The AIC Paintings Specialty Group

POSTPRINTS

VOLUME TWENTY-EIGHT 2015

Papers Presented at the 43rd Annual Meeting of the
American Institute for Conservation of Historic and Artistic Works
Miami, Florida, May 13–16, 2015

Compiled by Barbara Buckley

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Paintings Specialty Group Sessions

JOANNA R. DUNN

The Treatment of *Dr. William Hartigan* by Gilbert Stuart or the Treatment of Gilbert Stuart by Dr. William Hartigan

ABSTRACT

The article discusses the fairly complicated treatment of a portrait by Gilbert Stuart. Several questions arose during treatment including whether the format of the composition should be oval or rectangular and whether a bell jar in the background was meant to be visible or if Stuart had painted it out himself. Three copies of the painting, its history, and scientific analysis helped inform the treatment choices. In the end, despite these resources, the decisions remained educated guesses, as is so often the case in conservation treatments.

1. INTRODUCTION

The story of the portrait of *Dr. William Hartigan* by Gilbert Stuart in the collection of the National Gallery of Art (fig. 1) is an interesting one, fraught with a number of mysteries. Its history and ambiguities were brought to light when the painting was treated as part of a project funded by a generous grant from the Bank of America Foundation in 2012.

Figure 1. Gilbert Stuart, *Dr. William Hartigan,* National Gallery of Art, oil on canvas, 30 × 25 in. (76.2 × 63.5 cm.), before treatment with cleaning windows

The painting's story begins in the late 18th century when Gilbert Stuart, who is sometimes referred to as "America's old master," was in a stagecoach accident. His right arm was injured and became infected. The doctor treating Stuart wanted to amputate it. As a right-handed artist, this was completely devastating to him. Upon hearing of the plan to amputate, an acquaintance of Stuart's, who was a doctor, but not Stuart's treating physician, asked for the opportunity to try save Stuart's arm. Supposedly, he bathed the arm in fresh, cold water constantly to clear the infection. The treatment worked and Stuart was so grateful that he painted the doctor's portrait as an expression of his gratitude (Oliver 1914).

There is some disagreement about the location of the accident and the name of the doctor. Some argue that the incident occurred in New York, but most believe that it took place in Edinburgh or Dublin (Tuckerman 1966, 108).[1] By 1846, the painting was in the collection of the 19th-century American painter, Charles Loring Elliot. At that time, the sitter was unidentified, but in 1856, when the painting was in the collection of Abraham M. Cozzens, the sitter was recorded as "Dr. Houghton" of Dublin, of whom not much is known. In 1881, collector and dealer Charles Henry Hart began searching

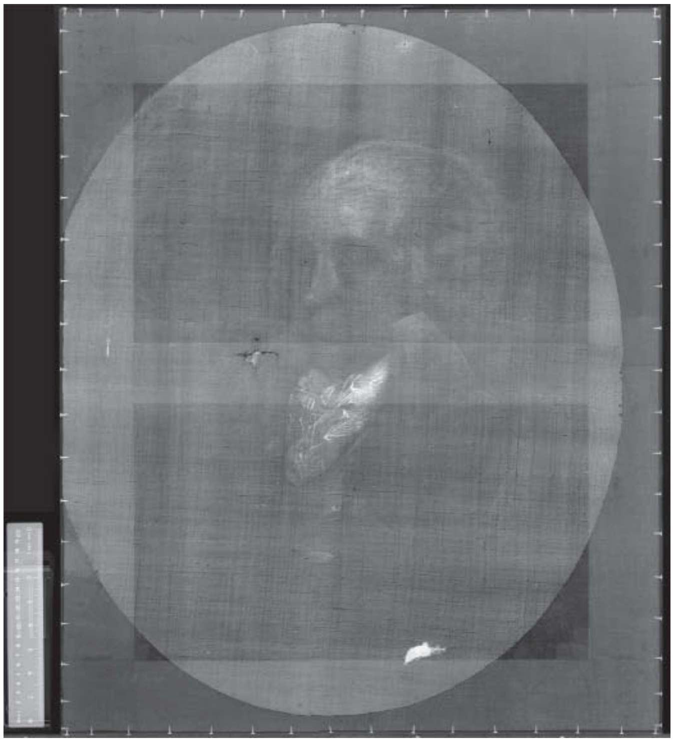

Figure 2. Gilbert Stuart, *Dr. William Hartigan,* National Gallery of Art, x-ray radiograph composite

for the painting. His search led him to a descendent of the sitter, Lucie Lull Oliver (Miles 1995, 180). In a letter from 1914, Oliver told Hart the story of the accident and identified the sitter as Dr. William Hartigan, a surgeon and professor of anatomy at Trinity College in Dublin, Ireland, in the late 18th century (Oliver 1914). On the basis of the account of the sitter's descendent, it can be concluded that the sitter is Dr. Hartigan and that the accident actually took place in Dublin.

Unfortunately, Hart died before he located the painting, but Thomas B. Clarke continued the search and eventually found it in the Sturges collection. Clarke acquired it in 1921 and, eventually, the painting made its way to the collection of Andrew Mellon, who donated it to the National Gallery of Art (Miles 1995, 179–80).

Before the treatment, a yellow varnish and a good deal of discolored retouching obscured the painting. The retouching extended from all four corners into the background of the painting. Close examination of the painting and its x-radiographs (fig. 2) indicated that at some point in its history, the original support fabric was actually cut into an oval and then lined onto a rectangular canvas, with inserts in the corners. The restorer painted the added spandrels and overpainted a good deal of the background, probably to blend in the corners. A later restoration campaign had added more retouching to the joins between the original and added fabrics. It was obvious that the spandrels were not original, but it was unclear if Stuart originally painted the composition as an oval or not. Interestingly, the painting was not centered on the lining fabric so the oval was cut off on the left side.

The shape of the original composition, and its off-center lining were more mysteries that would need to be solved during the treatment. Unfortunately, although the painting was written about a fair amount when it was in the collection of Charles Loring Elliot, no one described the shape of the painting. One thing that is clear is that the original canvas would have been a rectangle. Stuart is known to have painted oval compositions on rectangular canvases, such as the portrait of Luke White (fig. 3), which was also treated as part of the Bank of America project, and the Saltram-house portraits (Cross and Brummit 2011).

As the discolored varnish and restoration paint were removed from the portrait of *Dr. William Hartigan*, an object started to appear in the background to the left of the sitter (fig. 4). It looked like some type of medical equipment. Deborah Warner, curator of physical sciences at the American History Museum, agreed that it appears to be a type of large bell jar of the sort

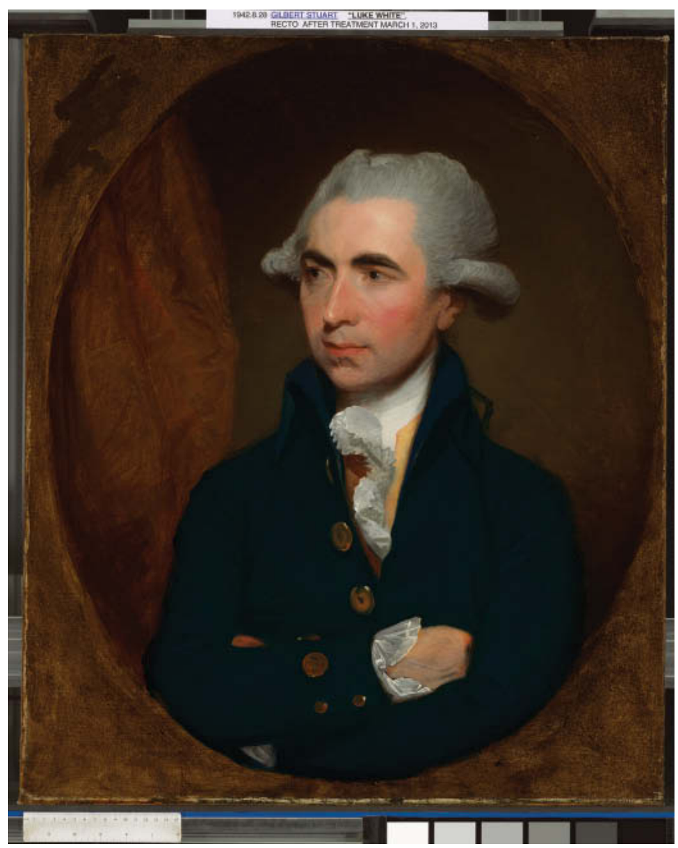

Figure 3. Gilbert Stuart, *Luke White*, National Gallery of Art

Figure 4. Gilbert Stuart, *Dr. William Hartigan,* National Gallery of Art, before inpainting

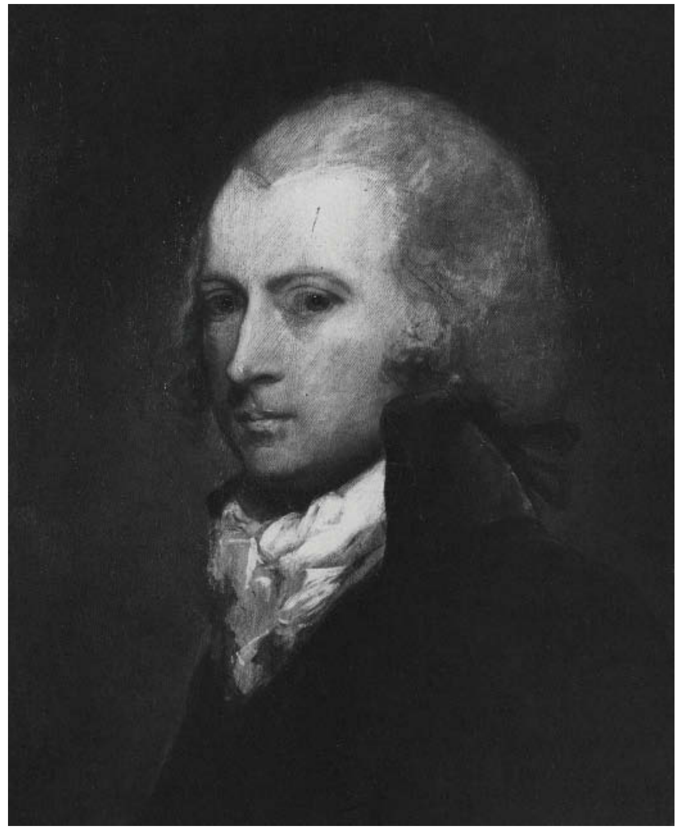

Figure 5. Unknown artist, *Dr. William Hartigan*, oil on panel, 24 × 18 3/8 in. (60.9 × 46.6 cm.), private collection, Washington, DC

used with an air vacuum pump in the late 18th century. This supports the theory that the sitter is Dr. Hartigan, but why did Stuart include this object? It does not add to the composition and it is not particularly attractive. Was it used in the treatment of Stuart's arm? Also, it appeared somewhat obscured. There was a layer of transparent greenish-colored paint, similar to that of the background, over the black paint used to create the bell jar. Did Stuart start to include the bell jar and then decide to paint it out? Or did he mean for it to show?

Michael Palmer, National Gallery of Art conservation scientist, took cross sections from the area of the bell jar and the general area of the background. Scanning electron microscopy[2] showed that the pigments used in the layer of paint that directly covers the bell jar were the same as those used in the rest of the background, which means Stuart probably added the layer of paint that sits directly on top of the bell jar. In addition, there weren't any layers of varnish or dirt between the black paint of the bell jar and the layer of paint directly on top of it. This means that no significant amount of time passed before the layer of paint was applied to cover the bell jar. The cross-section showed there was additional brown overpaint over a layer of varnish on top of the transparent greenish paint. Removal of the overpaint and varnish layers made the bell jar more visible, yet still somewhat obscured by the translucent greenish paint, which Stuart apparently applied. It remained unclear if that paint had become more transparent over time or if it had been abraded or if the bell jar was always meant to be partially obscured.

Fortunately, there are three known copies of the painting, which could help answer these questions. One of the copies is in a private collection in Washington, DC (fig. 5), one is in the collection of the Munson Williams Proctor Arts Institute (fig. 6), and the third is on long-term loan to the Baltimore Museum of Art (fig. 7). It is curious that the painting was copied so many times when the sitter was not one of Stuart's particularly notable ones like *George Washington*. The reason lies in the painting's fascinating history.

According to Henry T. Tuckerman's *Book of the Artists: American Artist Life Comprising Biographical and Critical Sketches of American Artists*, first published in 1867, the doctor's son gave the painting to a friend, an unnamed British artist. Somehow, that artist and the painting ended up in upstate New York. After the artist died, his widow traded the painting to Charles Loring Elliot, in exchange for a portrait of her family. Elliot knew the painting was by Gilbert Stuart and treasured it as such. According to

Figure 6. Charles Loring Elliot after Gilbert Stuart, *Dr. William Hartigan*, oil on canvas, 28 × 23⁵/₈ in. (71.1 × 60 cm.) Dr. David R. Rosendale Bequest, Munson-Williams-Proctor Arts Institute, Utica, New York

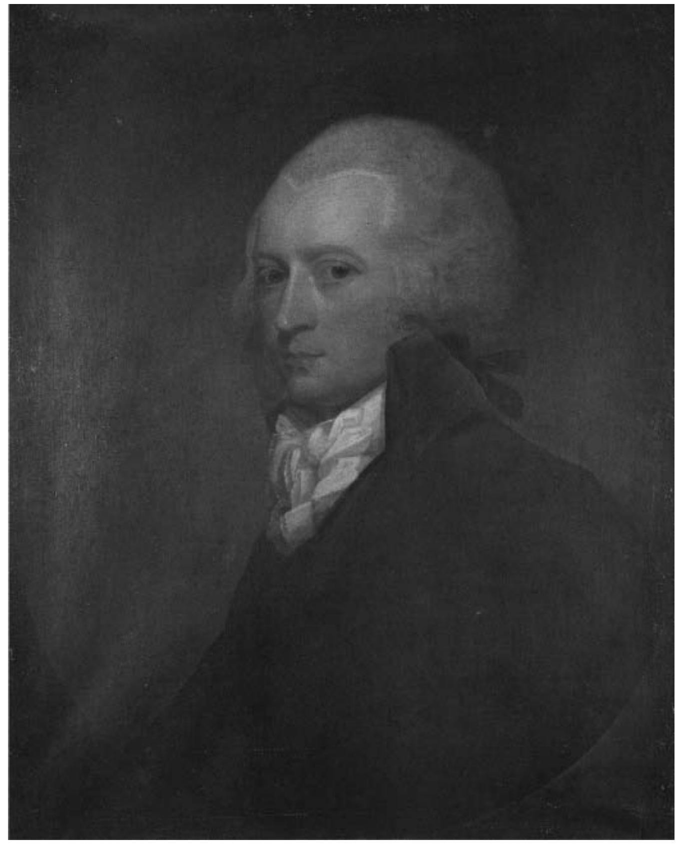

Figure 7. John Paradise (Amrerican, 1783–1833), *Dr William Hartigan, Irish Surgeon* [1756–1812], n.d., oil on canvas, 30 × 24 1/4 in. (76.2 × 61.6 cm.), The Baltimore Museum of Art: The Peabody Art Collection. Collection of the Maryland State Archives. MSA SC 4680 10 0077, BMA L. 1964.1.13

Tuckerman, "He made a study of his trophy; it inspired his pencil; from its contemplation he caught the secret of color, the breadth and strength of execution which have since placed him among the first American portrait-painters, especially of old and characteristic heads" (Tuckerman 1966, 305).

