the cover glass border near areas of contact with the cover glass may be sodium copper formate acetate (socoformacite), as observed corrosion products where copper is in contact with soda glass (Eggert et al. 2010, 174). The corrosion patterning may also be related to coating application and misses (see: "Ultraviolet (UV) Examination" for additional information). The variation in corrosion products, particularly on the exterior of the compass box and instrument attachment arms is aesthetically disfiguring and reduces the legibility of the object. In contrast, the corrosion products on the compass dial are much less disfiguring as this area may be more protected from both abrasion to any applied coatings and high or fluctuating relative humidity conditions due to the cover glass. The surface of the compass dial has abrasion consistent with use from the rotation of the arm with an indicator line. Darker corrosion and abrasion is present on the compass dial under the current orientation of the arm with an indicator line and on the north west side of the compass dial near the raised chapter ring.

Table 1. Corrosion characteristics and locations.

Reference # and location	Region	Characteristics	Image
(1) Compass dial, pivot mount	SW edge, NE screw, SE edge	Red and black surface product, minor flaking	 160x
(2) Compass dial, pivot mount	Under pivot, in small recessed hole	Green, crusty	 160x

(3) Compass dial, arm	SE side, near screw	Black, uniform	 160x
(4) Compass dial, face	**E to SE**: near engraved circle, underneath arm near raised chapter ring, by edge near raised chapter ring. **SE to S**: edge near raised chapter ring, near engraved circle. **S to SW**: between engraved circle and pivot mount, edge near chapter ring. **SW to W**: edge near raised chapter ring. **W to NW**: largest area, near raised chapter ring. **N to NE**: along incised line. **Raised chapter ring**: 70° (NE to E), 90° (E), 35° (SE to S), 30° (S to SW)	Yellow, green (to varied extents), slight iridescence, crusty, erupting	 160x
(5) Compass dial, face	Near “SE,” multiple patches on the SE side of “S,” SW side of “S”	Dark brown with red areas, abraded appearance as well as exposed underlying metal	 160x
(6) Compass dial, upper rim	Surrounding edges, particularly on W, N, NE, E, and SW edges.	Powdery green and white, particularly in areas of contact with glass and adjacent metal.	 160x
(7) Compass box and instrument attachment arm	Splotches and streaks across the surface.	Dark green, red-brown, and black low-relief corrosion product with slight glossiness	 160x
(8) Screw type A	N end	Bright pale-green encrustation	 1x
(9) Compass bottom	Compass box bottom, base A	Bright green encrustations	 160x
(10) Compass bottom	W, SW, W screw A	Red, pale-green black, low relief, high gloss regions	 64x

Under the cover glass and across the compass dial, there is loose soiling and evidence of insect activity. A winged insect is trapped under the cover glass border near the west side, and dead insects are present near corrosion and soiling on the compass dial near the east side. The black infill within engraved areas has some alligatoring and losses, particularly the center of “E” (fig. 10). The black material in the engraved text may be structurally unstable, but further examination is not possible prior to removal of the cover glass. The coating applied to the dial has some crazing and flaking, particularly in areas of thicker application on the raised chapter ring (fig. 11). The coating is highly brittle and has minor losses primarily visible under magnification. It may also be contributing to the slight yellow haze on the surface of the dial.

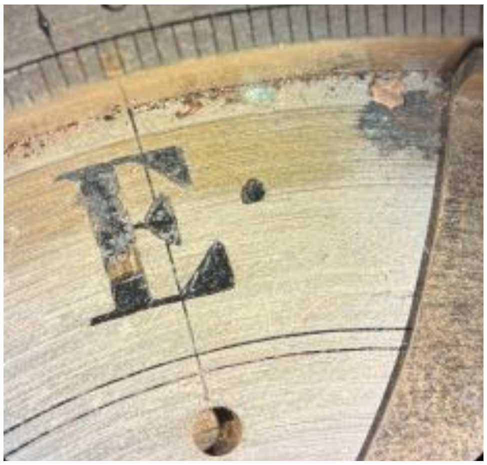


Figure 10. Losses and alligatoring, black infill within engraved text. 250x magnification.

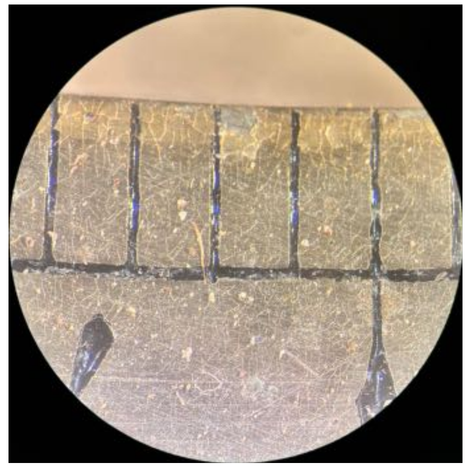


Figure 11. Coating crazing and flaking, raised chapter ring, between NE to E. 400x magnification.

The cover glass is split in two components with a 10.5 cm fracture structurally held in place by the cover glass ring. This is consistent with damage that may have occurred during the objects lifetime. There is a 1 cm surface abrasion on the glass on the eastern side. There is no change in condition report on EMu for this object. Otherwise, the glass is in good aesthetic condition. The metal cover glass border is slightly deformed along the eastern edge.

There are some missing components of this instrument. As previously discussed, the needle is no longer associated with the object and the northern instrument holder and base are missing one screw (type A). Additionally, pins may have been used to keep the instrument holder closed on the non-hinged sides. These are no longer associated with the object. There may have been an extended square pin on the underside of the northern instrument attachment arm that matched the one present on the southern instrument attachment arm. However, this is speculative and indeterminate at present. The pad on the underside of the northern instrument holder became dislodged and missing at an unknown time during object examination. Unfortunately, the missing component could not be located.

Some of the observed changes in condition are potentially connected to use. The cracked cover glass is consistent with damage caused during field instrument use. As the cover glass border could easily be lifted by removing two screws, it is likely that a surveyor would have replaced the cover glass themself when it broke (Martin Brückner, personal communication, November 13th, 2024). Additionally, there are small concentric circular scuffs approximately 1.2 cm in diameter around each hole on the underside of the instrument attachment arms, which is likely indicative of a missing component that was formerly screwed on here. Abrasion on the compass dial may have been caused by turning the arm with an indicator dial during use. The accession number “03.57” is applied in red paint on top of a barrier layer on the underside of the northern instrument extension arm.

Ultraviolet (UV) Examination

UV examination revealed information on the coatings and materials (fig. 12) (see “Appendix I: Before Treatment Photography” for overall UV images). Under long wave UV (UVA) examination, there are two characteristic fluorescences: the compass dial fluoresces yellow-green and everywhere else is bright orange. This indicates that the compass dial has a different coating than the rest of the compass. Yellow-green is often consistent with a natural resin, and orange is often consistent with shellac. Additionally, there is apparent streakiness in both coatings under UVA, and the corrosion observed is consistent with misses during application or abrasion to the coating. Under ultraviolet short wave (UVB) examination, the surveying compass absorbs all radiation, except for the glass which appears a uniform cloudy yellow (see “Appendix I: Before Treatment Photography” for additional information). The yellowish cast may be related to iron or manganese in the glass, but this is not conclusive; what is conclusive is that the glass is non-lead containing as it would otherwise fluoresce bright blue under UVB (Lauren Fair, personal communication, November 12th, 2024). The incised letters and lines fluoresce bright white due to the binder or a coating.