Both Thomas Bangs Thorpe, in his 1868 book *Reminiscences of Charles L. Elliot, artist*, and Tuckerman tell an interesting story about our painting. Apparently Elliot got into debt and an acquaintance who admired the Stuart painting bought his debts with the painting as collateral. When Elliot could not pay, a constable came to seize the painting; however, Elliot was prepared for him, and he had made a copy to give him instead, keeping the original for himself. The copy was so good; he fooled the constable and his creditor. A few months later, the acquaintance learned of the trick, but by then it was too late (Thorpe 1868, 7).

One of the three copies mentioned previously, was probably the one made by Elliot, and it was most likely the one in the collection of the Munson Williams Proctor Arts Institute for several reasons. First, the provenance indicates that the painting was always in New York, home of Charles Loring Elliot. Second, it is also the most similar in style to other paintings by Elliot, such as portrait of *William Sydney Mount* from the National Gallery of Art's collection (fig. 8). The smooth blending of the paint in the sitter's face is similar in the two paintings, as are the rough brushstrokes in the background, and the way the artist executed the highlights. The execution of the highlights also differs from Stuart's in the portrait of *Dr. William Hartigan* in a few areas such as the sitter's collar. In addition, the Munson Williams Proctor Arts Institute copy is the most like the original of all the copies, which would make sense since Elliot was trying to fool his creditor. The brushstrokes in the hair, cravat, and face are almost identical.

As for the other copies, the family of the sitter probably commissioned the one in the private collection in Washington, DC. It used to be in the collection of Clifford Kaye in Brookline, Massachusetts. In the same collection at the same time, there was also a copy of the National Gallery of Art's portrait of *Richard Yates* by Gilbert Stuart. Dr. Hartigan was married to Anne Elizabeth Pollack, who was a member of the Yates family. Both the copy of Richard Yates and the one of *Dr. William Hartigan*

Figure 8. Charles Loring Elliot, *William Sydney Mount*, National Gallery of Art

were smaller than the originals and both were executed on scored mahogany panels (Miles 1995, 181–2). These copies were probably by the same artist. They were likely commissioned by the descendants of the sitters, so each person could have a likeness of their relative, a practice that was not uncommon.

Not much is known about the third copy, which is currently on loan to the Baltimore Museum of Art. The unnamed British artist whose widow traded the Stuart painting to Charles Loring Elliot may have executed it, though it has been attributed to John Paradise.

The copies were consulted to help with the treatment decisions. One of the questions about the National Gallery of Art painting was whether or not the composition was originally in an oval format. As described previously, the canvas would have been rectangular but the design may have always been an oval. The Washington, DC, copy is a cropped version of the original, so it does not yield any information about the shape of the original composition. The Baltimore canvas is a rectangle and unfortunately, the painting is covered with facing tissue, so only an old photograph could be consulted, but in the photograph, it looks as though the composition is an oval. The Charles Loring Elliot copy is an oval, but closer inspection revealed that the paint extended onto the tacking margins, indicating that the painting had actually been cut down. The evidence that it was cut down, did not indicate if it was cut from an oval or a rectangle originally, just that it was formerly larger than it is now. On the basis of the fact that the Elliot copy is an oval and it looks as though the Baltimore copy is an oval as well, it was concluded that the painting was also probably an oval composition on a rectangular canvas.

The next question that had to be addressed was whether Stuart intended for the bell jar to show. If so, the treatment should allow it to remain visible. Following this logic, if Stuart was the one who painted out the bell jar, it should be toned it out again. Again the Washington, DC, copy is too small, so the bell jar would have been cropped out. The bell jar is not visible in the photo of the Baltimore copy, but it is visible in the Elliot copy.

If the theory regarding the origin of the three copies is correct, then the Elliot copy is the most recent one, so why is it the only one that shows the bell jar? If a later restorer painted the bell jar out, one would expect the earliest copy to show it, not the latest one.

Since the paint covering the bell jar is the same as the paint in the background, another possible scenario is that Stuart originally painted the bell jar, and then decided he did not like it and painted it out. Then the paint may have become more translucent with age or a restorer may have cleaned it overly aggressively, allowing the jar to show again. When the Baltimore copy was made, the bell jar may not have been visible, but by the time Elliot made his copy, approximately 50 or 60 years after the painting was first executed, the bell jar could have become visible.

A third possibility is that the bell jar was always slightly visible, but the copyist of the Baltimore painting did not like it and therefore did not include it. It is also possible that the bell jar is actually present in the Baltimore copy, but just not visible in the available photograph. Since Elliot was trying to fool his creditor, he would have had to include the bell jar whether or not he thought it belonged in the composition.

An interesting fact about the bell jar in the National Gallery of Art painting is that if it is covered up, the way the last restorer did, the composition becomes centered on the rectangular lining canvas, even though the oval is offset. Because of the bell jar, the sitter was positioned to the right of the center of the oval. When the painting was lined, the restorer probably put the oval off to the left so that he could center the sitter, then he covered the bell jar.

In the end, the painting was framed as an oval and the bell jar remains visible (fig. 9). The oval format was chosen because it looks as though the Baltimore and Elliot copies were oval and because the spandrels were not original. The bell jar remains visible because it makes sense in the oval composition, because it may relate to the sitter, and because there was not strong evidence that Stuart was trying to cover it completely.

Figure 9. Gilbert Stuart, *Dr. William Hartigan,* National Gallery of Art, after treatment

Although the copies and the painting's interesting history could not answer all of the treatment questions definitively, they certainly aided in the decision-making process.

ACKNOWLEDGMENTS

I would like to thank Lance Mayer, Gay Meyers, Ellen Miles, Nancy Anderson, Deborah Chotner, and Michael Swicklik for sharing their invaluable knowledge about Gilbert Stuart; Michael Palmer for analyzing samples; Sarah Fisher and Jay Krueger for giving me the opportunity to work on this project; and the Bank of America Foundation for their financial support.

NOTES

1. Tuckerman, 108. Although Gilbert Stuart is a famous American artist, in the early part of his career he travelled to Edinburgh, Dublin, Paris, and London where he studied with Benjamin West, before returning to America to make a name for himself.
2. Paint chips excised from the painting were embedded in Ward's Bio-Plastic and subsequently ground and polished at right angles to the layering to prepare the samples as cross sections. The cross sections were examined using a Leica DMRX polarizing light microscope configured for reflectance observations using 10x eyepieces in conjunction with Fluotar 10x, 20x, and 50x objectives. An ultra high-pressure mercury lamp and Leica filter cubes D and I3 were used for fluorescence examinations. All observed fluoresce was of the primary type; that is, no stains were used to induce fluorescence. A high-pressure halogen lamp was for all nonfluorescent examination of the cross sections. The Bio-Plastic blocks containing the cross sections were mounted onto aluminum stubs using carbon tape and analyzed in an uncoated state using a Hitachi S-3400N variable pressure electron microscope fitted with an Oxford Instruments X-max detector and AZtec x-ray spectrometer. An accelerating voltage of 20 kV was used at a working distance of 10 mm at a chamber pressure setting of 30 Pa. SEM imaging was carried out in backscattered electron mode. Elemental profile data were collected in both point and ID mode (i.e., spot analysis) and element mapping.

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THIS ARTICLE HAS NOT UNDERGONE A FORMAL PROCESS OF PEER REVIEW.

KELLY KEEGAN and INGE FIEDLER

Rediscovering Renoir: Materials and Technique in the Paintings of Pierre-Auguste Renoir at the Art Institute of Chicago

ABSTRACT

Recent examinations of the Art Institute's 15 Renoir paintings for the online catalog Pierre-Auguste Renoir: Paintings and Drawings at the Art Institute of Chicago, *provided the opportunity to study the artist's technique and materials over much of his career, especially the 1870s and 1880s. Each painting underwent an in-depth systematic examination with technical imaging, and the pigments and grounds were analyzed. Renoir utilized a variety of supports and methods of paint handling, but was somewhat consistent in his palette. These findings will be illustrated and placed within the context of previous studies for a fuller understanding of Renoir's artistic practice.*

I. INTRODUCTION

The Art Institute of Chicago's 15 paintings by French Impressionist Pierre-Auguste Renoir (1841–1919) are some of the collection's most popular works. Between 2009 and 2013, the paintings were systematically examined for the online catalog *Pierre-Auguste Renoir: Paintings and Drawings at the Art Institute of Chicago* (Groom and Shaw 2014). This provided the opportunity to study the artist's technique and materials over much of his career, concentrating on the 1870s and 1880s, including the influence of his early training as a porcelain painter, his material experimentation and style change after his travels in the early 1880s and the possible effect of rheumatoid arthritis on his working method late in life.

The paintings, executed from 1875 to 1883, in 1899/1900 and 1914, were each given an in-depth technical examination and imaged, including x-ray radiography; infrared reflectography; transmitted light, transmitted infrared, ultraviolet and raking light photography; and photomicrography. Technical images were systemized in their capture and fully registered to provide multilayer overlays for more precise comparison and detection of compositional changes. The x-ray radiographs were processed using Thread Count Automation Project (TCAP) software to determine individual thread counts, and allow for possible identification of count and weave-pattern matches (Johnson, et. al. 2009). Additionally, the weave-angle maps generated by TCAP software provided information, via cusping patterns, about canvas preparation and stretching. The materials (primarily the paint and grounds) were analyzed using a variety of techniques including x-ray fluorescence spectroscopy (XRF) and scanning electron microscopy coupled with energy dispersive x-ray spectroscopy (SEM/EDX). Cross sections were taken from both the compositional area and the tacking margins where possible, for ground and pigment analysis, paint stratigraphy and microscopic fiber identification. A series of scraping samples from the early 1970s, related to the seminal Renoir exhibition at the Art Institute in 1973 (Butler 1973) were reexamined with polarized light microscopy (PLM). Some samples were additionally analyzed with Raman spectroscopy and select red lakes were analyzed with surface-enhanced Raman spectroscopy (SERS).[1]

II. SUPPORTS

Recent analysis of Renoir's supports confirmed previous accounts of the artist's preference for standard-size canvases (Bomford et. al. 1990, Burnstock, Van den Berg, and House 2005) as all 15 supports appear to be or approximate a standard size (Table 1), and most of them are the squarer *figure*, or portrait format. In two cases, Renoir may have adjusted his compositions to fit a standard size. The account Jean Renoir gave of his father late in life, saying the artist "had in mind antique picture frames which he admired so much, as they usually correspond to the standard stretchers," suggests the preference for standard sizes was long-held (J. Renoir 1962, 363). In terms of the canvases themselves, microscopic fiber identification and TCAP analysis revealed that Renoir preferred medium-weight linen, with an overall thread count average of 23 threads/cm. TCAP software allowed for identification of commercial and artist-stretching patterns on all 15 canvases, however no thread count or weave matches were found.[2]

Table 1 Canvas supports

Title	**Year**	**Current Dimensions (cm)**[a]	**Standard size**[b]	**Supplier's Mark (location)**	**Thread Count V × H threads/cm (standard deviation)**[d]
Lunch at the Restaurant Fournaise (The Rower's Lunch)	1875	55 × 65.9	*figure* 15	Deforge Carpentier (canvas verso)	22 (0.9) × 23.9 (0.8)
Woman at the Piano	1875/6	93 × 74	*figure* 30	–	22.4 (0.8) × 26.1 (0.5)
Alfred Sisley	1876	66.2 × 54.8	*figure* 15	Rey & Cie (canvas verso, stretcher)	22.6 (0.7) × 16.8 (1.3)
The Laundress	1877/79	81 × 56.4	*marine* 25 *basse?*	–	16.4 (0.7) × 13.8 (0.4)
Young Woman Sewing	1879	61.4 × 50.5	*figure* 12	Rey & Perrod (canvas verso)	29.8 (0.5) × 24.9 (1.2)
Seascape	1879	72.6 × 91.6	*figure* 30	–	30.2 (0.7) × 24.3 (0.9)
Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg)	1879	131.2 × 99.2	*figure* 60	–	28.1 (1.2) × 29.4 (0.6)
Near the Lake	1879/80	47.5 × 56.4	*figure* 10	P: Aprin (canvas verso)	26.0 (0.9) × 29.9 (0.6)
Two Sisters (On the Terrace)	1881	110.4 × 80.9	*figure* 40	P: Aprin (canvas verso)	30.9 (0.8) × 25.9 (1.1)
Fruits of the Midi	1881	51 × 65	*paysage* 15	–	22.8 (0.7) × 23.0 (1.1)
Crysanthemums	1881/2	54.8 × 65.8	*figure* 15	Rey & Perrod (canvas verso)	29.7 (0.7) × 27.3 (0.9)
Lucie Berard (Child in White)	1883	61.3 × 49.8	*figure* 12 *haute*	–	19.8 (0.5) × 15.3 (0.7)
Madame Léon Clapisson	1883	81.2 × 65.3	*figure* 25	–	21.7 (0.8) × 21.6 (0.5)
Jean Renoir Sewing	1899/1900	55.4 × 46.3	*figure* 10	[Troigros Frères][c] (original stretcher)	20.1 (0.5) × 16.4 (0.6)
Seated Bather	1914	81.1 × 66.5	*figure* 25	–	16.8 (0.3) × 12.0 (0.5)

a. Small discrepancies between the current measurements and standard sizes may be a result of this approximation, in addition to restretching, lining, slacking, and keying out of the canvas over time. It should also be noted that the dimensions of many lined paintings were extended as part of the lining process.

b. Standard sizes available from Bourgeois Aîné in 1888, reproduced in Bomford, et. al (1990, 46, fig. 31); and those from Lefranc & Cie in 1889 reproduced in Callen (2000, 15, fig. 24).

c. A transcription in the Conservation Object file contains the address 35 Rue Victor Mosse. The identification of Troigros Frères is based on this address (Constantin 2001, 66).

d. Weave information determined by TCAP software. For thread count reports for individual paintings, see Groom and Shaw 2014. For information on TCAP, see Johnson, et. al. 2009.