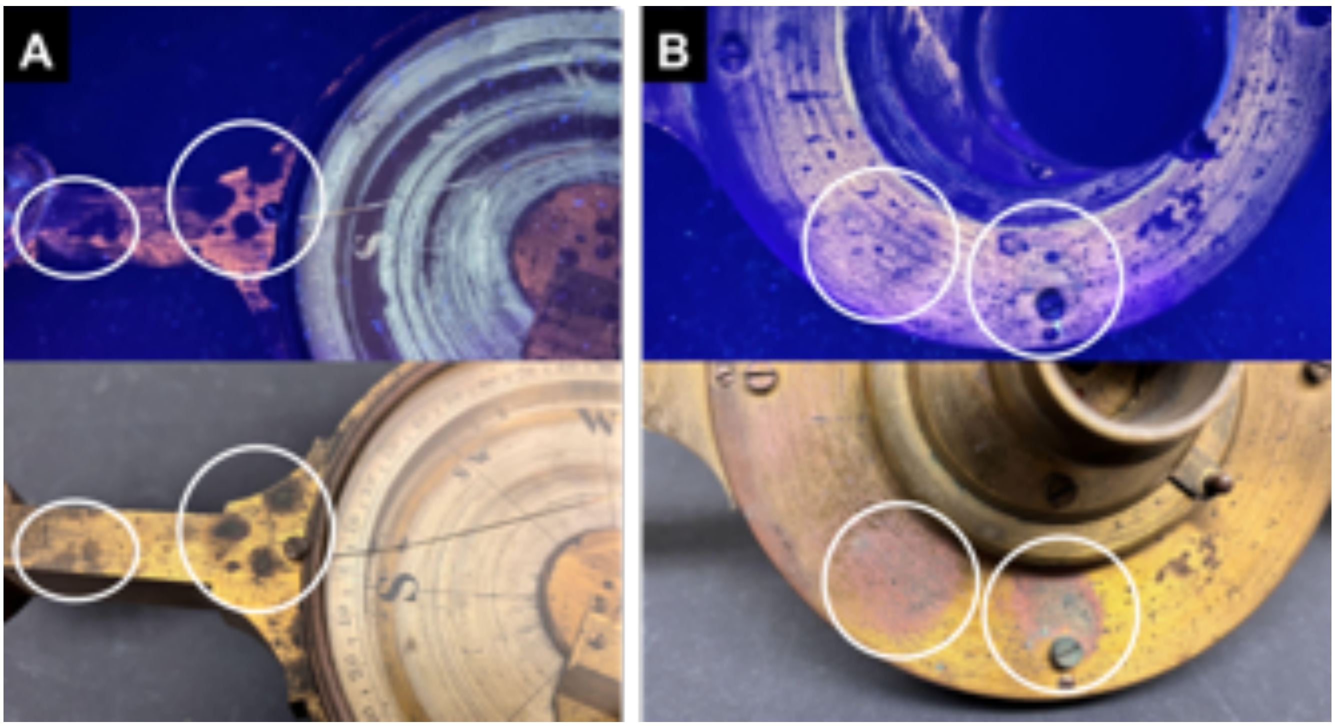


Figure 12. UVA and visible light comparisons that illustrate regions where corrosion and abrasions correspond to regions of absorption in UV. 12.A depicts larger corrosion patches, and 12.B depicts more mottled areas of corrosion.[3]

Purpose of Treatment

The purpose of this treatment is to reduce aesthetically disfiguring corrosion, remove hygroscopic soiling accelerating corrosion, and stabilize the partially attached instrument holder and instrument holder base. In consultation with stakeholders, this treatment will preserve the integrity of the original object and/or functional value with as minimally invasive methods as possible.

[3] Documented with an iPhone 15 (ISO 125160, 26mm, f 1.6, 1/60s for visible documentation; ISO 1000-1250, 26 mm, f 1.6, and 1/5-1/2s for UV documentation). The UV light source was the Model UVL-56 Blak-Ray® Lamp Long Wave UV - 365nm, 115V, 60 Hz, 0.16 amps.

Additional Considerations

When considering the importance of no-longer-functioning objects, a decision must be made: should elements be reconstructed to reinstate functionality, or should the unaltered object be preserved with minimal intervention? This question is essential to understanding the significance of this surveying compass and evaluating the appropriateness of re-introducing a magnetized compass needle. Stewardship by amateur enthusiasts has resulted in only a small number of historical scientific instruments remaining unaltered, which impacts the availability of information about original materials or construction techniques (Appelbaum 2007, 144). Scientific instruments are an invaluable source of direct, original evidence about past processes of invention, meaning-making, discovery, and cultural values (Keene 2000, 57). However, conservation ethics has expanded in the recent past to acknowledge the value of objects in enhancing meaning through use or function rather than arrested change, particularly as influenced by conservators supporting the preservation of Indigenous belongings (Henderson 2024). Martin Brückner expressed that a needle would be very useful for the curatorial interpretation of the object, but that the broken cover glass was historically consistent as these frequently cracked during transit and use. (personal communication, November 13th, 2024). There is no objectively right or wrong answer regarding the re-introduction of a magnetized compass needle, so long as the decision is made with appropriate stakeholders and the reproduction needle does not have a detrimental material impact on the compass, is documented, and is reversible.

Treatment Proposal

1. **Carry out pre-treatment examination, consultations, and photo documentation** (*5 hours, completed*).

2. **Remove the cover glass for access to the compass dial during analysis and treatment** (*est. 30 minutes*).
    - Remove the two screws, distinguishing which came from the north end, and which came from the south end. Remove the cover glass border, and carefully lift the cover glass. Save these with the object.

3. **Conduct additional analysis to inform material and mechanical interpretations for treatment** (*8 hours*).
    - Conduct X-ray fluorescence (XRF) spectroscopy to investigate suspected brass composition.
    - Complete X-radiography to guide interpretation of internal compass mechanisms.
    - Evaluate chloride presence in select corrosion products with the silver nitrate and sulfuric acid spot test.

4. **Consolidate black incised lettering and decorative motifs on the compass dial** (*est. 3 hours*).
    - Under magnification, isolate and save flaked black colorant no longer associated with specific incised letters for future research.
    - Surface clean intended consolidation areas with a cosmetic sponge to prevent soiling imbibition.
    - Consolidate with appropriate adhesive following solvent testing.
    - Create a fill for the larger loss in the “E”

5. **Surface clean the interior, exterior, and cover glass of the compass** (*est. 3 hours*).
    - Dry clean the interior and exterior of the metal components. With a soft-bristled brush into a low-speed HEPA filtered vacuum and cosmetic sponge, reduce loose soiling and particulate matter from the formerly enclosed compass dial.
    - Following testing, solvent clean (i.e. Shellsol D38) the interior and exterior of the metal components without disrupting the coating.
    - Clean the surface of the glass with a cosmetic sponge. If necessary, further clean the glass with 1:1 ethanol:deionized water and dry with a microfiber cloth (Lauren Fair, personal communication, November 25th, 2024).

6. **Reduce corrosion** (*est. 3 hours*).
    - Reduce corrosion with mechanical excavation with insect pins, scalpel, or similar tool to the extent possible without disrupting the surface coating or creating visually disrupting bright spots.
    - Reduce corrosion further with chemical chelation using 0.5% disodium EDTA pH 6 (citric acid) or BTA.

7. **Construct a replacement screw (type A) for the northern instrument holder base** (*est 3 hours*).
    - Machine a screw of identical dimension. Inpaint with Golden Fluid Acrylics to match the patination of the remaining screws.
    - Alternatively, a screw with identical threading could be sourced and the top could be sawed off. A replacement top could be sculpted with Milliput epoxy, attached to the shank, and inpainted with Golden Fluid Acrylics to match the patination of the remaining screws.

8. **Evaluate the feasibility, safety, and value of replacing the missing magnetic needle** (*est 0-10 hours*).
    - In consultation with stakeholders, consider needle replacement sources, aesthetics, functionality, and impact on the condition of the original object.

9. **Construct a replacement pad for the underside of the instrument holder on the northern instrument holder, if determined necessary following consultation** (*est 1 hour*).
    - Potential materials could include sueded polyethylene.

10. **Reattach the glass in place with original screws, taking care not to overtighten** (*est. 15 minutes*).
    - If determined additional stabilization is necessary, use museum wax to hold glass in place.

11. **Update housing enclosure as needed** (*est. 2 hours*).

12. **Carry out post-treatment photodocumentation and complete the treatment report** (*est. 2 hours*).

Total estimated time: 40.75 to 50.75 hours.

Daisy Diamond Daisy Diamond **Date:** January 12, 2025
Conservation Graduate Fellow

Lauren Fair Lauren Fair **Date:** January 13, 2025
Supervising Conservator

Ann Wagner Ann Wagner **Date:** January 27, 2025
Curator

Additional Observations

A greenish hue and conchoidal fractures along the edges of the cut glass were noted when the cover glass border was removed. The small raised attachment, noted as a magnetizing/aligning pin (?) in Figure 1, might have been a leveling attachment and was noted to be removable during further examination after removing the cover glass (Brittany Cox, personal communication, January 13th, 2025).

Treatment Summary

For the treatment of this surveying compass, corrosion was reduced and stabilized. Missing components were replaced for structural and aesthetic integrity.

Treatment Steps

1. **Carried out pre-treatment examination and photo documentation** (5 hours).

2. **Removed the cover glass for access to the compass dial during analysis and treatment** (0.25 hours).

    - This was completed by removing the two screws with a small flathead screwdriver, distinguishing which screw was associated with the north and south ends (fig. 13). I covered the tip of the screwdriver with painters tape to avoid scratching any metal surfaces. I removed the cover glass border and then the cover glass lifted from the recessed lip.

Figure 13. Cover glass removed and components separated.

3. **Conducted additional examination and analysis** (6 hours).

    - **Silver nitrate[4] and sulfuric acid[5] spot tests**: these microchemical spot tests resulted in faint positives, confirming the powdery green corrosion on the compass contained chloride ions. This is consistent with active chloride corrosion products. These tests were performed with the guidance of Lauren Fair (figs. 14-15).

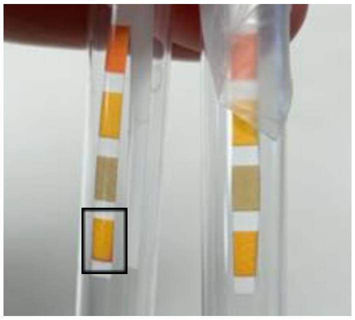


Figure 14. Faint positive silver nitrate spot test result indicated by dark red border of the lower square (left) when compared to the negative control (right).

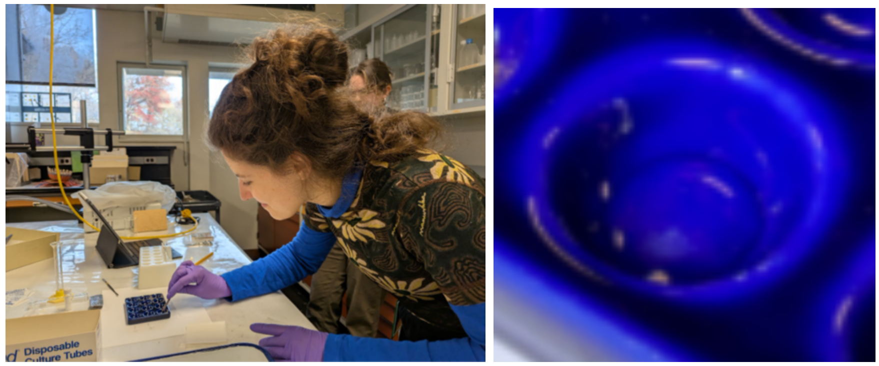


Figure 15. Conducting sulfuric acid spot test (left). Faint white results after the test was completed (right) indicated a positive test for chlorides.

    - **Micro X-ray fluorescence (μ-XRF) spectroscopy**: I conducted μ-XRF with the assistance of Patricia Gonzales, SRAL Visiting Scientist at the Winterthur Museum, Garden & Library. From this, we determined that the composition of the compass is brass, there are two different brass alloys used for the enclosure and the dial, and the dial is silvered. Additionally, the compass dial has a relatively higher zinc percent composition and lower copper percent composition than the compass enclosure. See "Appendix III. μ-XRF Results" for results and additional information.

    - **X-radiography**: with the assistance of Lauren Fair, I conducted X-radiography to investigate the manufacturing methods of the compass. While the interior mechanisms could not be elucidated further with our equipment, we could see that there are incised marks underneath the black inlays on the dial numerals. Refer to "Appendix IV. X-Radiography" for full images and additional information.

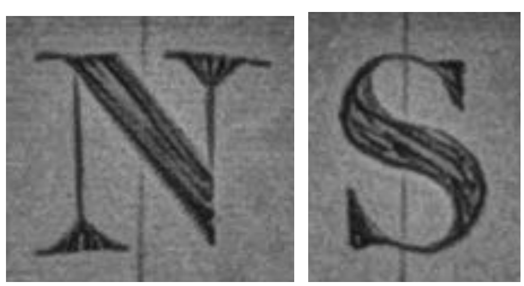


Figure 16. Incised metal of compass dial lettering. Crop of X-radiograph without filter.

[4] This spot test establishes the presence of chloride ions (Cl-) in corrosion products and other substances. Chloride ions are dissolved and acidified in a solution of nitric acid (HNO_3), then reacted with silver nitrate ($AgNO_3$) to form silver chloride (AgCl), a white precipitate (Odegaard, Carroll, and Zimmt 2000, 108).

[5] This spot test establishes the presence of chloride ions (Cl-) in inorganic compounds with sulfuric acid. Concentrated sulfuric acid (H_2SO_4) reacts with chloride salts to form volatile hydrogen chloride (HCl), which can be shown by the reaction with acid indicators on pH paper. (Odegaard, Carroll, and Zimmt 2000, 104).

4. **Addressed loss and stabilized flaking black inlay** (1 hour).

    - **Solvent tests**: I conducted solvent testing to inform consolidant selection. Shellsol D-38, acetone, and ethanol all penetrated quickly with no discernible change in condition.

    - **Consolidated and reattached fragment**: Once the cover glass was removed, I identified a fragment of the inlay among the loose soil particles on the compass dial. After applying a 5% Regalrez 1094[6] in Shellsol D-38[7] barrier layer, I reattached the fragment to the “E” with 40% Paraloid B-72[8] in acetone (fig. 17). The other letters were stable and no further stabilization was necessary.

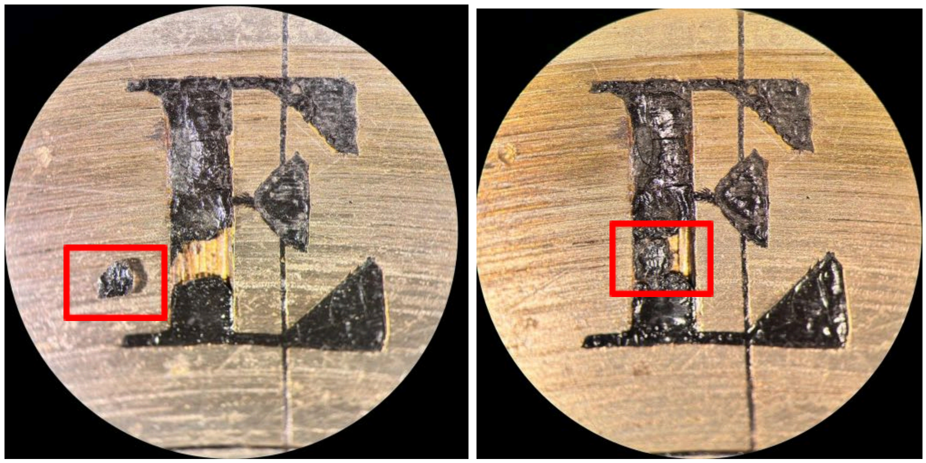


Figure 17. Before (left) and after (right) consolidating and reattaching the inlaid colorant fragment.

5. **Surface cleaned** (3 hours).

    - First, I overall surface cleaned the compass enclosure, compass dial, cover glass, and cover glass border with a low-speed HEPA-filtered vacuum and cosmetic sponges (fig. 18).

Figure 18. Soiled cosmetic sponges, after cleaning.

    - Then, I overall surface cleaned the compass enclosure, compass dial, and cover glass border with Shellsol D-38 applied with a swab and cosmetic sponge. Once embedded soiling was removed, light green corrosion products were less evident (fig. 19).

[6] Low molecular weight hydrocarbon resin consisting of a hydrogenated oligomer of styrene and alpha-methyl styrene. It is often used with a small amount of wax and a hindered amine light stabilizer (HALS) to improve working and aging properties when used as a varnish. It is soluble in petroleum hydrocarbons and insoluble in water, alcohol and acetone.
[7] A highly refined petroleum solvent with very low aromatic content and rather slow evaporation rate.
[8] Clear colorless thermoplastic acrylic resin composed of an ethyl methacrylate (70%) and methyl acrylate (30%) copolymer. Previously manufactured by Rohm & Haas, now produced by The Dow Chemical Co. and available from conservation suppliers.

Figure 19. Detail of the south end instrument attachment arm before (left) and after (right) solvent cleaning.

- Lastly, I surface cleaned the cover glass with 1:1 ethanol and deionized water with a Kimwipe[9] and dried with a microfiber cloth[10] (fig. 20).

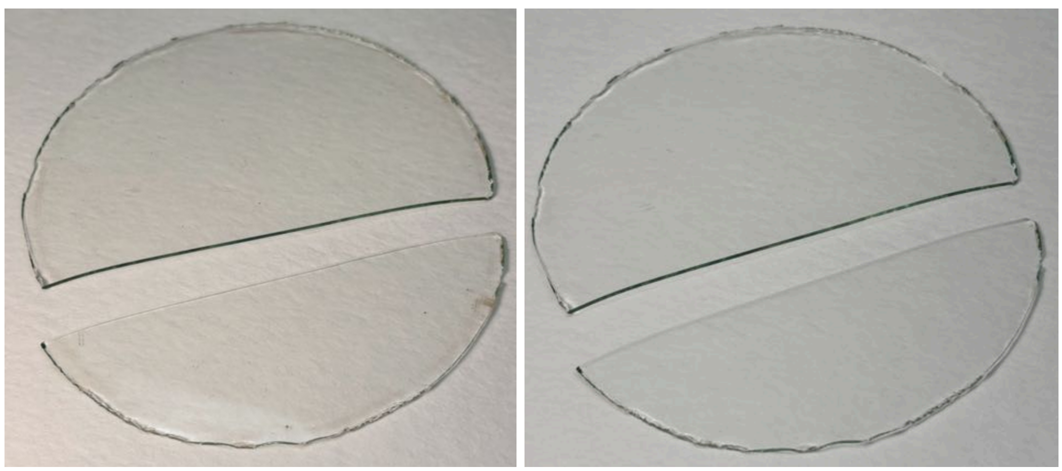


Figure 20. Before (left) and after (right) solvent cleaning the cover glass.

6. **Reduced corrosion and locally stabilized active chloride corrosion** (19 hours).

   - **Mechanical**: With a scalpel, insect pin, and Shellsol D-38, I significantly reduced most areas of corrosion and achieved flat smooth surfaces (fig. 21). I further reduced corrosion locally with 0.3 micron alpha alumina Buehler micro polish[11] with 1:1 ethanol and DI water, cleared with 1:1 ethanol and DI water. The goal of this step was to reduce the visual prominence of corrosion products and maintain the original

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[9] Single-ply, low lint disposable wiping cloth. Manufactured by Kimberly-Clark Inc; available from chemical and conservation suppliers.

[10] Microfiber or microfibre is a synthetic fiber finer than one or 1.3 denier or decitex/thread. The most common types of microfiber cloths are made from polyesters, polyamides (e.g., nylon, Kevlar, Nomex, trogamide), or a conjugation of polyester, polyamide, and polypropylene. The Mr. Clean Streak Free Fiber Cloths are a blend of 70% polyester and 30% polyamide, fabricated through a heat melding process that makes these cloths very durable. Available at many suppliers online.