The artist adjusted the dimensions of two of the Art Institute paintings during their execution. Cusping seen in the x-ray radiograph and TCAP-produced weave-angle maps for *Woman at the Piano* (1875/6, 1937.1027) suggests an original size close to a *figure* 30 (92 × 72 cm). Its current dimensions are somewhat larger, as they were expanded during a previous treatment, leaving a small margin of unpainted canvas around the perimeter, and exposing what appears to be a section of partially painted composition. Additionally, the right edge appears to have been extended and is now heavily retouched. The unevenness of the edges suggests that Renoir began the work off the stretcher or on a larger secondary support and later stretched it to a standard size. The artist appears to have lined up the painting for stretching on a standard stretcher by

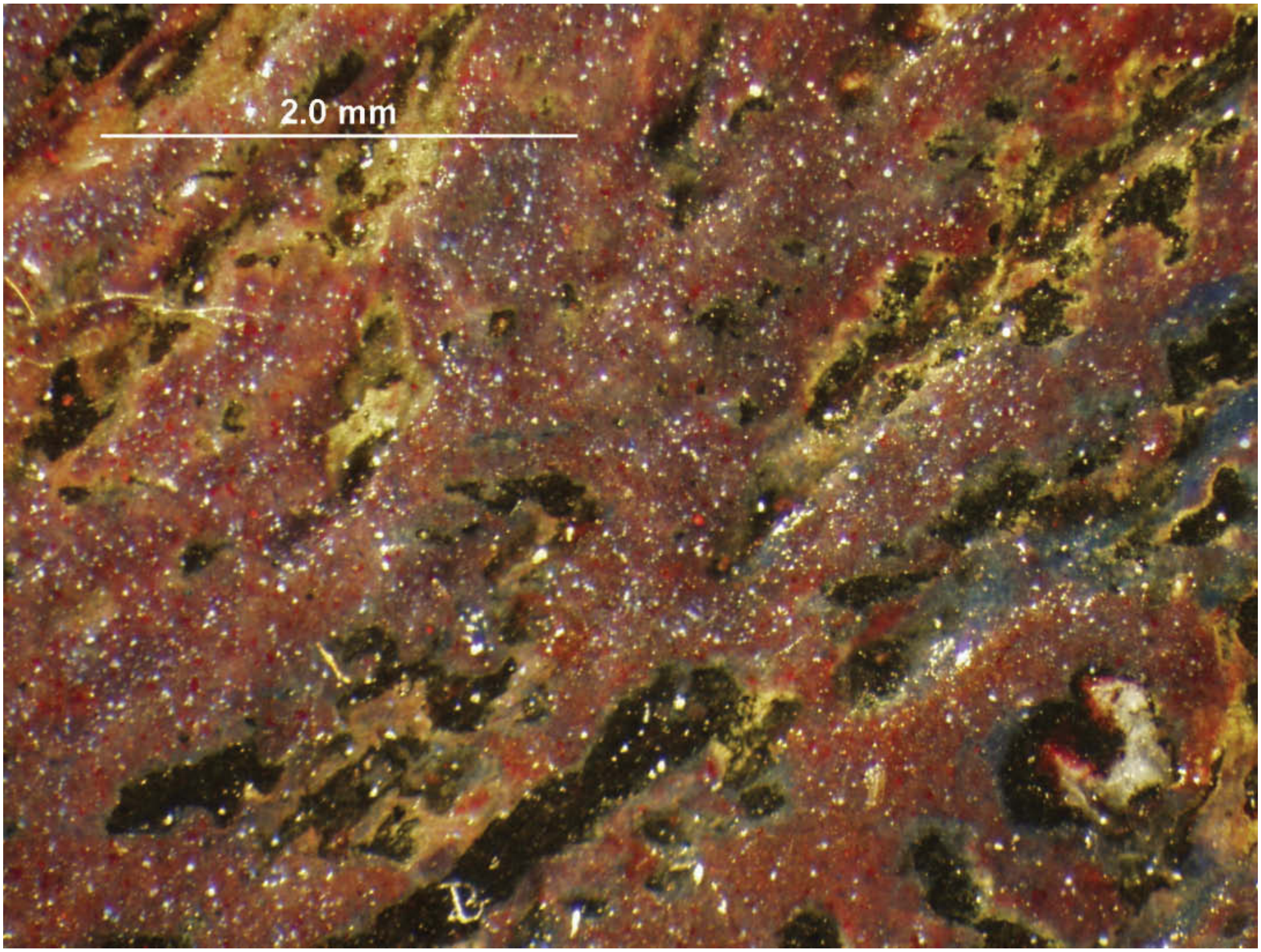

Figure 1. Photomicrograph of the piano with artist scraping in *Woman at the Piano,* 1875/6, oil on canvas, 93 × 74 cm. The Art Institute of Chicago 1937.1025. Courtesy of the Art Institute of Chicago

the left side, folding over a small portion of the scraped-back, dark-red piano paint at the right. This scraped back paint appears to coincide with the earlier version of the composition in which the piano was portrayed at a slightly different angle, and evidence of this scraping is visible amid skips in the upper paint layers of the second version (fig. 1). Lining up the canvas by the left edge and stretching to this size also required Renoir to add a narrow triangle of background paint to the bottom edge at left and the top at right to square the composition.

In the case of *The Laundress* (1877/79, 1947.102), the situation is more complicated as the current measurements closely approximate a standard-size, but there is evidence that the dimensions have changed. The painting is lined but appears to retain its original stretcher and the tacking margins are largely obscured by paper tape. Unclear edges and individual brushstrokes that pass onto the tacking margins also complicate an assessment of the painting's original size. Additionally, there is almost no discernible cusping in the weft-angle map associated with the original stretching or in the x-ray radiograph for the left side. Near the right edge of the composition, there is a crease approximately 0.5 cm from the edge, and a corresponding set of extra tack holes appears just beyond the current foldover. These holes are not always visible but may correspond to the faint cusping on the right edge in the weft-angle map. If this crease represents an earlier foldover, the width of the painting would have been about 56 cm. It is unclear at this time whether the extension of the right edge was the decision of the artist or a consequence of the lining. This extension, however, brings the painting's dimensions closest to *marine* 25 *basse*, which measures 81 × 56.7 cm.

Despite previous linings, five of the paintings appear to retain their original stretchers, while others were documented prior to treatment. Many of the stretchers or canvas versos bore standard size stamps: *Alfred Sisley* (1876, 1933.453) "15"; *Fruits of the Midi* (1881, 1933.1176) "15w"; *Chrysanthemums* (1881/2, 1933.1173) "15"; *Lucie Berard (Child in White)* (1883, 1933.1172) "12"; and *Madame Léon Clapisson* (1833, 1933.1174) "25w". These indications do not appear to differentiate between the types of standard size (*figure* [portrait], *paysage* [landscape], and *marine* [seascape]); two stretchers (*paysage* 15 and *figure* 25) both bear the suffix "w" which may relate to some other aspect of the preparation.

III. GROUND AND PREPARATION

The aspect of Renoir's technique that shows the widest variety is in the preparation of his canvases, as there is a mix of predominantly commercial with some artist preparation, and within the commercially prepared canvases, there is great variety. Transmitted light and transmitted infrared imaging allowed visibility of color merchant's stamps on the backs of many now-lined paintings. Transmitted imaging revealed supplier's marks on six of the 10 paintings able to be examined in this way,[3] while archival information provided information on a seventh. Interestingly, there were supplier's marks from four different suppliers among them: Deforge Carpentier, P: Aprin, Rey & Cie/Rey & Perrod, and Troisgros Frère (fig. 2, table 1).

All but two paintings have commercially applied preparations (table 2). The grounds tend to be white or nearly white with one exception, *The Laundress*, which has a double-layer preparation with a warm gray upper ground. With this painting, the tinted ground is utilized as a compositional element and left exposed in many areas. Additionally, its perceived hue changes in conjunction with the colors on top of and around it, an affect Callen describes in detail (1987, 63–66). Many of the white or almost white commercial preparations are multilayered, a facet that is not always readily

Figure 2a–d. (Clockwise from upper left) a. Pretreatment detail of the DEFORGE CARPENTIER stamp on the verso of Renoir's (oil on canvas; 55 × 65.9 cm), 1922.437, and transmitted-infrared details (1.0–1.1.µm) of suppliers' marks from 2b. REY & Cie, 2c. REY & PERROD, and 2d. P: APRIN on the versos of 2b. Renoir's *Alfred Sisley,* 1876, oil on canvas, 66.2 × 54.8 cm. 1933.453; 2c. *Two Sisters (On the Terrace),* 1881, oil on canvas, 100.4 × 80.9 cm. 1933.455; and 2d. *Young Woman Sewing*, 1879, oil on canvas, 61.4 × 50.5 cm. 1933.452, respectively. Courtesy of the Art Institute of Chicago

Table 2 Grounds

Title, Date	Ground color[a]	Ground composition[b]
Lunch at the Restaurant Fournaise (The Rower's Lunch), 1875	1. (C) off-white 2. (A, S) warm beige	1. Lead white and barium sulfate, with small amounts of iron oxide red or yellow, iron-containing aluminosilicates, silica, calcium-based whites, and trace amounts of bone black. 2. Not determined.
Woman at the Piano, 1875/6	(C) warm white	Lead white, with small amounts of calcium-based white, iron oxide yellow and red (and associated silicates), and traces of bone black, complex silicates, and barium sulfate.
Alfred Sisley, 1876	(C) almost white	Lead white with small amounts of barium sulfate; iron oxide yellow, orange, and/or brown; and associated silicates and clay minerals, calcium-based compounds, and traces of alumina.
The Laundress, 1877/79	1. (C) white 2. (C) warm gray	1. Lead white with small amounts of iron oxide yellow, associated silicates, barium sulfate, and calcium sulfate. 2. Lead white, bone black, and iron oxide red and yellow, with associated complex silicates, quartz, calcium sulfate, and a trace amount of Naples yellow.
Young Woman Sewing, 1879	(C) white	Lead white with barium sulfate and variable trace amounts of silica; calcium-based white; silicate minerals with associated iron oxides, including umber; alumina; and small particles of ultramarine blue.
Seascape, 1879	(C) white	Lead white with barium sulfate and small amounts of silicates, calcium compounds, and traces of bone black.
Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg), 1879	1. (C) white 2. (S) white	1. Lead white with a small amount of calcium-based white (including calcium sulfate) and trace amounts of alumina, silica, and iron-containing complex silicates. 2. Lead white with some calcium sulfate and barium sulfate.
Near the Lake, 1879/80	1. (C) white 2. (C) white 3. (C) white 4. (A, CO) warm white	1. Chalk with traces of alumina, silica, iron-containing silicates, and occasional magnesium-containing carbonates. 2. Lead white with calcium sulfate and traces of aluminosilicates, silica, and iron-containing silicates. 3. Lead white with some calcium sulfate and traces of iron-containing silicates, silica, alumina and carbon black. 4. Lead white with some zinc yellow and small amounts of cobalt blue, emerald green, barium sulfate, alumina, and possibly chrome yellow.
Two Sisters (On the Terrace), 1881	1. (C) creamy white 2. (C) white	1. Calcium-carbonate (chalk) with traces of complex silicates (clays). 2. Lead white with a small amount of calcium-based white and traces of barium sulfate, silica, alumina, and complex iron-containing silicates.
Fruits of the Midi, 1881	(A, CO) white	Lead white with traces of alumina, complex silicates, and some calcium-based white.
Crysanthemums, 1881/82	(C, CO) white	Lead white with moderate amounts of calcium carbonate (probably chalk), and traces of alumina and complex silicates (clays).
Lucie Berard (Child in White), 1883	(A, CO) white	Lead white with traces of alumina, calcium-based white, and complex silicates.
Madame Léon Clapisson, 1883	1. (C) off-white 2. (C) off-white 3. (A, S) warm white	1, 2. Lead white with some calcium carbonate, small amounts of iron oxide yellow and associated silicates, silica, and a few large carbon black particles; the upper layer of the commercial ground is distinguished by a slightly higher proportion of calcium carbonate and iron oxide. 3. Not determined.

Jean Renoir Sewing, 1899/1900	1. (C) translucent white 2. (C) semi-translucent white	1. Calcium carbonate (chalk) with traces of complex magnesium- and aluminum-containing silicates, or clays. 2. Lead white and calcium carbonate (natural chalk with associated microfossils), with traces of associated complex silicates, silica, and alumina.
Seated Bather, 1914	(C) semi-translucent white	Lead white with trace amounts of alumina, silica, calcium carbonate and various complex silicates, some containing iron.

a. (C) commercial, (A) artist, (CO) compositional area only, (S) selectively-applied

b. Elements detected with SEM/EDX.

apparent until the cross sections are examined in the SEM in BSE (backscattered electron) mode. Even then, many of the double layers have a soft interface, suggesting the layers were applied in relatively quick succession.

Renoir sometimes modified the existing commercial ground by adding selective and overall preparation layers. In *Lunch at the Restaurant Fournaise (The Rower's Lunch)* (1875, 1922.437), the added ground appears selective, and is left visible throughout the background in the upper half of the picture, providing a warm contrast to the cool tones of the river and foliage. A similar selective ground in a slightly warmer tone than the commercial layer was also found in *Madame Léon Clapisson*. *Near the Lake* (1879/80, 1922.439), features a smooth, artist-applied layer over the commercial ground on the compositional area only. It is comprised almost entirely with artist pigments, predominantly lead white, and without the significant proportion of fillers seen in commercial grounds. Interestingly, Renoir chose to add this ground to a commercial preparation that was already three layers (a chalk layer followed by two lead-white-based layers, fig. 3, table 1). With this painting, as many others, Renoir appears interested in a pale ground over which he can layer translucent glazes, perhaps harkening back to his early training as a porcelain painter.

The smoothness of ground layers was not always the main objective, however, as there were some lightly textured commercial grounds and others with chunky inclusions. Strange, broad sweeping forms seen in the x-ray radiograph of *Seascape* (1879, 1922.438) as well as a ridge of paint at the end of the sweep on the right edge as if excess ground material were pushed over the edge, suggested added preparation on the compositional area. This layer appeared to match the commercial ground in composition, mainly lead white with a moderate amount of barium sulfate, suggesting it was not added by the artist.[4] The ground is also marked by a faint diagonal brushed texture that was later accentuated as the artist's fluid paints sank into the depressions, especially in the sky. The effect is akin to watercolor, where the texture of the preparation allows the surface to hold more paint.

There are two paintings with a pronounced texture in the preparation. *Young Woman Sewing* (1879, 1933.452), which

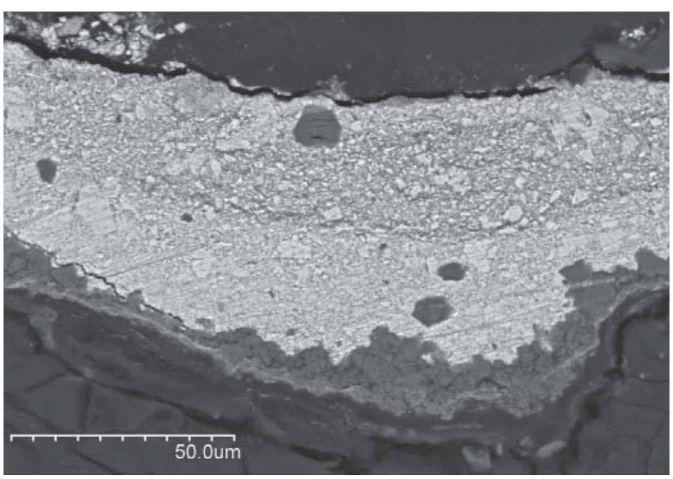

Figure 3. Backscattered electron image of a cross section of the three-layer commercial ground on *Near the Lake,* 1879/80, oil on canvas, 47.5 × 56.4 cm. The Art Institute of Chicago, 1922.439. Original magnification: 850×. Courtesy of the Art Institute of Chicago

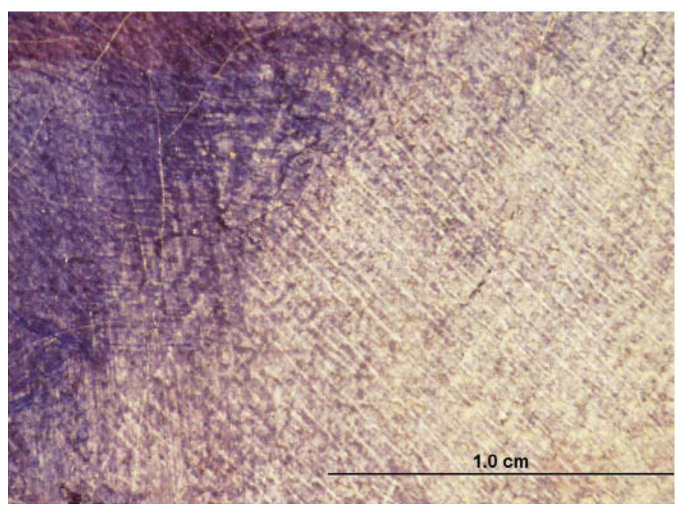

Figure 4. Photomicrograph of the textured ground on *Young Woman Sewing*, 1879, oil on canvas, 61.4 × 50.5 cm. The Art Institute of Chicago, 1933.452. Courtesy of the Art Institute of Chicago

bears a Rey & Perrod canvas stamp, has a thick, white, commercially applied ground that fills the weave, appears systematically textured with shallow, diagonal strokes, and extends to the edges of the tacking margins (fig. 4). The x-ray radiograph shows an apparent buildup of material in a vertical section just left of center that does not correspond to any visible element in the painting. The haphazard, sometimes sharp-edged marks seen in the x-ray radiograph in combination with brushstrokes visible near the top, suggest this layer may initially have been applied with a palette knife, then worked into the surface with a brush. While across most of the painting, the ground has a faint diagonal texture, not unlike *Seascape*, in this area it is heavily and unevenly textured and contains a number of large protrusions. Small diagonal scratches or cracks in this area visible only in the x-ray radiograph suggest some kind of damage may have occurred during the preparation of this canvas. Whatever the reason, the area was covered by extra material which, despite the differences in texture, appears to have the same composition as the rest of the ground. Likewise, the protrusions appear to be bits of already dried ground that were present in the mixture. The effect on the painting is that the thin paint pools more heavily in these areas, making them appear darker and more saturated. While it is unlikely that this was an intentional effect desired by the artist, Renoir would have been aware of the effect immediately, and there is no evidence that he made any attempt to diminish it.