[11] Mineral with formula Al_2O_3 used in a slurry as a metal polish; two grades are commonly used: alpha alumina (corundum, a hexagonal form with a particle size of 0.3 micron) and gamma alumina (a tetragonal form with a particle size of 0.05 micron). Available from chemical suppliers.

coatings in areas where it was not disrupted by surface corrosion. A highly polished uniform surface appearance was not desired, in order to preserve the historical context of the object.

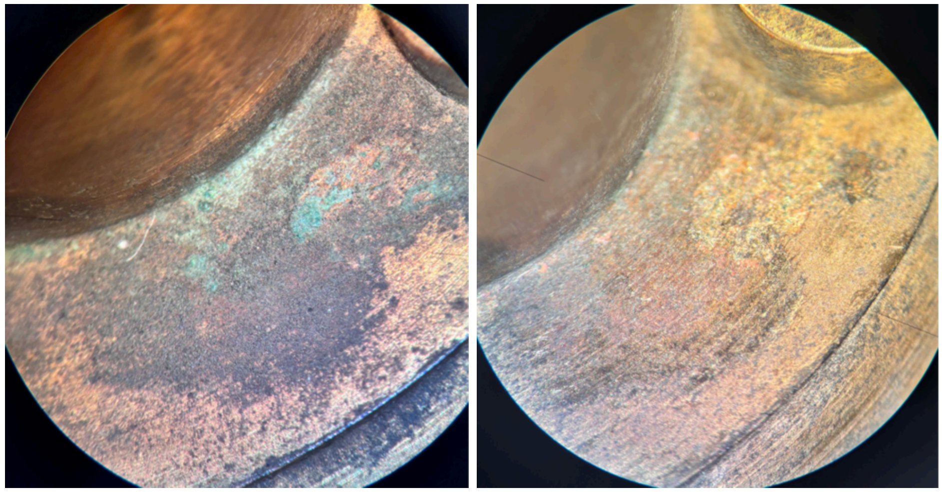

Figure 21. Detail of Figure 19 before (left) and after (right) mechanical corrosion reduction.

- **Chelation**: I additionally chemically cleaned areas of active chloride corrosion locally with 5% EDTA[12] 3% borax pH 8 NaOH applied with a fine tip brush.

7. **Replaced missing components** (15 hours).

- **Instrument holder pad, north end**: I cut a replacement pad to size from polyester ultrasuede adhered to toned Japanese tissue to imitate the smoother top side and fibrous edges of the leather pad on the south end. I tamped down fibers of the replacement edges with 2% Klucel G[13] in DI water (w/v). I adhered the replacement pad to the underside of the instrument holder hinged component with 15% Paraloid B-48N[14] (w/w) in 98% acetone and 2% ethanol.

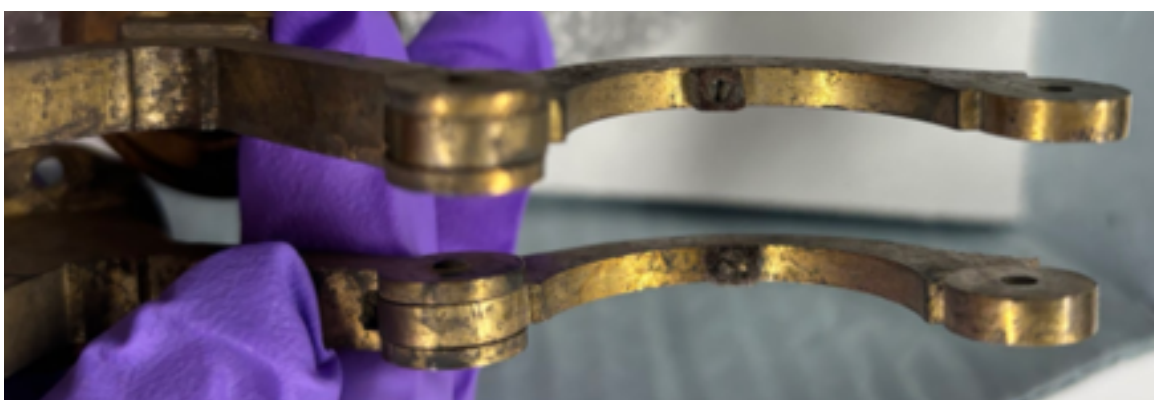

Figure 22. Original instrument holder pad (top) and replacement (bottom).

[12] Acronym for ethylenediamine tetraacetic acid and many of the metal salts derived from this acid. The metal salts, such as calcium, sodium, etc., are generically called edates. EDTA has colorless crystals that are slightly soluble in water and insoluble in organic solvents. EDTA is a strong chelating agent used to remove metallic salts from solutions.

[13] Low molecular weight hydroxypropyl cellulose compound (nonionic, water soluble ether of cellulose) often used as a paper size or leather consolidant; soluble in water (below 38°C), ethanol, acetone, and many organic solvents; pH 5-8.5 in water solution. Manufactured by the Aqualon division of Hercules; available from conservation suppliers.

[14] Clear colorless thermoplastic acrylic resin composed of a methyl methacrylate/ butyl acrylate copolymer. Contains an adhesion promoter that assists bonding to bare and primed metals. Manufactured by Rohm & Haas and available from conservation suppliers.

- **Slotted screw type A, north end**: I created a replacement screw with the guidance of Kate Jennings, Metals Subject Leader in the Conservation Studies Program at West Dean College, and Lauren Fair. 18-gauge brass rod was thinned slightly by periodically annealing and drawing the rod through #1 on ART 110 draw plate for the screw body (fig. 23). I threaded the screw with a 6-32 die (fig. 24). To create the head, I cut larger gauge brass to length to match the head of other screws, and then I matched the slot with a hack saw of similar kerf width as the original screw slot width (figs. 25-26). To finish the screw, I soldered the head onto the body with silver brazing solder and flux (fig. 27). Finally, I polished the new screw with Solvol Autosol[15] and steel wool #0000, clearing polishing residues with ethanol (fig. 28). I completed inpainting to the visible screw head with Gamblin Conservation Colors[16] solubilized with 80% isopropanol with 20% petroleum benzene. A final layer of inpainting was completed with a wash of golden fluid acrylics[17] before fitting the screw to the north instrument attachment arm (figs. 29-30).

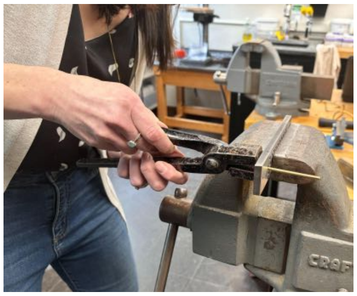

Figure 23. Lauren Fair drawing the brass to the correct gauge.

Figure 24. Brass rod, threaded on one end.

Figure 25. Head of the replacement screw.

Figure 26. Marking the height for the replacement screw head, cut with a jeweler saw.

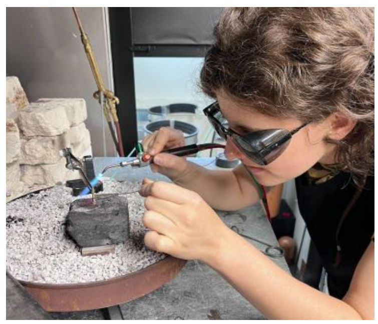

Figure 27. Soldering the replacement screw components together with an oxyacetylene torch.

Figure 28. Matched dimensions of the replacement screw.

[15] Metal polish in paste form consisting of alpha alumina, approximately <4µ to 28µ, in white spirits. Manufactured by Hunting Lubricants and Specialized Products, Ltd., Leeds, UK.
[16] Clear, lightfast pigments bound in Laropal A-81 synthetic urea-aldehyde resin. Dry film remains soluble in mineral spirits and acetate solvents. http://www.conservationcolors.com/tds01.html
[17] Lightfast, low-viscosity acrylic paints with a high pigment load. Manufactured by Golden Artist Colors; available at art stores and from Golden Artist Colors.

Figure 29. Inpainting to match the original screw.

Figure 30. Replacement screw in place (right side), north instrument holder base.

- **Needle**:[18] Mia Kaplan, metalsmith at Night Shift Studio, fabricated a replacement compass needle based on a design that was approved by Ann Wagner. Refer to “Appendix V: Needle Replacement” for a discussion of what this design and construction should entail. The needle was laser cut from 1008 mild steel[19] based on a digital rendering. The cap of the needle was made from 5/16” diameter Ultra-Machinable 360 brass rod.[20] This cap also incorporated a small sapphire set into the underside; the sapphire was provided by Brittany Cox at Memoria Technica. Mia fabricated the needle from these materials (figs. 31-36). I joined the needle to the needle cap with Epo-Tek® 301-2 epoxy resin.[21] When placed on the pivot, the needle spins freely. However, if tilted, the needle can become slightly askew. I coated the needle with Cosmoloid H-80 microcrystalline wax[22] in Shellsol D-38, buffed slightly. To hold the needle in place long-term, I rolled a small piece of Parafilm M[23] to wrap around the base of the pivot. The needle does not move freely in this arrangement. The needle was not magnetized, but this can be pursued at a later date. Additionally, no “north” marker was pursued at this time, but this can also be added at a later date if desired.