Chrysanthemums presents an unusual set of circumstances: the ground was haphazardly applied to the compositional area and contains many aggregates, probably clumps of dried preparation that were dragged across the surface during application with a palette knife, resulting in large meteoric gouges (fig. 5). These are traditionally markers of an artist-applied ground layer (Callen 2000, 68), however the presence of the Rey & Perrod color merchant's logo on the verso as seen in the transmitted infrared image as well as the composition of the ground, lead white with moderate amounts of chalk, suggest a commercial preparation. Additionally, the chunky particulates

Figure 5. Detail of the ground on *Chrysanthemums*, oil on canvas, 54.8 × 65.8 cm. The Art Institute of Chicago, 1933.173. Courtesy of the Art Institute of Chicago

in the ground are not unlike those seen in *Young Woman Sewing*, which bears the same supplier's stamp. This appears to be an example of a color merchant preparing a single canvas, as proposed by Hendriks and Geldof (2005, 42–43) and discussed in Labreuche (2008). Again, Renoir made no attempt to lessen or obscure this texture, and in fact covered it largely with translucent glazes and semi-glazes, which sank into these gouges, visually accentuating them.

As mentioned earlier, two of the canvases in the Art Institute collection appear to be artist-prepared, *Fruits of the Midi* and *Lucie Berard (Child in White)*. In both cases, the grounds cover the compositional area only, were initially applied with a palette knife, and their material compositions, almost entirely lead white with only traces of other materials, are reminiscent of a paint layer rather than a commercial mixture. In the case of *Fruits*, the ground was worked into the canvas weave with the knife, often leaving the thread tops exposed (fig. 6), not unlike the preparation on the National Gallery's *Boating on the Seine* (1879–80) (Bomford et. al. 1990, 174). While the x-ray radiograph suggests the ground on *Lucie* was also applied with a palette knife, examination of the surface suggests it was subsequently worked with a brush. The unevenness of Renoir's self-prepared grounds is also visible, with areas of thick preparation amid exposed thread tops. Unlike *Chrysanthemums,* pronounced texture seen in *Lucie* appears to be the effect of the nubby canvas and lining rather than the preparation.

Figure 6. Detail of the artist-applied ground and thin, red-lake underdrawing in *Fruits of the Midi,* 1881, oil on canvas, 51 × 65 cm. The Art Institute of Chicago, 1933.1176. Courtesy of the Art Institute of Chicago

IV. COMPOSITIONAL PLANNING AND UNDERDRAWING

In terms of compositional planning, it appears that Renoir often drew his works in some way before painting them, sometimes employing multiple media. The most common method, seen in at least six paintings, was a contour outline in blue paint. These lines are often most readily visible in transmitted and transmitted infrared imaging, and can be further examined under the microscope along the edges of forms. Contours indicating earlier positions for the legs of both figures in *Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg)* (1879, 1922.440) are clearly visible in transmitted imaging, among other compositional changes, while reflected infrared reveals fine, possibly graphite underdrawing related to the figure's faces. As with many of the paintings studied, these painted lines appear to initiate the painting stage and create blue shadows along the edges of forms, and are especially visible in the fleshtones.

The portrait *Lucie Berard (Child in White)* showed two independent rounds of substantial underdrawing in different media as revealed by different infrared filters: an initial campaign in charcoal or black chalk, and a second campaign, very close to the visible composition, in blue paint (fig. 7). In both cases, the underdrawing media are visible under the microscope: particles of charcoal or black chalk are visible amid skips and in areas where they appear to have been partially swept up into the paint layer, as in the figure's eyes, whereas the blue lines of the second campaign are visible along the edges of forms and appear to have been allowed to dry somewhat before further painting. Looking at the two sets of contours, it is clear that Renoir made substantial changes to the figure's pose between the first and second phases, especially with regard to her arms, and adjusted her costume as well.

At times, Renoir's choice of underdrawing media, or even its presence, is not readily apparent upon initial review. The x-ray radiograph of *Fruits of the Midi*, with its radio transparent edges and almost no compositional changes, suggests the presence of underdrawing; however, no drawing was visible in reflected or transmitted infrared. Examination under the stereomicroscope revealed that a thin wash of red lake was used for the underdrawing (fig. 6). *Chrysanthemums*, with its blooming, somewhat loose, wet-in-wet flowers does not appear to be a painting where one would expect underdrawing' however, the reflected infrared image revealed that many of the chrysanthemums have extremely fine, graphite underdrawing, with individual petals articulated (fig. 8). In other areas of the painting, the artist used thin brown lines applied by either a very fine brush or a pen directly on the ground; these lines were at times left exposed.

Examination of Renoir's late painting, the 1914 *Seated Bather* (1945.27) showed the effects of Renoir's degenerative rheumatoid arthritis on his technique. By this time, the artist was

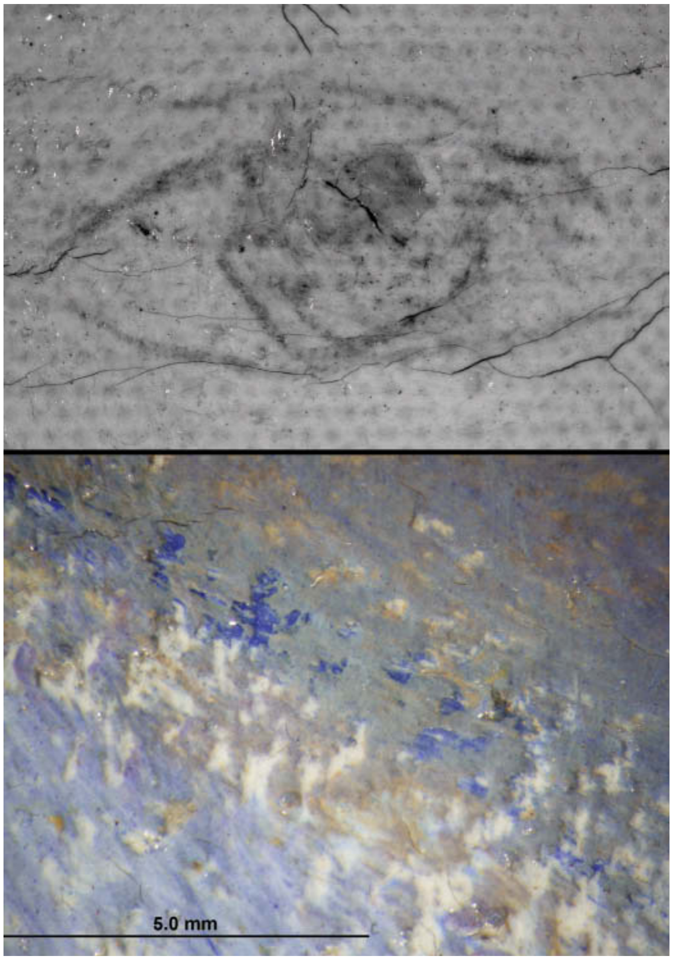

Figure 7a,b. *Lucie Berard*, 1883, oil on canvas, 61.3 × 49.8 cm. The Art Institute of Chicago, 1933.1172. [*from top*] Infrared detail (1.0–1.1 μm) of the figure's eye, and photomicrograph of the figure's shoulder showing the two campaigns of underdrawing in charcoal and blue paint, respectively. Courtesy of the Art Institute of Chicago

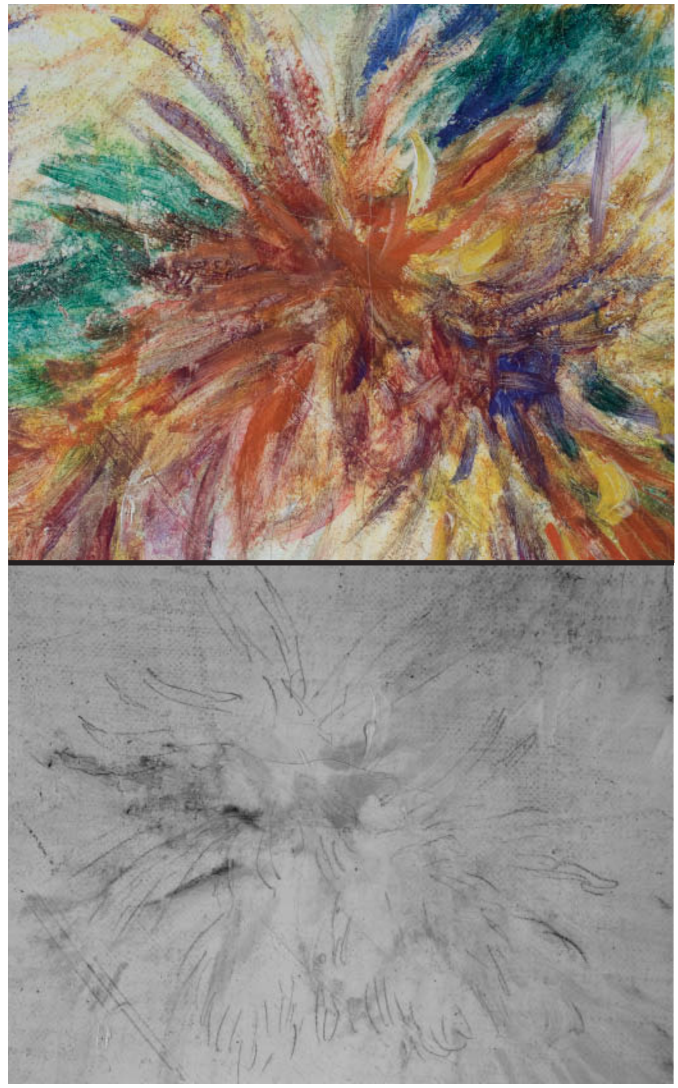

Figure 8a,b. Normal and infrared (1.0–1.1 μm) details of a flower in *Chrysanthemums*, 1881/2, oil on canvas, 54.8 × 65.8 cm. The Art Institute of Chicago, 1933.173. Courtesy of the Art Institute of Chicago

executing works with implements tied to his hands. The state of his hands is evident in the underdrawing: broad contours in graphite appear as if marked by the movements of the shoulder rather than the wrist, and the uncertain lines are easily thrown off by the bumps in the canvas. Although the underdrawing shows through the thin paint layers in some areas, it seems Renoir added graphite contours to the small figures at the right on top of the paint. This appears to be the only painting that began with the reddish-brown underpainted contours characteristic of some of Renoir's other works (Burnstock, et. al. 2005).

V. PAINT LAYER

Renoir's palette was fairly consistent, and in some cases, the artist appears to have gone through phases of preference for one pigment over another (table 3). The results of the recent study are congruent with other published literature (Bomford et. al., Burnstock et. al. 52, table 2) The artist used lead white almost exclusively as his white, and carbon or bone black was found in 12 of the 15 paintings examined. It is worth noting that, as stated in the literature, black was often used as a local color rather than as a means of darkening the hue or creating shadow (Callen 1987, 107). Vermilion was the bright red of choice, and while cerulean or ultramarine blues were sometimes also found, cobalt blue was present in every painting. Renoir favored both emerald green and viridian, especially in the 1870s. More than half the paintings studied contained two red lakes, most consistently madder and carmine (cochineal). UV examination

Table 3 Pigments

***Title*, Date**	Lead white	black (B) bone, (C) charcoal	Iron-oxide (R) red, (Y) yellow, (Br) brown, (BS) burnt siena	Chrome yellow	Zinc yellow	Naples yellow	Emerald green	Viridian	Cobalt blue	Cerulean blue	Vermilion	Red lake (M) madder, (C) carmine, (X) not identified	Other
Lunch at the Restaurant Fournaise (The Rower's Lunch), 1875	a, b	g		a, ? b			b	a, ? b	a, b		a, b	(2X) b, h, i	Chrome orange [a]
Woman at the Piano, 1875/6	a, b, c	(B) b, c		a, b, c	b		a, c	a, b, c	a, b, c	b, c, j	a, b, c	c (M, C) d, i	Zinc white [a,b] Red lead [c]
Alfred Sisley, 1876	a, b, c	g	(Y-Br) b, c	a, b, c (2 shades)			a, b, c	a, c	b, c	a, b, c, j	a, b, c	i (M) b, c, d (X) b, c	Cadmium yellow [a] Barium yellow? [a]
The Laundress, 1877/79	a, b	(B) a, b	(R/Y) a, b	a, b, c			a		a, b	a, b	a, b	(2X) b, c, g, i	
Young Woman Sewing, 1879	a, b	(B) b	(R) a, b	a, ? b	a, b				a, b		a	b, h (M) d	Barium yellow [a,b] Strontium yellow [a,b]
Seascape, 1879	a, b	(B) b	(R/Y) a				a, b		a, b			b, h, i	Barium yellow? [a], Ultramarine blue? [b]
Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg), 1879	a, b	(B) b	(R/Y) a, b	a, b			a		a, b	b, j	a, b	b, h, i	
Near the Lake, 1879/80	a, b			a, b	a, b		a, b	a, b	a, b		a	h (M) b, d, i, (X) b	
Two Sisters (On the Terrace), 1881	a, b, c		(Y, Br) a	a, b, c	a, b, c		a, b, c	c	a, b, c		a, b, c	b, c, h	Ultramarine blue [b,c,e]
Fruits of the Midi, 1881	a, b, c	(B) b	(R/Y) b	? a	a, b, c	? a	a, c		a, b, c		a, b, c	(2X?) c, g	Cadmium yellow [a,b]
Chrysanthemums, 1881/82	a, b, c	c	(R/Y) a, b		a, b, c, f	a, b, c		c	a, b, c		a, b, c	i (C) b, c, d (X) b, c	Cadmium yellow [a,b,c] Malachite [b,c,f]
Lucie Berard (Child in White), 1883	a, b, c		(R/Y, BS?) a, b, c		a, b, c				a, b, c		a, b, c	(2X) b, c, i	Ultramarine blue? [c,e]
Madame Léon Clapisson, 1883	a, b, c	(C) c			a, b, c		b		a, b, c		a, b, c	(C) b, c, d, i	Strontium yellow? [a,b]
Jean Renoir Sewing, 1899/1900	a, b, c	(B) b	(Y) a, c (R) b			a, c			a, c		a, b, c	b, c	Terre verte [a,c]
Seated Bather, 1914	a, b, c	(B) a, c	(Y) a, b, c		? a	a, b, c		a, c	a, b, c		a, b, c	c	Terre verte [b], Zinc white [a,b]

a. XRF
b. SEM/EDX
c. PLM
d. SERS
e. Electron microprobe
f. Raman
g. Stereomicroscopic examination of the surface
h. Optical microscopy of cross sections
i. UV fluorescence of the painting surface indicates the presence of red lake
J. Mg-containing

revealed some distribution of fluorescent red lakes throughout many of the works, and in cross section, two lakes were often found mixed together. The artist seems to have shown the most variance with yellows. Chrome yellow was found in almost every painting from 1881 and before; zinc yellow appears sporadically in the earlier pictures and consistently in the works from the early 1880s; and Naples yellow similarly appears sporadically and appears to be favored in Renoir's later years. Other yellows made limited appearances: cadmium yellow was found in a few cases, as were strontium and/or barium yellow, which may be varieties of a "lemon yellow" sold at the time. Iron oxides were found in small amounts in most of the paintings in this study.

Interestingly, a color found in both *Young Woman Sewing* and *Near the Lake* resembling yellow ochre did not show the presence of iron when analyzed with XRF. Stereomicroscopic examination revealed the paint to be a mixture of more expensive pigments that was likely created on the palette and included either chrome or zinc yellow, red lake, and blue and/or black. This may be the type of mixture Renoir referred to in his notebook, ca. 1877: "The yellow ochre, Naples yellow and Siena earth are intermediate tones only and can be omitted once their equivalents can be made with other colors" (J. Renoir 1962, 360; Callen 1978, 15).

The ability to carefully examine a pigment mixture under the microscope to aid in identification and interpretation is likely the result of Renoir's preference for hand-ground pigments. Industrial milling of pigments made the particle size uniform, often detracting from the optimal brilliance each individual pigment required, and as a result, many artists preferred to make their own paints, or, more often, purchase paint from a color merchant who dealt in the old methods. Renoir, along with Claude Monet (1840–1926), Alfred Sisley (1839–1899) and Gustave Caillebotte (1848–1894) were known to have accounts with Maison Edouard and his successor Mullard, both well-known and respected for their handmade paints. Renoir felt strongly about his pigments: "I, for one, strongly believe that it is more advantageous for a painter to create his own paints or have his apprentice create them for him. Since there are no more apprentices and I prefer to paint, rather than produce paints, I buy them from my old friend Mullard, the colourman on the rue Pigalle, who makes them for me" (J. Renoir 1962, 69).

In addition to their preparation, the mixing of colors was of paramount importance. *Peinture claire*, or "light painting," was the preferred style of color mixing among the Impressionists, and is a technique whereby colors are uniformly mixed with white (Bomford, et. al. 1990, 89). While some of the paintings in this study are mainly done using this technique, such as *The Laundress*, Renoir does not seem to have embraced the technique as a sole means of executing a picture. The dark chair and background in the portrait of Sisley, and the saturated glazes in *The Rower's Lunch, Near the Lake* or *Two Sisters*, for instance, suggest Renoir was interested in more contrast that *peinture claire* alone could offer. In many cases where the paintings appear pale in their overall tonality, such as *Seascape* or *Seated Bather*, much of the perceived pallor results from the artist's almost watercolor-like application of thinned paint over a white ground.

Renoir's use of saturated, translucent glazes and "jewel-like" tones also set him apart from his colleagues (Callen 2000, 78). The thin, medium-rich red lake and cobalt blue glazes are especially evident in the figures' dresses in both the Clapisson portrait and *The Rower's Lunch* where they were applied in directional, wet-in-wet strokes with a flat-tipped brush. The artist's glazing technique can result in cross sections where the paint layers are substantially thinner than the preparation beneath them (fig. 9). These samples highlight one trend in

Figure 9. Cross section of the ground and paint layers in *Near the Lake*, oil on canvas, 47.5 × 56.4 cm. The Art Institute of Chicago, 1922.439. The upper portion of the commercial ground as well as the artist-applied ground are visible. Original magnification 200×. Courtesy of the Art Institute of Chicago

Renoir's painting where much of a work is executed in thin paint layers, punctuated by areas of thick impasto. Both *Young Woman Sewing* and *Chrysanthemums* are painted so thinly that aside from a few touches of impasto, the compositions do not register in the x-ray radiograph. These glazes are often countered with heavy impasto, especially in the highlights. The nature of Renoir's wet-in-wet modeling, often executed in sure strokes with several unmuddied colors (fig. 10), speaks to the apparent meticulousness of his studio practice and cleanliness of his brushes proposed by Callen (1978, 22).

For the most part, Renoir's works at the Art Institute show no evidence of the fading caused by fugitive pigments that plagued his contemporaries like Van Gogh. In one case, however, unframing *Madame Clapisson* revealed significant fading of the background lake pigment. Not only could the intense color be viewed where the frame rebate had protected the work, toward the top of the work, hints of the original color could still be seen under the microscope in paint depressions and cracks and the undersides of the impasto; elsewhere, the background contained a sea of translucent particles that are likely a mixture of faded lake and starch, a manufacturer's additive. A cross section from the background shows the upper portion of faded paint, appearing blue from the surface, with deep, unfaded red lake particles just beneath it (fig. 11). Analysis suggests that two types of red lake derived from the same dyestuff (carmine) were used in this painting (Pozzi, et. al., 2014).

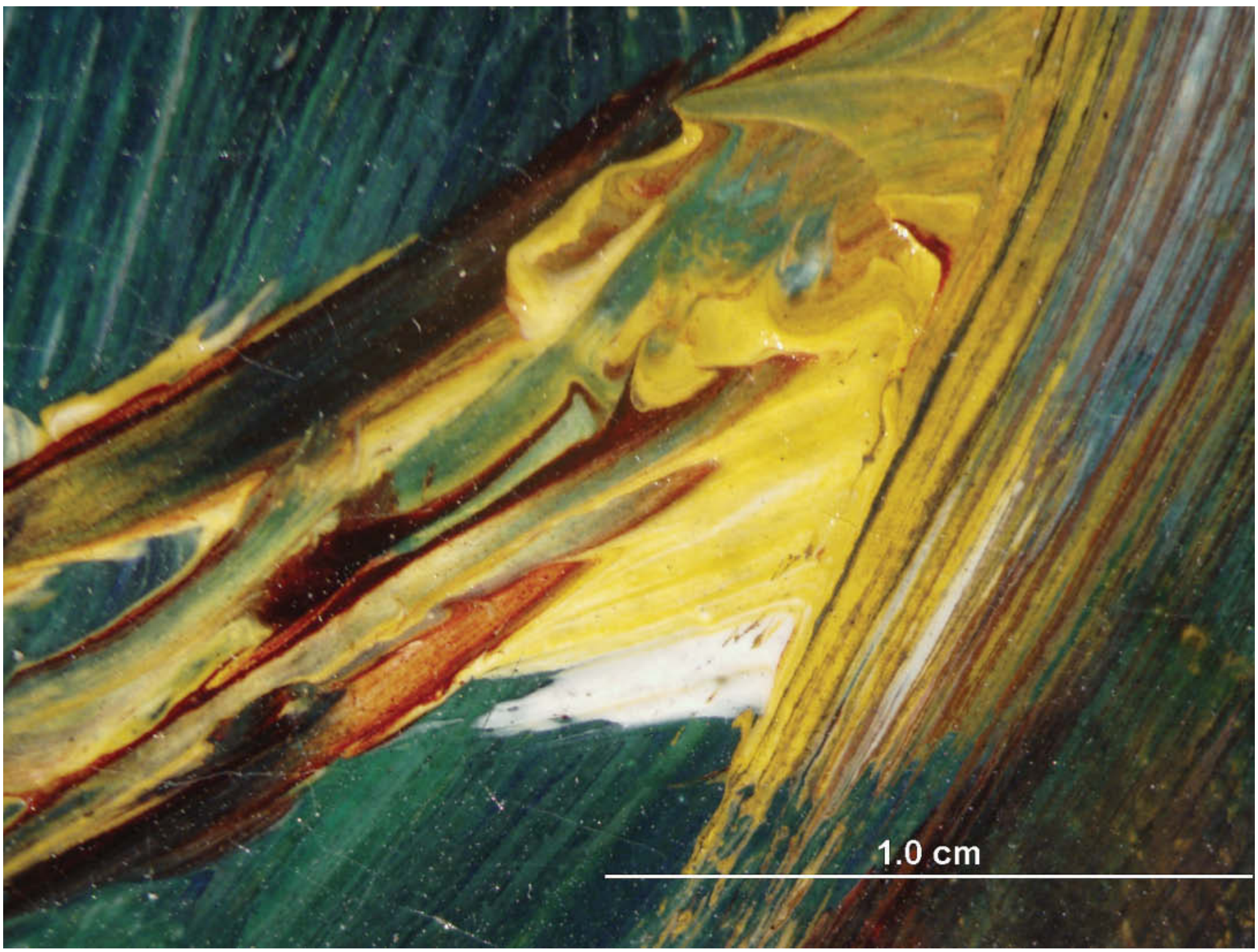

Figure 10. Photomicrograph of the background in *Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg),* 1879, oil on canvas, 131.2 × 99.2 cm. The Art Institute of Chicago, 1922.440. Courtesy of the Art Institute of Chicago

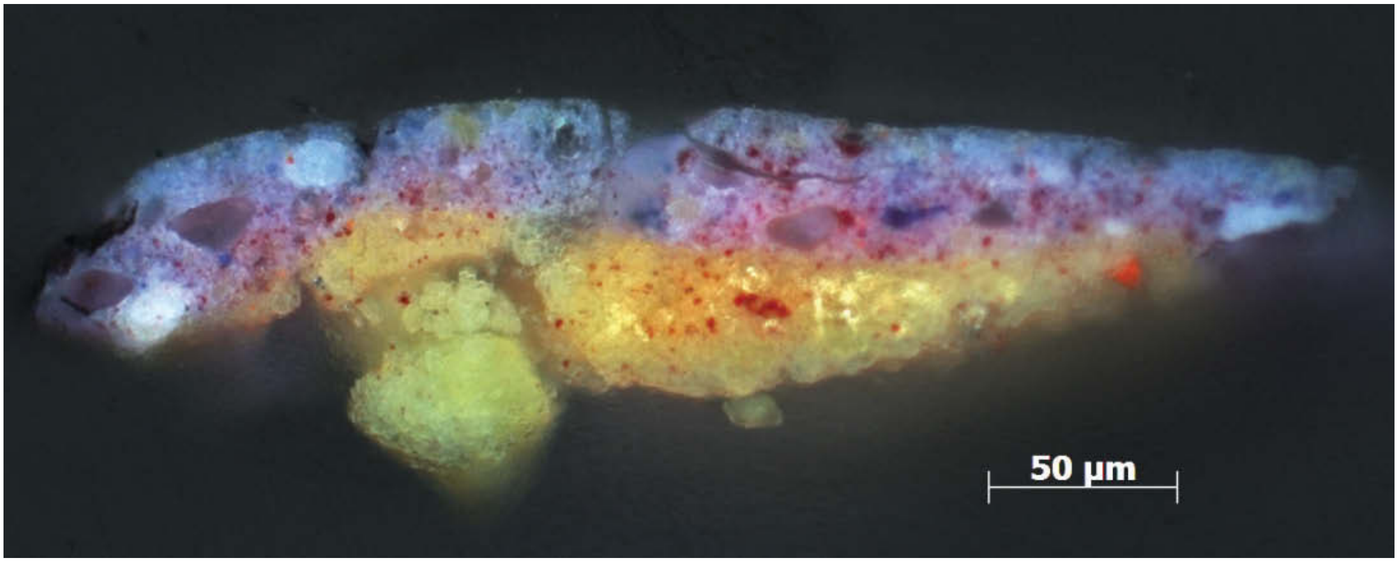

Figure 11. Cross section of the background in *Madame Léon Clapisson*, 1833, oil on canvas, 81.2 × 65.3 cm. The Art Institute of Chicago, 1933.1174. Original magnification 200×. Courtesy of the Art Institute of Chicago

Fading has previously been associated with "starch-containing carmine" in other works by the artist (Burnstock, et. al. 2005). The fading seen in *Clapisson* does not seem to be associated strictly with the substrate or the dyestuff; therefore, it is not entirely clear why some areas have faded while others have retained their original hue. The left side of the painting displays a particularly sharp boundary between the protected and unprotected areas, while the top edge shows a gradual fade, illustrating the protection not only of the frame, but of its shadow, as the painting is often lit from above.

On the basis of the color revealed along the left and top edges, a digital image with the faded red color restored to the background was generated as a visualization of the painting's original appearance (fig. 12). This was Renoir's second attempt at the background of this portrait, and covered the shades of mossy green, rusty red, and earthy yellow that, worked wet-in-wet with one another, created a warm and vibrant backdrop still reflected in the highlights and shadows of the figure's skin, especially at the chin, neck, and arms. This first background recalls the garden seen in Renoir's earlier, failed attempt of the portrait, *Among the Roses (Dans les roses)* (1882. Oil on canvas; 99.7 × 81.3 cm, Private collection), which was rejected by the client upon completion. The original background in *Clapisson* is still visible in many areas of the composition where the new background was not heavily worked, as well as immediately around the forms, creating a kind of halo. Rather than paler and more muted, the background reworking appears to have once been a cooler alternative

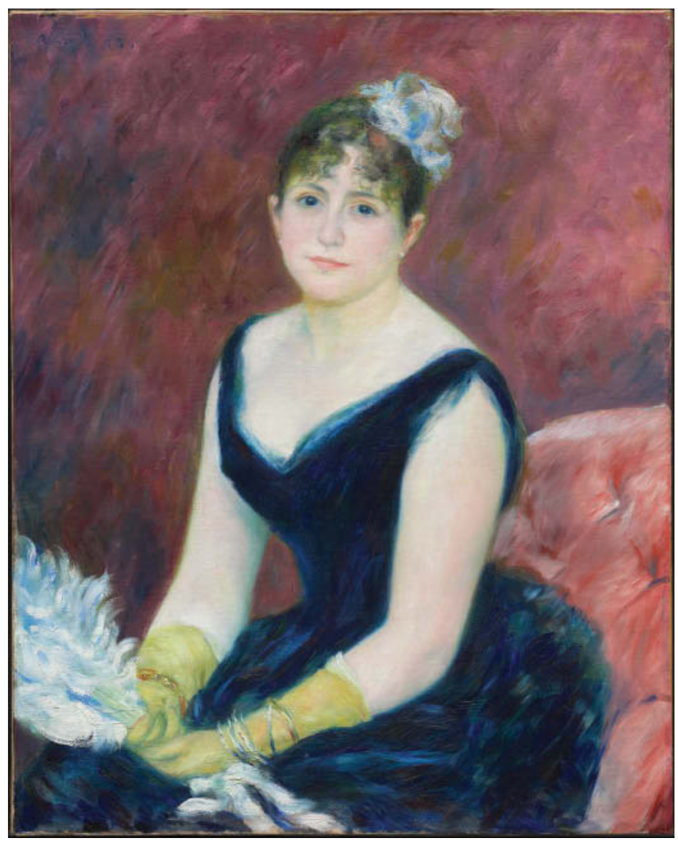

Figure 12. Recolorized visualization of *Madame Léon Clapisson*, 1833, oil on canvas, 81.2 × 65.3 cm. The Art Institute of Chicago, 1933.1174 Courtesy of the Art Institute of Chicago

to the original. As seen in the digital visualization, the background with a much more saturated, darker, and more purple palette increases the perception of a rosy quality in areas of the figure's flesh. This change in the background appears to have been made very late in the process, as it was still wet when Renoir signed the work.