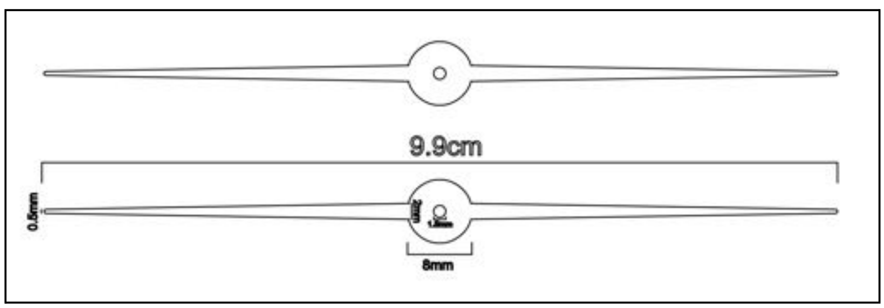

Figure 31. Needle digital rendering. Image courtesy Mia Kaplan.

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[18] Prior to pursuing reconstruction, already fabricated replacements were sought out through personal connections, the National Association of Watch and Clock Collectors (NAWCC) Business Member Directory and the NAWCC “Parts Wanted” online Member Forum.

[19] Purchased online from SendCutSend: Custom Sheet Metal Fabrication, April 2025.

[20] Purchased from McMaster-Carr, April 2025.

[21] Low viscosity epoxy that bonds well to most glass, metals, and plastics. RI=1.564; sets in 18-24 hours and can be sanded in 36-48 hours. Manufactured by Epoxy Technology.

[22] Different from other traditionally used microcrystalline waxes such as Renaissance wax, which are blends, Cosmoloid H 80 is a pure wax and has been proven to have comparably better reversibility (Moffett, D.L., “Wax Coatings on Ethnographic Metal Objects: Justifications for Allowing a Tradition to Wane,” In JAIC 1996, Vol. 35, No. 1, Article 1, pp. 1-7). Available from Kremer Pigments.

[23] Registered trademark for a stretchable plastic film composed primarily of polyolefins and paraffin wax without any added plasticizers; insoluble to water and ethanol and resistant to alkalis and acids for up to 48 hours. Manufactured by American Can Co; available from major chemical suppliers.

Figure 32. Needle, tempered with a torch to around 575°F (300°C), the temperature at which a blue iron oxide layer forms. Image courtesy Mia Kaplan.

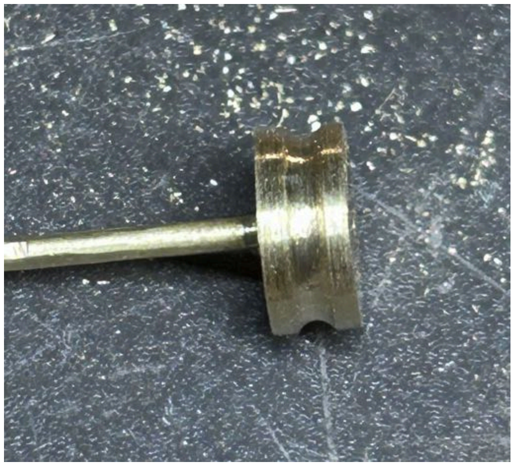

Figure 33. Lathe-turned needle cap. Image courtesy Mia Kaplan.

Figure 34. Needle cap, underside hole for jewel bearing. Mia created the hole with the three tools pictured: a drill bit, ball bur, and baby end mill. Image courtesy Mia Kaplan.

Figure 35. Sapphire flush with the underside of the needle cap. The hole in the center marks the surface where the pivot comes into contact with the needle. The sapphire was provided by Brittany Cox. Image courtesy Mia Kaplan.

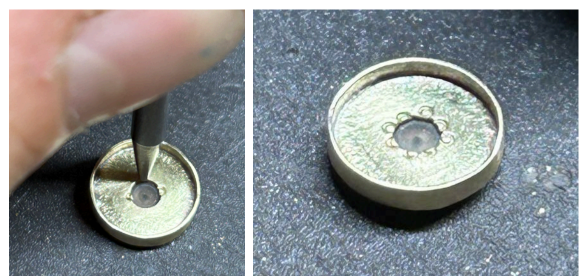

Figure 36. Bead-set sapphire (left image: process; right image: complete), with lip to create a pressure-fit reversible lid attachment between this component and the lathe-turned needle cap. Image courtesy Mia Kaplan.

Figure 37. Needle in place, with cover glass reattached.

8. **Reattached the glass in place with original screws** (0.25 hours).

    ○ I returned the glass to the raised shelf and secured it in place with the cover glass border and two screws. The border was returned to the object with a slightly different orientation to minimize stress on warped areas. I covered a screwdriver with tape to minimize the risk of any surface marks (fig. 38).

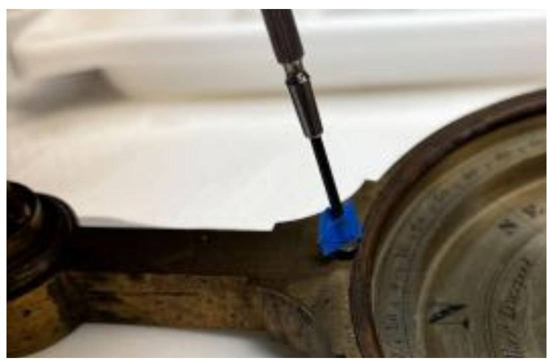

Figure 38. Screwdriver with tape for abrasion protection.

    ○ The cracked glass was arranged to match the original orientation. Ann Wagner determined that the structurally stable cracked glass does not need to be repaired at this time, due to the potential historic origins of the crack.

9. **Fabricated a storage mount** (2 hours).

    ○ I constructed a storage mount out of carved Ethafoam[24] and Volara foam[25] that is suitable for supporting the compass in storage (fig. 39).

[24] Closed-cell, low density polyethylene foam made by injecting halogenated gas (dichlorodifluoromethane) into the polymer melt. Some products may contain stearyl stearamide (1%) as a slip agent, as well as trace amounts of antioxidants and UV absorbers. Manufactured by Dow Chemical Co.

[25] Closed cell plastic foam made from polyethylene. It has a smooth surface that is resistant to water absorption and chemical reactions. Made in various thicknesses and colors. Manufactured by Voltek. Available from conservation and plastics suppliers.

Figure 39. Storage mount.

- A mount design for exhibition was discussed with Ann Wagner, which can be pursued at a later date: “[T]he compass originally would have been stored in a wooden box in a horizontal plane. A wooden base stained to an aged walnut color with the brass rod and an attached barrier layer (mylar or other) is fine. In my humble opinion, painted wood doesn't have the right look or lasting power, but check with Kathy G. and Lauren to see if stain is an option. Essentially the mount should "disappear" as you look at the compass” (Ann Wagner, email communication, April 29, 2025). I illustrated what this potential display mount could look like based on Ann’s current desire for a chamfered or rounded edge for the wooden base (fig. 40). Rick Starr, Furniture Conservation Volunteer, saw a surveying compass wooden mount with a rounded chamfer edge at an auction preview in Pennsylvania (fig. 41-42); while likely more ornate than would be useful, it nonetheless may serve as a helpful reference later on.

Figure 40. Potential mount design with a chamfered edge.

Figure 41. Side view of mount seen at auction. Image courtesy Rick Starr.

Figure 42. Top view of mount seen at auction. Image courtesy Rick Starr.

10. **Completed after treatment photo documentation and report** (3 hours).

Total treatment time: 54.5 hrs

Environmental and Handling Recommendations

In compliance with the Environmental Management Policy at the Winterthur Museum, Garden & Library, the environmental conditions should be maintained approximately within the following margins: 60-77°F, 40-66% relative humidity in summer, 30-55% relative humidity in winter, and a maximum of +/- 10% fluctuations in relative humidity within a 24-hour period. High relative humidity conditions will increase corrosion risk. Leak protection is vital for storage environments, as any moisture enclosed in the compass dial will quickly accelerate and initiate corrosion. As metal is also susceptible to pollutants and off-gassing, this object should not be stored in enclosed areas where this is occurring (i.e. in wooden storage cabinets, around degrading plastic, etc.). Vibrations should be minimized with strategic object housing for transport. Due to the free-standing compass needle and cracked glass, the compass should be maintained horizontally. The object should be elevated when stored to protect it from standing water in the event of a leak. Gloves are essential for handling to minimize the risk of corrosion.

Treated By: Daisy Diamond **Report Date:** May 12th, 2025

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Appendix I: Before Treatment Photography

Figure I-1. Before treatment, side view.[26]

Figure I-2. Before treatment, side view.

[26] Figs. I-1 through I-4 documented with Nikon D850 device, Nikon D series 60 mm focal length, f/16, exposure 1/125. Post-processing included white balance, -0.30 exposure, and cropping.

Figure I-3. Before treatment, overall top.

Figure I-4. Before treatment, overall bottom.