The artist modified his method of application and the consistency of his paint to achieve specific ends, at times describing the similar materials differently in multiple paintings. The fleshtones in many paintings are marked by an almost brushless surface with soft edges and subtle transitions, such as that seen in *Clapisson* or *Two Sisters*. Alternately, the artist sometimes employed high impasto with directional streaks of wet-in-wet modeling, as seen in the portrait of Sisley, or ordered, cross-hatched brushstrokes like those in *The Laundress*. Other times the paint application seems to defy material reality: the wooden elements in *Near the Lake*, including the tree trunk and balustrade, are described via thin, translucent, medium-rich layers (fig. 9), while the foliage, lake and clouds are heavily impastoed. Hard and soft, flat and round, medium to very fine, Renoir had a variety of brushes at his disposal with which he could manipulate the paint. The paint itself varied in consistency from straight from the tube to thinned with mineral spirits or a mixture of oil and spirits.

Renoir was not limited to brushes alone, and at times favored applying stiff, opaque paint with a knife. In *Seascape*, the artist alternated between application with a palette knife and subsequent working with a brush to froth his waves. The artist seemed particularly fond of the knife for describing citrus rinds, such as the oranges in the *Acrobats*, and the large citrons in *Fruits of the Midi* (fig. 13). In other paintings, the palette knife was used to remove paint rather than to apply it. Technical images reveal compositional changes were scraped away in *Woman at the Piano, Two Sisters,* and *Madame Clapisson.* On the portrait of Sisley, the artist's scraping of the forehead reveals a riot of color previously beneath the pale fleshtones. In *Jean Renoir Sewing*, Renoir covered part of the ribbon in his son's hair, then, changing his mind, removed the additional paint to reveal the original choice. Scraping seems to be quite common throughout this work in particular, which shows a strange texture in many areas where the scraping removed the paint on the thread tops preferentially, leaving craters and a pockmarked texture. Similarly, there is also evidence of wiping with a cloth or similar material. The cloth the woman holds in *Young Woman Sewing* is articulated via wiping, leaving paint only in the interstices and depressions of the lightly textured ground (see fig. 3). On the *Seated Bather*, the artist may have used wiping to blend tones as well as make corrections. The heavily thinned paint easily lends itself to being worked in this manner.

Figure 13. A large citron in *Fruits of the Midi,* 1881, oil on canvas, 51 × 65 cm. The Art Institute of Chicago, 1933.1176. Courtesy of the Art Institute of Chicago

The presence of compositional changes is common in Renoir's work. Despite the obvious signs of planning and underdrawing, all but one of the paintings in this study show obvious pentimenti, in keeping with other studies of his painting technique.[5] These range from small adjustments to larger changes that affect the painting's meaning from an art historical perspective. The lower left quadrant of *The Rower's Lunch* showed some forms in raking light that did not correspond to the surface image, and the x-ray radiograph revealed there was once a single figure rather than the two that are currently visible (fig. 14). Although the outline is rather simplistic, it is believed that the figure is female (Groom and Shaw 2014), making this painting originally much like its pendant from the same year *Luncheon (Le Déjeuner)* at the Barnes Foundation (BF45).

Renoir seemed to adjust his figures most frequently, and often made such adjustments before bringing in the background. In addition to changing the angle of the piano, the figure in *Woman at the Piano* appears completely reworked, her earlier dress appearing extremely voluminous in the x-ray radiograph, and her hair was altered from a simple, downswept roll to an upswept style with added volume at the crown. The young Wartenberg sisters featured in the *Acrobats* in the early stages resembled one of Renoir's only known preparatory drawings *The Acrobats* (1874–78, Black chalk on canvas, Private collection; Bailey 2012, 129, fig. 5). The legs, arms, and hands were adjusted several times in a flurry of sweeping contours and partially painted forms. The arms and hands in Renoir's portraits of Sisley and Madame Clapisson were similarly adjusted, as were Jean Renoir's fingers. In fact, Renoir's fairly consistent

Figure 14. X-ray radiograph and raking light details of *Lunch at the Restaurant Fournaise (The Rower's Lunch)*, 1875, oil on canvas; 55 × 65.9 cm. The Art Institute of Chicago, 1922.437. Author's annotations outline the visible figures in red and the earlier single figure in green. Courtesy of the Art Institute of Chicago

adjustments to the hands of his figures may belie some difficulty in their execution, as the hands are often curled or tucked away. His adjustments to *The Laundress* may be the most curious, as they leave the figure with six fingers on her left hand.

VI. CONCLUSIONS

One of the most interesting insights into Renoir's technique revealed through these examinations is the variety of materials and methods of execution exemplified in these 15 works: canvas stamps from four different suppliers were found, in addition to two artist-applied preparations; underdrawing in various media, at times more than one type in a single painting, was also discovered; and the paint handling varies from textured, opaque strokes in mixed tones to washes and glazes of almost pure color. At the same time, Renoir appeared to have some consistency in his choice of pigments, and mixed most hues on the surface rather than on the palette. Renoir consistently made changes to his works, major and minor, at times wiping or scraping back previous choices. The artist seems to work through his paintings, adjusting his materials, application, and the composition in order to achieve his ends. He embraced many painting techniques favored by his Impressionist colleagues, such as *peinture claire*, high impasto, *plein air* painting, and used other more traditional techniques, such as glazing, in new and interesting ways. Under the microscope, the true complexity of his methods is clear as many brushstrokes have several colors mixed wet-in-wet. One of Renoir's common last steps: to accentuate highlights with impastoed strokes of almost pure white tinged with the surrounding colors (fig. 15). The resulting paintings, especially those of the 1870s and 1880s, are dynamic in their color ranges and varied strokes and show Renoir's true mastery of his materials and his craft.

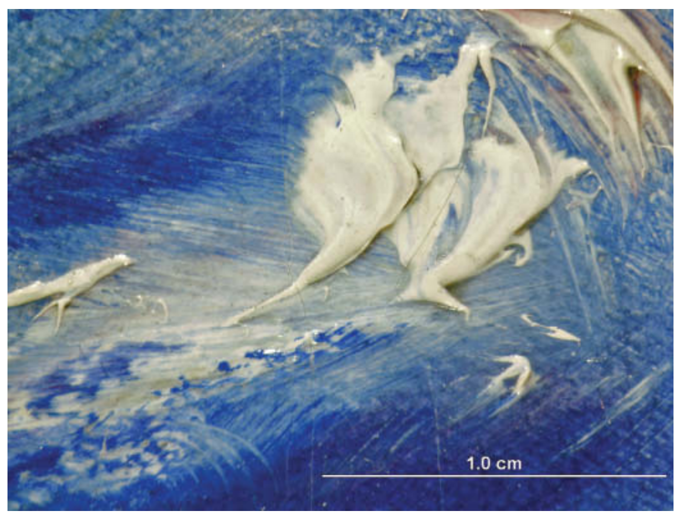

Figure 15. Bright highlight on the vase in *Young Woman Sewing*, 1879, oil on canvas, 61.4 × 50.5 cm. The Art Institute of Chicago, 1933.452. Courtesy of the Art Institute of Chicago

APPENDIX: REFERENCED ARTWORKS

A. Paintings by Pierre-Auguste Renoir from the Art Institute of Chicago

(*In rows: top to bottom, left to right)*

Lunch at the Restaurant Fournaise (The Rower's Lunch), 1875 (oil on canvas; 55 × 65.9 cm) 1922.437

Woman at the Piano, 1875/6 (oil on canvas, 93 × 74 cm) 1937.1025

Alfred Sisley, 1876 (oil on canvas, 66.2 × 54.8 cm) 1933.453

The Laundress, 1877/79 (oil on canvas, 80.8 × 56.5 cm) 1947.102

Young Woman Sewing, 1879 (oil on canvas, 61.4 × 50.5 cm) 1933.452

Seascape, 1879 (oil on canvas, 72.6 × 91.6 cm) 1922.438

Acrobats at the Cirque Fernando (Francisca and Angelina Wartenberg), 1879 (oil on canvas, 131.2 × 99.2 cm) 1922.440

Near the Lake, 1879/80 (oil on canvas, 47.5 × 56.4 cm) 1922.439

Two Sisters (On the Terrace), 1881 (oil on canvas, 100.4 × 80.9 cm) 1933.455

Fruits of the Midi, 1881 (oil on canvas, 51 × 65 cm) 1933.1176

Chrysanthemums, 1881/2 (oil on canvas, 54.8 × 65.8 cm) 1973.1173

Lucie Berard (Child in White), 1883 (oil on canvas, 61.3 × 49.8 cm) 1933.1172

Madame Léon Clapisson, 1833 (oil on canvas, 81.2 × 65.3 cm) 1933.1174

Jean Renoir Sewing, 1899/1900 (oil on canvas, 55.4 × 46.3 cm) 1937.1027

Seated Bather, 1914 (oil on canvas, 81.1 × 67.2 cm) 1945.27

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NOTES

1. Thread count reports and analytical results for each of the examined paintings can be found in their respective technical reports by K. Keegan in Groom and Shaw (2014).
2. A thread-count match, though not a conclusive weave match, was found between the Art Institute's *Jean Renoir Sewing* (1899/1900, 1937.2017) and the version at the Wallraf-Richartz-Museum in Cologne *Jean Renoir* (c. 1900, WRM FC 680). Interestingly, these paintings are the same size, appear to have a similar double ground application, and records suggest they originally had similar five-member stretchers. Both versions also feature numerous compositional changes and a strange, pock-marked surface texture due to artist scraping. See Groom and Shaw (2014, cat. 24) and Lewerentz (2008).
3. Five of the 15 paintings were lined and hard-mounted, making transmitted imaging impossible, and as they were lined prior to acquisition, there is no extant pretreatment archival information.

4. Similar sweeping in the ground layer was noted on the Frick Collection's *La Promenade* (1875–6, 1914.1.100) and is presumed to be added material by the artist (Bailey and Hale 2012).
5. These studies include Bomford, 1990; Burnstock, Van den Berg, and House 2005; Schaefer, von Saint-George, and Lewerentz 2008; Lucy and House 2012; Roy, Billinge, and Riopelle 2012.

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CAITLIN BREARE

The Other Woman: The Nature of the Fine Arts Museums of San Francisco's *Breton Girl*

ABSTRACT

The practice of producing copies and versions of artworks formed an integral part of the exploratory practices of Paul Gauguin and his circle. Breton Girl *at the Fine Arts Museums of San Francisco depicts a figure from Gauguin's* Human Misery, *(Ordrupgaard Museum), with little else known about the time, place, or authorship of its production. Technical examination revealed a painting technique consistent with Gauguin's. The painting's unusual format and lack of cusping at the edges with no tacking margins raised suspicions it had been cut down. This was confirmed by the discovery of an image of a now-lost painting that constitutes the missing portion of* Breton Girl. *The combined composition incorporates imagery from Gauguin's* Human Misery *and* Yellow Christ, *changing its status from a copy to a version. Gauguin's friend and fellow painter, Claude-Emile Schuffenecker is proposed as the possible author of* Breton Girl.

1. INTRODUCTION

Breton Girl (fig. 1) came to the paintings conservation studio of the Fine Arts Museums of San Francisco as a result of their storage survey project, when it was flagged as a work in need of both research and treatment. It is related to Paul Gauguin's *Human Misery* (fig. 2), painted in 1888 during the two famous and infamous months he spent in Arles living and working with Vincent van Gogh.[1] Gauguin discussed this painting several times during its creation in letters to friends and fellow artists. He declared it his best painting of the year to painter Emile Bernard; superior even to *Vision After the Sermon* (1888, National Galleries of Scotland, NG 1643) a work much better known today.[2] It was a composition Gauguin returned to repeatedly over several years and in various media, especially the central figure. It is the other major figure at the left edge of Gauguin's prized composition that we see depicted in *Breton Girl*.

Entering the collection in 1969 as a work attributed to Paul Gauguin, San Francisco's *Breton Girl* was a gift from Dr. T Edward and Tullah Hanley. The couple bought the painting in New York around 1949, likely from the Hammer Gallery. It was published in John Rewald's book on Gauguin in 1938 as authentic, and in the collection of the Kate Perls Gallery, either in New York or Paris (Rewald 1938). No other provenance details are known. In 1991, curators deattributed the painting from "Gauguin" to "after Gauguin" for stylistic reasons.

Figure 1. After Paul Gauguin, *Breton Girl*, c. 1889, oil on canvas, 36.5 × 81.0 cm; Fine Arts Museums of San Francisco, A303821; shown before treatment (left) and after treatment (right)

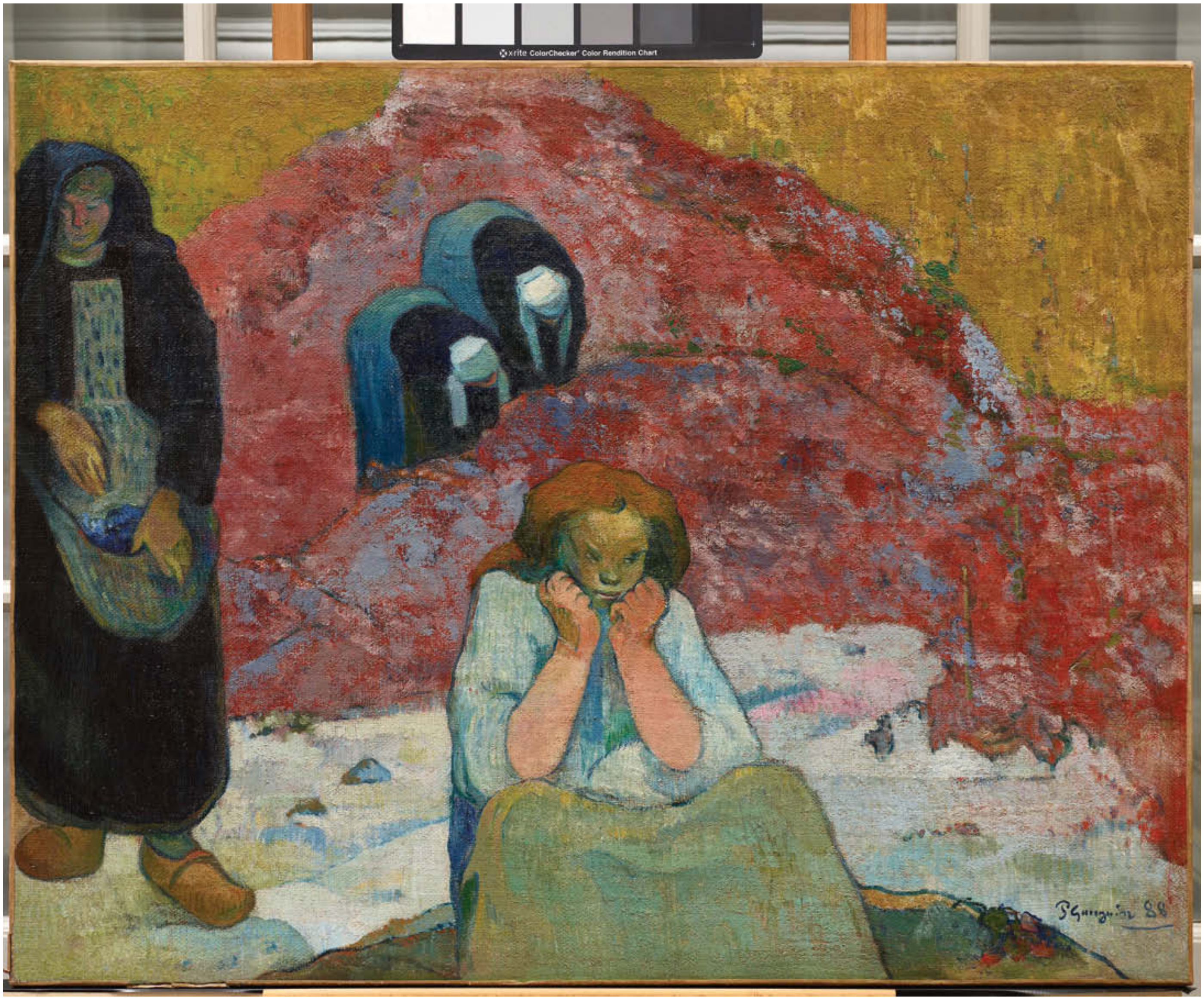

Figure 2. Paul Gauguin, *Human Misery,* 1888, oil on jute sackcloth, 72.5 × 92.0 cm, Ordrupgaard, Copenhagen, 223WH. Courtesy of Anders Sune Berg.

What wasn't realized before this project was just how close a copy *Breton Girl* was to Gauguin's painting. A tracing of *Breton Girl* on mylar overlaid on *Human Misery* at the Ordrupgaard Museum, revealed a very close match of all contours. The only disparities were a shift of about 3 cm that elongates the body of *Breton Girl,* and a pentimento in the hood of the 'same figure,' altered from the contour in *Human Misery* to one a few millimeters higher (fig. 3). This suggests either a tracing was made of *Human Misery* to create *Breton Girl*, or a common drawing was used for both. For both works, it seems the composition was carefully planned before painting, as the x-radiographs of both and the infrared reflectogram (IRR) of *Breton Girl* show no changes to the highly stylized figures. This is corroborated by Gauguin's correspondence, which documents some of the thought process behind *Human Misery's* creation.[3]

The technical examination of the San Francisco painting involved mostly nondestructive methods including microscopic examination, XRF, x-radiography, IRR, and examination in ultraviolet illumination. One sample was taken of the canvas for fiber identification. Following is a summary of the findings of this examination:

No clear underdrawing or squaring up is visible in IRR as most of the contours were reinforced with black or dark blue paint at various stages of the painting process, though remnants of a

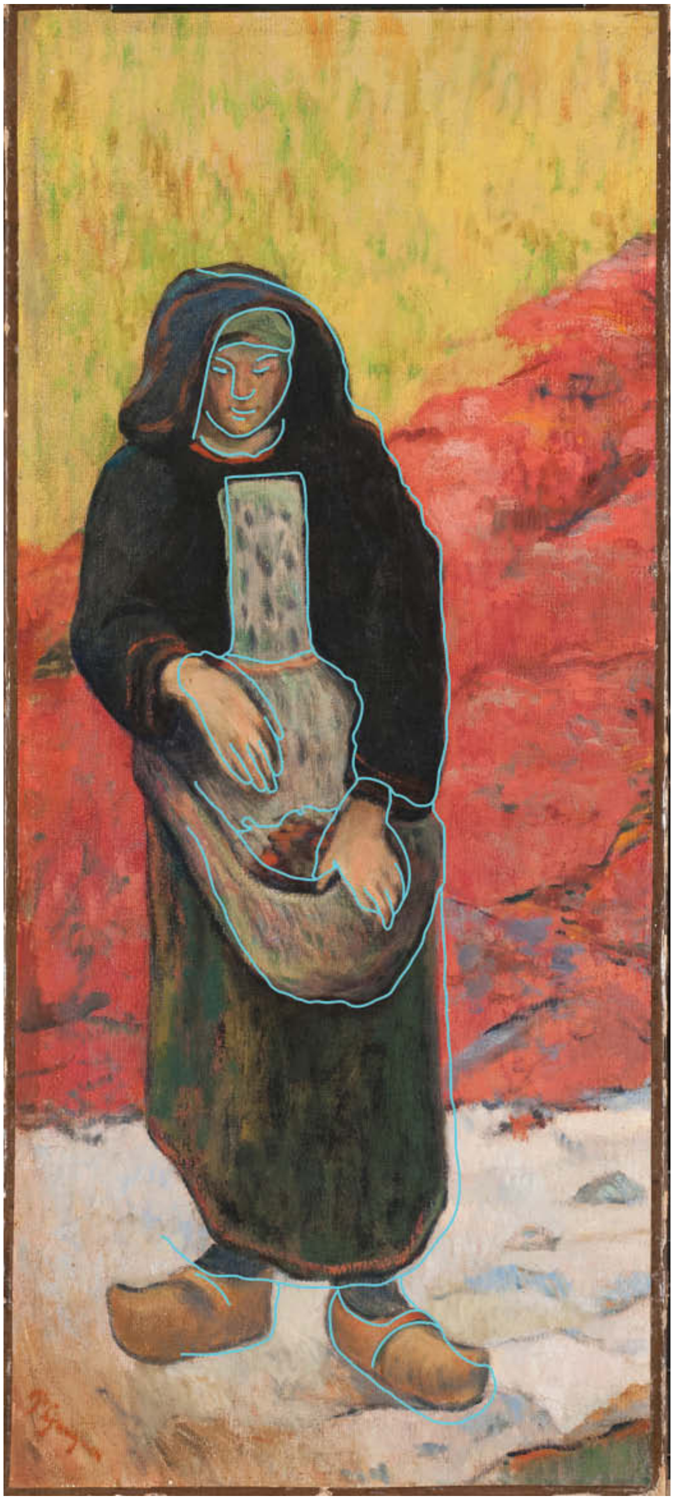

Figure 3. Digital overlay of the outline of *Human Misery* over a photograph of *Breton Girl*

charcoal-like outline are visible in areas of exposed ground, such as in the rocks in the foreground (fig. 4). This outline was then painted over with a dark blue paint, followed by the application of color, both wet-in-wet and wet-on-dry. In the final stages some contours were reinforced with more blue paint. This design and painting method is consistent with what has been observed in Gauguin's practice (Jirat-Wasiutynski and Newton 1990; Christensen 1993; Jirat-Wasiutynski and Newton 2000; Hoermann-Lister, Peres, and Fielder 2001; Stevenson and Thomson 2006).

Across the composition, specific passages of brushwork have been replicated with painstaking exactitude, suggesting the copy was made in the presence of the original (fig. 5). The painting does have two Gauguin signatures, though it cannot be determined if they are original. Another inscription that does appear to be original is the number "89," painted in the lower center of the foreground. The year 1889 is the year after *Human Misery* was completed. Adjacent to this number there appears to be a longer inscription, though it is mostly covered by other layers of paint and is illegible.

XRF analyses indicated a pigment palette typical of Gauguin's, though as Carol Christensen notes in one of the first in-depth technical studies of the artist (Christensen 1993), with the exception of his choice of canvases Gauguin was not as innovative with his materials as he was stylistically, and his palette represents that of a typical late 19th- or early-20th-century painter. One identification that may bear some significance is the detection of chrome in the yellow background, as in a letter to painter Emile Bernard, Gauguin specifically mentioned using chrome pigments in the yellow background of *Human Misery*.

The x-radiograph and XRF results indicate a lead ground with zinc present. *Human Misery* had a barium sulfate ground, though Gauguin began using a lead ground, also containing zinc, later in the Arles period. Gauguin's change in grounds may be in response to damage sustained by *Human Misery* and other paintings during transport to Paris, when large chunks of paint began flaking from the canvas (Hoermann-Lister, Peres, and Fielder 2001). *Human Misery* is painted on coarse jute sackcloth, part of a 20 meter piece Gauguin took to Arles and shared with van Gogh. The Thread Count Automation project, which uses high-resolution digital images of x-radiographs to evaluate thread-count density and deviations, has analyzed over 30 Gauguin canvases to date, many from the Arles period.[4] Don Johnson, codirector of the project, analyzed the weave of *Breton Girl* against the canvases in their database.[5] There was no match, though the analysis mathematically confirmed observation that there was no cusping on any edge, all of which had the tacking margin trimmed. This suggests the painting was either cut down on all four sides or the canvas was cut to size and stretched after priming.

In summary, the technical examination combined with documentary evidence suggested *Human Misery* was painted first, and

Figure 4. Detail of *Breton Girl*, showing remnants of charcoal-like underdrawing along the contour of a rock in the foreground

that *Breton Girl* was a close copy made by a painter with detailed knowledge of Gauguin's technique who had access to the original, and probably done in the late 19th or early 20th century.

Concurrent with the technical examination of *Breton Girl* was the assessment and treatment of several condition issues. The lining was the most concerning problem. It appeared to have been executed in France, with French customs stamps on the verso marking the painting's entry into the United States, and remnants of a facing in the form of tiny snippets of French newspaper adorning the edges of the canvas. There was an open-weave muslin cloth interlayer, and two layers of glue-based adhesives used to attach the muslin layer, and then the lining canvas. These two adhesive layers were of different consistencies, application method, and states of preservation. The layer between the muslin and the lining canvas was sparingly applied and very brittle. Examination of the edges revealed that the original canvas, with no tacking margins and the muslin layer firmly attached, was delaminating from the lining canvas. Raking light showed bulges in the canvas that corresponded with detached areas. The extent of the issue was too severe to address the delamination locally, so the lining was reversed.

The first stage of reversing the lining was relatively easy. By sliding a large spatula behind the canvas, very little force was required to separate the lining. The verso of the newly freed canvas revealed an unevenly applied glue paste that was making incomplete contact with the lining canvas. Conversely, the muslin interlayer was very securely attached to the original canvas with a continuous glue layer of a consistency different from the other; less pastelike, and more akin to pure glue.

Releasing the muslin layer proved much more difficult. The adhesive softened with moisture, but delivering this moisture in a controlled and even way was complicated by the muslin layer and uneven residual glue. Tests with dampened blotter paper and cotton were not providing the contact necessary, resulting in patchy and uneven areas of softened adhesive.

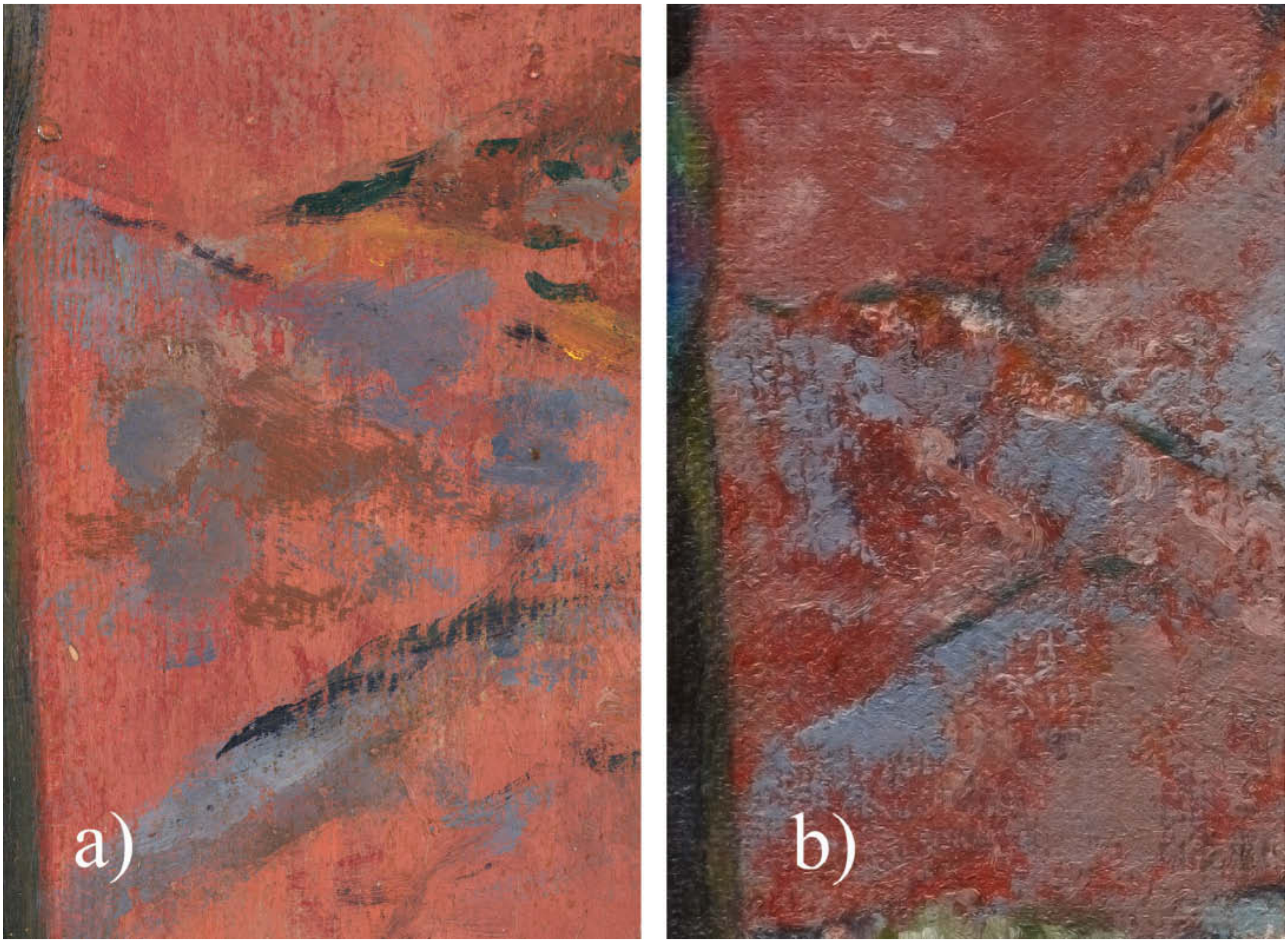

Figure 5. (a) Details of brushwork in the pink foreground of *Breton Girl* and (b) the corresponding area of *Human Misery*

This stage of treatment was taking place during last year's AIC annual meeting in San Francisco, during which Fiona Beckett delivered a paper in the Paintings Specialty Group session on the lining reversal of Thomas Couture's *Supper After the Masked Ball* (Beckett 2014). Gellan gum, a high-molecular-weight polysaccharide polymer similar to agarose was used in the form of a rigid gel to deliver moisture to reduce residual lining glue. This prompted testing with this and other rigid gel materials.[6] The results demonstrated gellan gum was indeed the most ideal material for the treatment of *Breton Girl*.