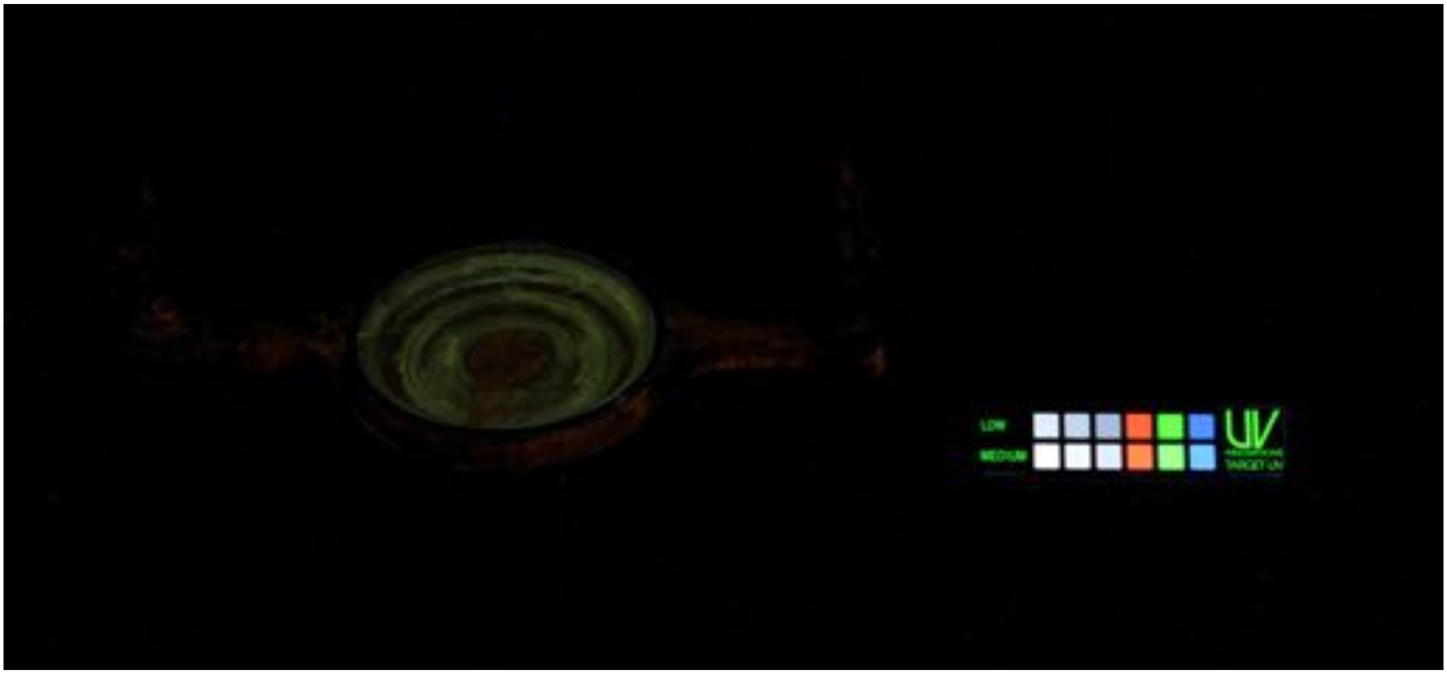

Figure I-5. Before treatment, side view, UVA (long-wave).[27]

Figure I-6. Before treatment, side view, UVB (short-wave).

[27] Figures I-5 and I-6 documented with Nikon D850 device, Nikon D series 60 mm focal length, f/16, exposure 5.” The light source for UVA was long wave UV with peak wavelength of 365 nm +/- 10 nm with the Wildfire UltraBlade ® Single Lamp LED Series UB-42-1. Post-processing for UVA included white balance (medium), +0.50 exposure, highlights -15 to match observed fluorescence, and cropping. The light source for UVB was a Spectro-UV Dual UV Blacklight Lamp – E-Series 365nm & 254nm, 8-Watt Tubes with Filter Assembly P/N ENF-280C, used at 254 nm. Post-processing for UVB included +0.55 exposure, highlights +15, temperature 7850, and tint +12 to match observed fluorescence. Note: there is no color target available for UVB imaging at this time.

Appendix II: After Treatment Photography

Figure II-1. After treatment, side view.[28]

Figure II-2. After treatment, side view.

[28] Figs. II-1, II-2, and II-4 documented with Nikon D800 device, Nikon D series 60 mm focal length, f/18, exposure 1/125. Fig. II-3 documented with Nikon D850 device, Nikon D series 35 mm focal length, f/16, exposure 1/8. Post-processing included white balance adjustment within Adobe Capture Raw to Neutral 8 patch of the X-Rite Color Checker, -0.15 exposure, and cropping.

Figure II-3. After treatment, overall top.

Figure II-4. After treatment, overall bottom.

Appendix III: µ-XRF Results[29]

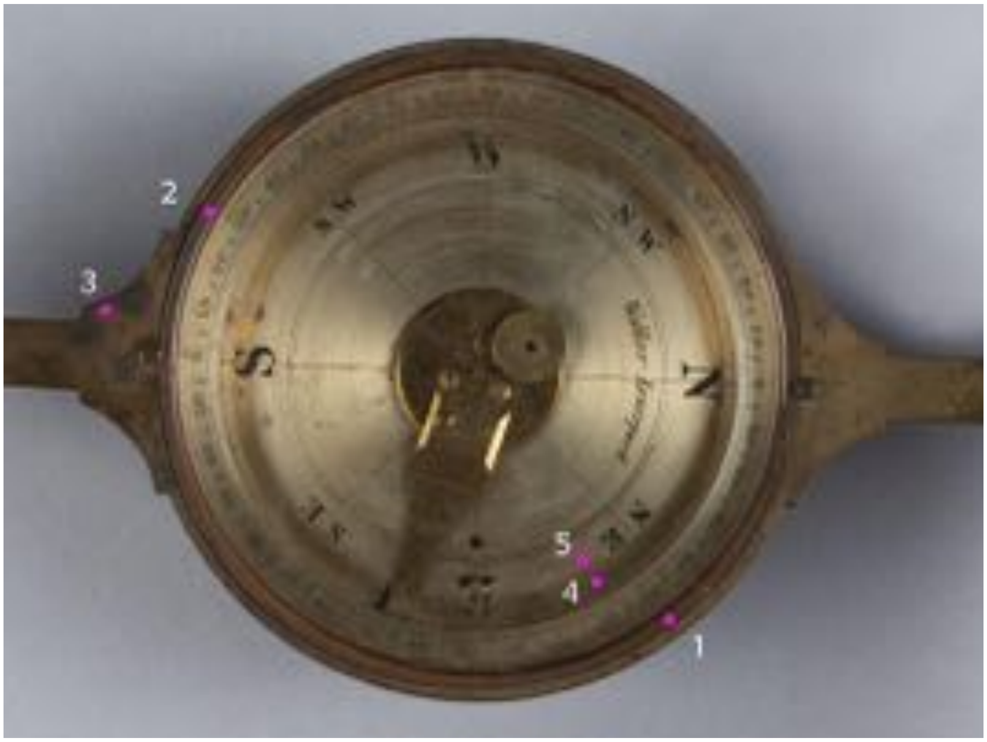

Figure III-1. Analysis locations (cover glass removed for µ-XRF).

Table III-1. Summary of µ-XRF interpretation.

Location #	Description	Elemental information	Conclusion
1	Lower rim under the cover glass border	Cu, Zn, Fe, Ni, Pb, Ca	These components have the same alloy composition.
2	Upper rim		
3	Compass enclosure		
4	Compass dial (abraded)	Cu, Zn, Fe, Ni, Pb, Ca, Ag	The dial is silvered with less silver present on abraded areas. The dial has a different alloy composition than the rest of the compass.
5	Compass dial (non-abraded)		

[29] Non-destructive, qualitative ED-XRF (energy-dispersive x-ray fluorescence) spectroscopy was performed to determine the sample area's elemental composition. Analysis was performed with the ARTAX µXRF spectrometer using a rhodium tube (600µA current, 50kV voltage, 100 seconds live time irradiation, approximately 70-100 micron spot size) with element detection range of potassium (K) to uranium (U). Spectra were interpreted using the ArTAX version 7.4 software; an integrated CCD camera allowed a magnified image of the region of analysis to be acquired.

Spectra

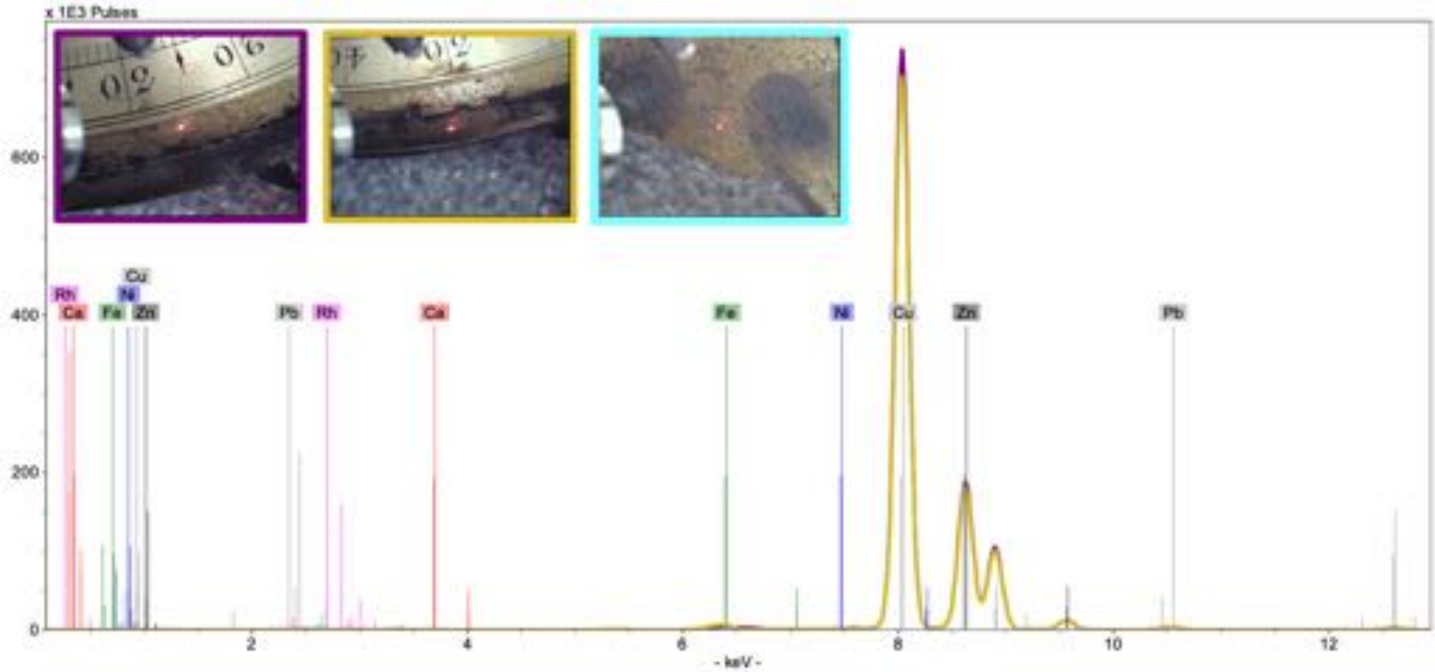

Figure III-2. XRF spectrum of the lower rim (purple, location 1), upper rim (dark yellow, location 2), and enclosure (cyan, location 3).

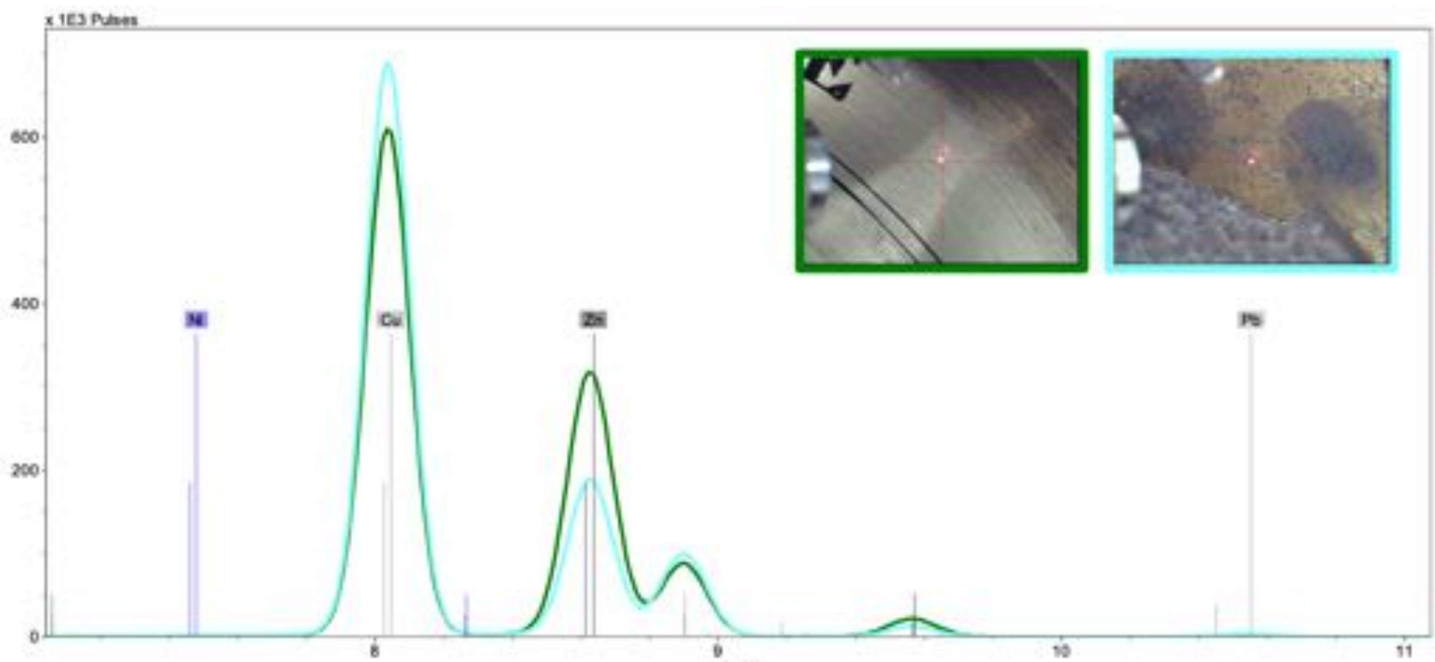

Figure III-3. Select region of the XRF spectrum of the dial (green, location 5) and enclosure (cyan, location 3).

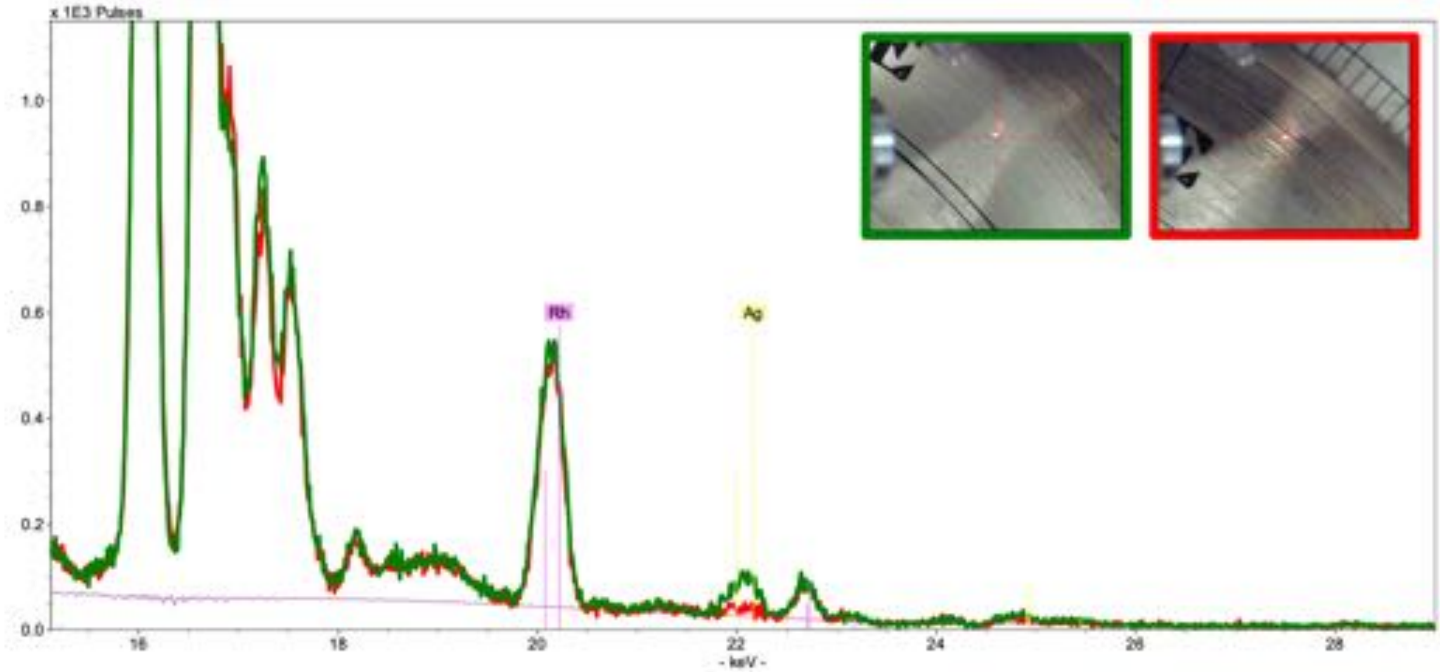

Figure III-4. Select region of the XRF spectrum of the non-abraded region of the dial (green, location 5) and the abraded region (red, location 4).

Appendix IV: X-Radiography[30]

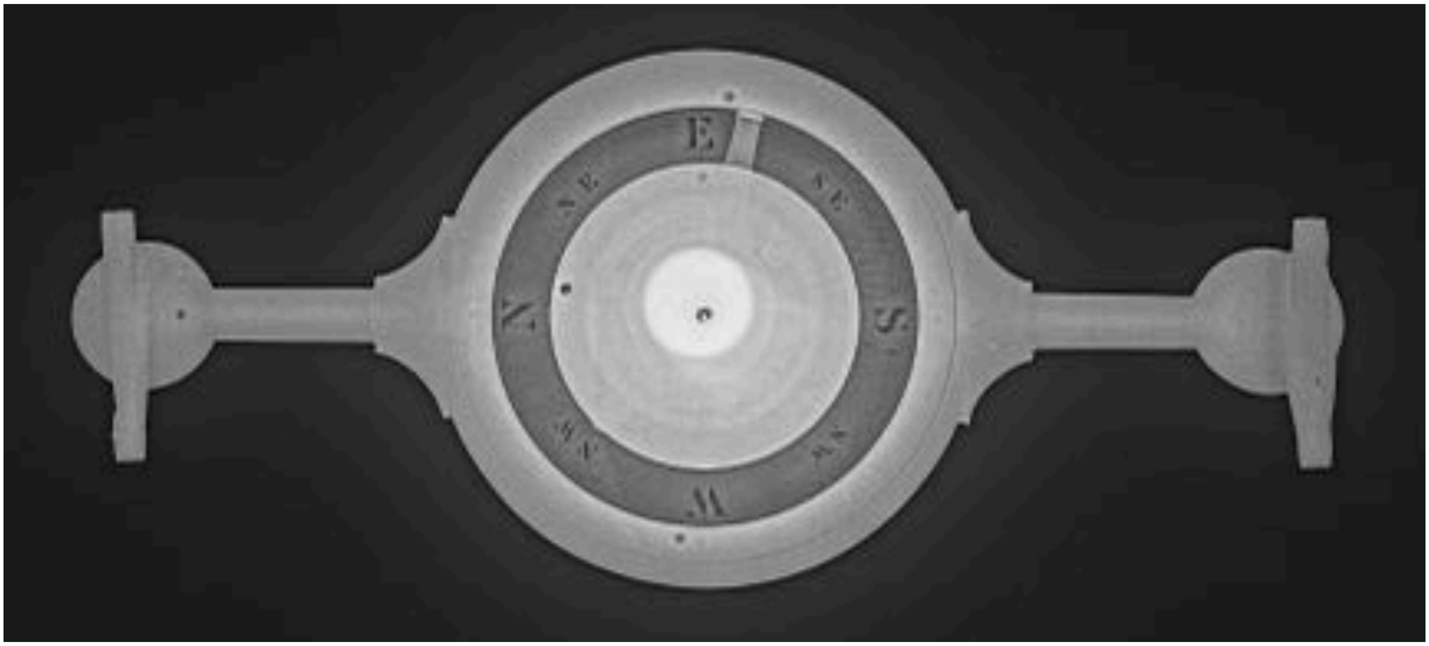

Figure IV-1. X-radiograph. Image captured in collaboration with Lauren Fair, March 2025.

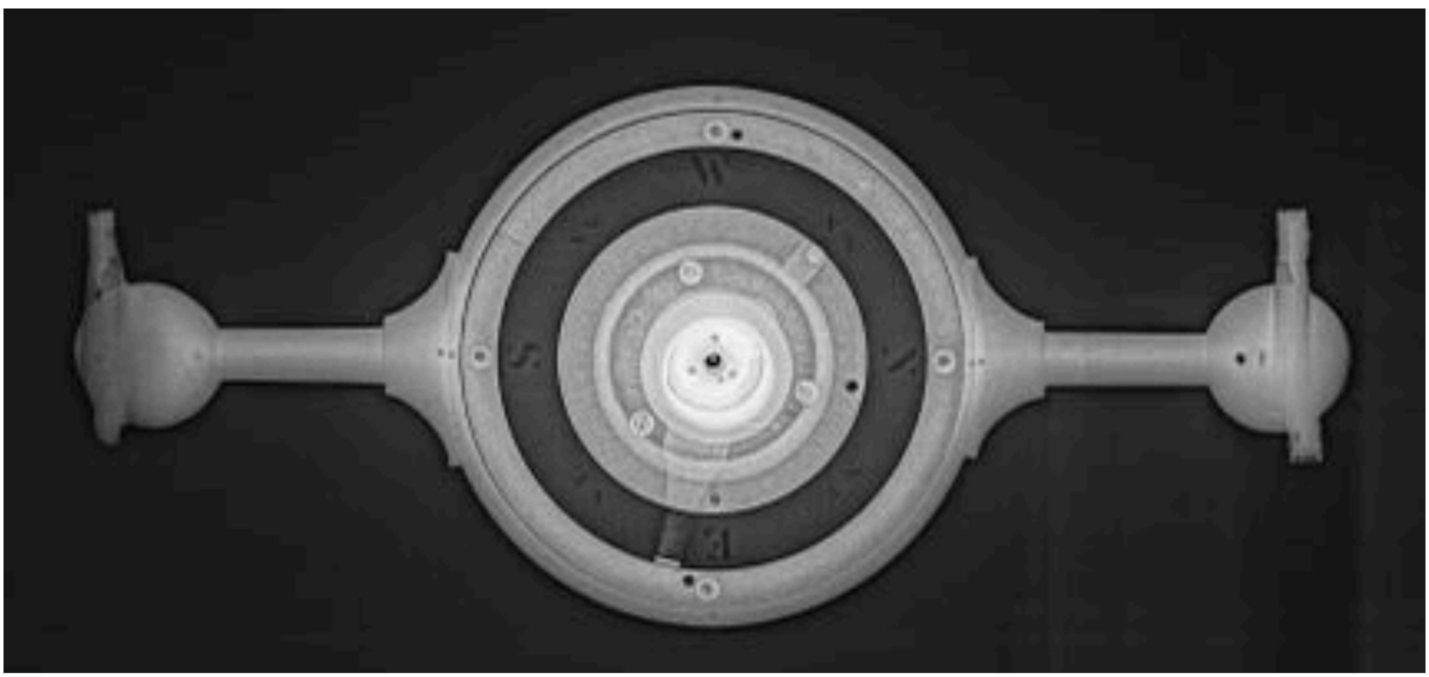

Figure IV-2. X-radiograph with GE Rhythm Review Flash! filter. Image captured in collaboration with Lauren Fair, March 2025.

[30] The compass was imaged with X-ray radiation with a Pantak-Seifert Eresco 65 MF2L with digital control (80kV, 4mA, 3mm focal spot) with an imaging plate underneath the object for an exposure time of 60 seconds. CrxVision Versatile Computed Radiography (CR) Tabletop Scanner with IPS Phosphor Imaging Plates read and digitized the latent image from the plate. The GE Rhythm Acquire software acquired scans and the GE Rhythm Review Flash! filter (GE Rhythm Review Software) was applied to optimize the brightness, contrast, and definition of Figure IV-2.

Appendix V: Needle Replacement

To create a magnetized compass needle, steel must be filed to shape, a sharp stone must be embedded into the needle as a jewel bearing to rest atop the pivot, and the metal must be magnetized. The compass clearance between the needle and the glass should be such that there's not enough room for it to fall off (Brittany Cox, personal communication, January 13th, 2025). The steel needle could be filed to shape. Brittany Cox provided a pre-formed and polished sapphire for use as the jewel bearing. The jewel can be drilled to accommodate the tip of the pivot. This bearing can be measured and a hole of identical diameter drilled within the underside of the needle, and the sapphire can be set with HXTAL NYL-1 Epoxy Adhesive or with a stone setting technique. A magnetizer can be used to generate a magnetic field within a piece of steel. Three compasses in the Winterthur Museum collection served as approximate visual comparanda. The steel needles are blackened or blued, extend within 1 mm of the raised chapter ring, northern markers with either a small cross or a wrapped brass-colored wire, and variable central mounts (figs. V-1 to V-6). The needles are fixed in place, except for 1969.2041A, which quivered slightly and was restrained due to its similar length in comparison to the inner diameter of the chapter ring.

Figure V-1. Surveying compass made by Isaac Chandlee (Chester, PA). 1790-1813. Image courtesy Winterthur Museum (2003.0054).

Figure V-2. Close up image of 2003.0054.

Figure V-3. Surveying Compass, Field Case, and Box made by Frederick Augustus Heisely Jr (Dauphin, PA). 1820-1836. Image courtesy Winterthur Museum (2010.0042.001).

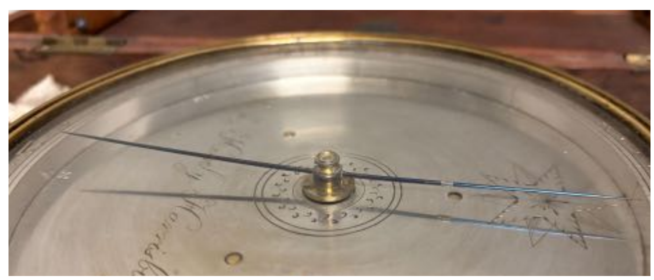

Figure V-4. Close up image of 2010.0042.001.

Figure V-5. Surveying compass made by Henry Shuttleworth (London, UK). 1780-1798). Image courtesy Winterthur Museum (1969.2041A).

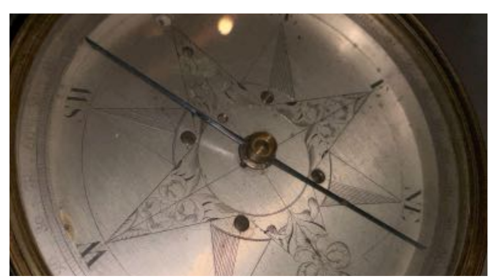

Figure V-6. Close up image of 1969.2041A.