The treatment proceeded using the gellan gum gel at a concentration of 2 percent (w/v), cast in a tray where it was allowed to cool before cutting to shape and applying it to the verso (fig. 6). At this concentration the gel conforms to the surface it is placed on and is completely transparent, allowing for full visibility of the material underneath as the treatment takes place. Any air gaps and bubbles can be tapped out, and the amount of moisture in the glue layer could be judged by how dark it became. The material leaves behind no residue, and, as a common ingredient in the food and cosmetic industries, it is safe to handle. A dwell time of 3 minutes provided enough moisture to soften the glue and allow the muslin cloth to be separated from the original canvas with a microspatula. Most of the adhesive was removed during this process, and any residue was removed with a scalpel once dry.

As the muslin and adhesive were being removed, a layer of off-white paint that was applied directly to the verso was uncovered. It had the appearance of a chalky priming layer, applied with a broad brush before the tacking margins were trimmed. IRR examination of the verso revealed an inscription below this priming layer, reading "P. Gaug [...] 89." This inscription is written vertically, and the number "89" is cropped

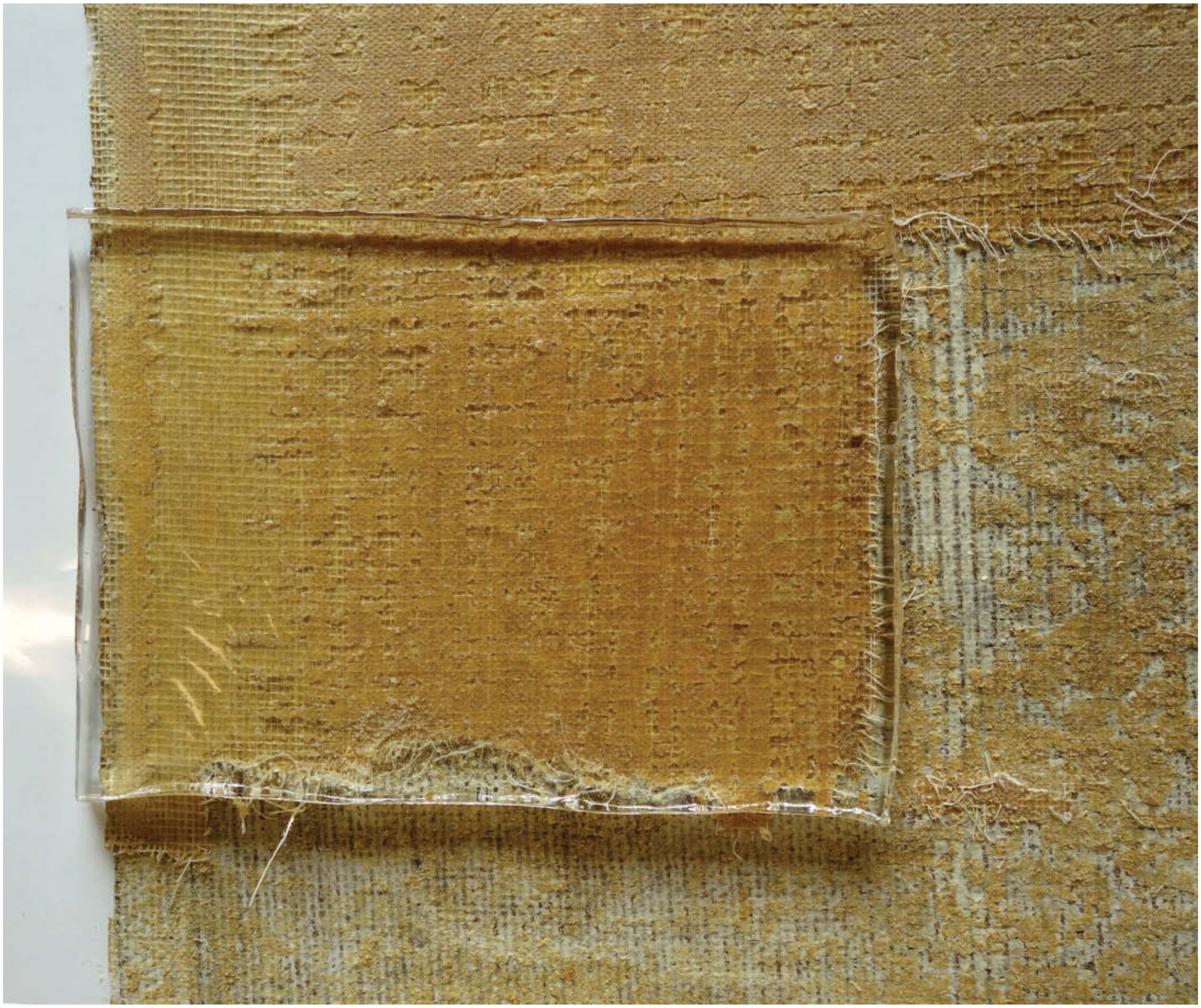

Figure 6. Detail of the verso of *Breton Girl* during lining reversal. A rectangular piece of transparent Gellan gum is positioned the verso with the painting face down. Below the piece of gel and to the right, the muslin and glue layer have been removed and cut away. Above is an area yet to be treated.

along its bottom edge, which corresponds to the right edge of the composition. The painting was edge lined, leaving this verso accessible. As for the verso, the painting was surface cleaned and layers of natural resin and synthetic varnish were removed.

In light of this new knowledge gleaned during examination and treatment, further information on Gauguin's *Human Misery* was needed to better understand the relationship between the two paintings. The Ordrupgaard Museum and the conservation department of the Statens Museum for Kunst that oversees the conservation of the Ordrupgaard Collection kindly provided conservation records for *Human Misery*. This included a treatment report from 1962. The report describes the reversal of a failing lining. Although brief, it notes the lining consisted of a finely woven lining canvas, an openly woven interlayer, and two distinct types of glue used to adhere each layer, one described as stronger than the other. All of this corresponds exactly with what was observed on *Breton Girl*. Finally, it describes a priming layer on the verso of the original canvas accompanied by a photograph that appears consistent with the layer on *Breton Girl*. Research conducted at the Art Institute of Chicago on paintings of the Arles period identified a similar layer on the verso of three other

Figure 7. Image of the verso of *Breton Girl* after lining reversal, with priming-like layer exposed

Gauguin works (Hoermann-Lister, Peres, and Fielder 2001, 359, 362). One of these other paintings is unlined, suggesting the layer is applied as part of the painting, not the lining, process.

At the time of the first lining of *Human Misery*, a strip of canvas 5 cm wide was added to the left edge, bringing the overall size of Gauguin's artist-prepared canvas to the equivalent of a standard size 30 landscape canvas. This addition was done before 1906, as it was present at an exhibition in Vienna of that year. At this time, the painting was still in the possession of its first owner, a fellow painter and friend of Gauguin's by the name of Claude-Emile Schuffenecker.

Today, Schuffenecker has all but fallen into obscurity. His name, if known at all, is usually associated with accusations of forgeries of the paintings of his contemporaries that were first made in the 1920s. But in the 1880s, he was exhibiting and working with Gauguin, Charles Leval, and Emile Bernard, as well as collecting their works to form one of the greatest post-Impressionist collections at the turn of the century. He and Gauguin were close; they met as young stockbrokers working at the same firm, when Schuffenecker introduced Gauguin to painting. Their friendship continued over the years, and each named a son after the other. After Gauguin committed himself to his art full-time, Schuffenecker offered him occasional financial support, and periodically allowed him to stay at his home in Paris where they shared his studio. When Gauguin was away, they would write often, and much of what we can learn about Gauguin comes from his surviving correspondence to Schuffenecker. In a similar fate as so many of Gauguin's relationships, their friendship ended after the two quarreled in the early 1890s.

It is likely Schuffenecker who lined and enlarged *Human Misery*. He had adopted a liberal attitude toward modifying the paintings in his collection as he saw fit. He allegedly extended the dimensions of one of van Gogh's sunflowers, and painted in the sky of a Cezanne landscape, claiming the artist had left it "unfinished" (Van Tilborgh and Hendriks 2001; Grossvogel 2000, 2008). Schuffenecker also made several copies of works in his collection. While many believe Schuffenecker was a forger, the evidence is scarce and circumstantial. Given these practices and the fact *Human Misery* was in his possession, it is very possible Schuffenecker painted San Francisco's *Breton Girl*.

While the figure in *Breton Girl* is copied from *Human Misery,* the presence of a black-and-white image of a painting in the Witt Library Archive, London, discovered late in the research process alters the status of *Breton Girl* as a copy (fig. 8b).[7] When this painting is brought to scale with *Breton Girl*, they align almost perfectly along the right edge of *Breton Girl*, and the left edge of the Stockholm painting. This confirms earlier suspicions the painting was cut down from a larger composition. The combined work would be only 1 cm short of a standard size 50 landscape painting in both directions. The Stockholm painting (current location unknown) is signed "P Gauguin 89." The image depicts two figures, one of which

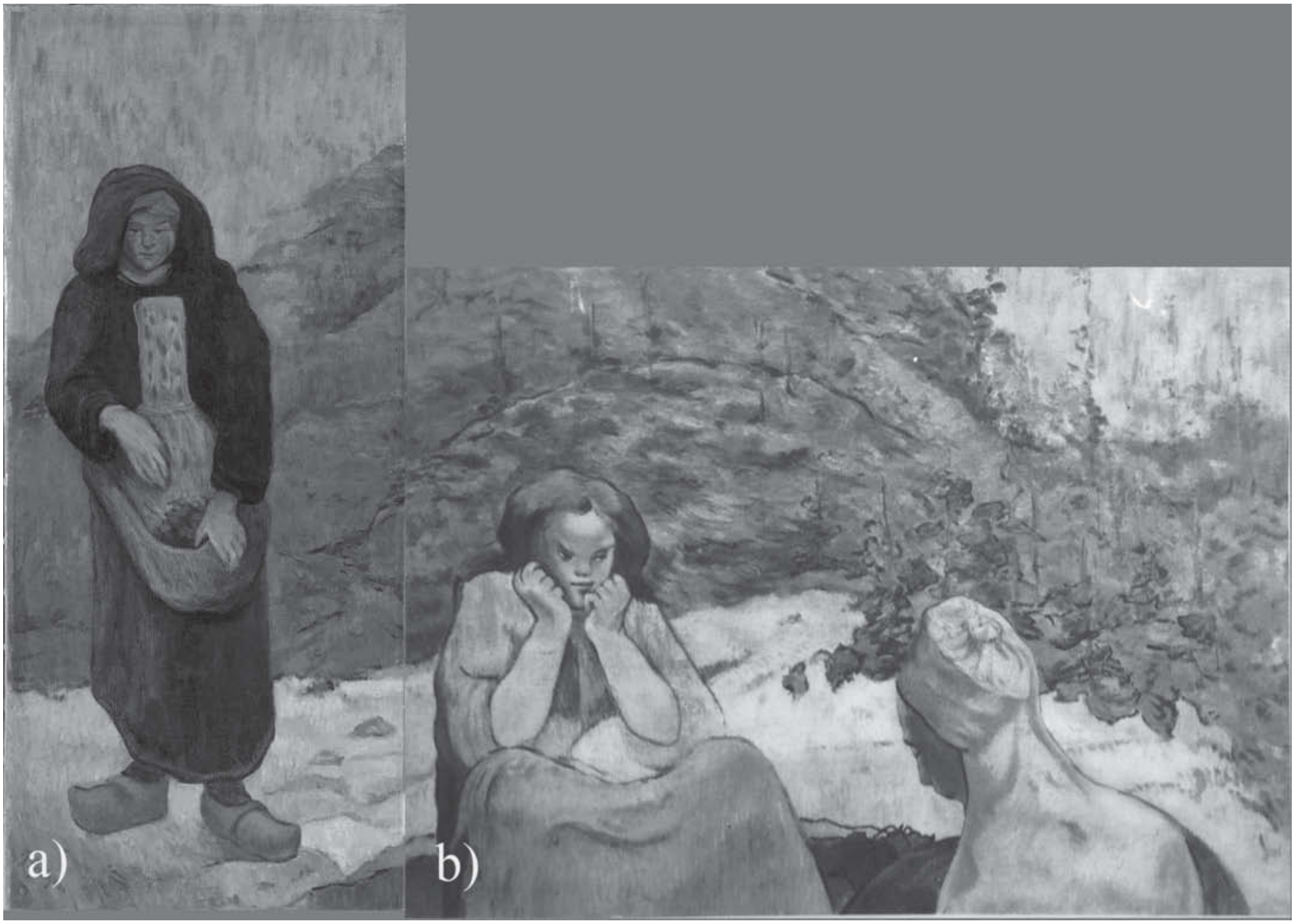

Figure 8. (a) Composite image of *Breton Girl* converted to grayscale and (b) the Stockholm painting. The images are to scale according to the dimensions published with the printed image of the Stockholm painting.

looks very much like the central figure of *Human Misery*. When scaled to size using the dimensions published and digitally traced, the contours align as they did with *Breton Girl*, again suggesting a tracing or common drawing was used.

This revelation transforms *Breton Girl* from a copy to a version. Compositional differences include the absence of the two figures in the background, and the addition of a figure in the foreground. The latter resembles a woman in the foreground of Gauguin's *Yellow Christ*, painted in 1889 (Albright Knox Art Gallery, Buffalo NY). Schuffenecker was also the first owner of this painting (Wildenstein 1964, W327, 125–6). Again, scaling and tracing indicates a transfer method or common drawing was used.

The question of when and by whom the painting was cut remains. Whether *Breton Girl* was produced as a fake or a version in homage to Gauguin is also unknown. In some sense, this is really a question of when the signatures were added, which may have been from its inception, from the time it was cut, or sometime thereafter. The idea that Gauguin himself may have painted the work cannot be ruled out, though the painstaking replication of brushwork would be uncharacteristic.

His access to the two works from which this painting comes, his intimate knowledge of Gauguin's technique, and the connection forged by the identical linings of *Breton Girl* and *Human Misery* make for a compelling case that Schuffenecker painted this montage. At this moment, the artists surrounding Gauguin were also engaging in the practice of making versions and repetitions of their own and others' work, most notably van Gogh, so producing something like this would not have been unusual (Rathbone, Robinson, and Steele 2014). If one accepts the date of 1889, Gauguin would have probably seen this painting as he stayed with Schuffenecker and used his studio during his trips to Paris the same year.

Schuffenecker has emerged as a figure intimately involved in the lives and artistic activity of some of the most influential artists of the late 19th century in France, yet little is known about him. Whether or not Schuffenecker painted it, and assuming it was not produced as a fake, *Breton Girl* embodies the concept of communicating and developing artistic ideas through the practice of producing copies and versions. While this practice is steeped in tradition, it was integral to the development of some of the most avant-garde thinking of the period.

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NOTES

1. Now in the Ordrupgaard collection in Copenhagen, 223WH. Also often referred to in English as *Grape Harvest in Arles*, *The Wine Harvest*, *The Red Vineyard*, or *Poverty*; in French as *Misères Humaines*, *Vendages à Arles*, or *La Pauvresse*. *Human Misery* is the most commonly used title in English literature and will be used to refer to the painting in this article.
2. See Gauguin's letter to Bernard, November 10 1888 (M179 in Merlhès 1984). Gauguin also wrote to Claude-Emile Schuffenecker about the composition on December 20, 1888 (M193).
3. The letter (M179, see note 2) includes a sketch of the painting corresponding to the final composition. This sketch, now in the Fondation Custodia, Paris, is reproduced in Fonsmark 2014, fig. 106.
4. The results of this were used to identify many works by van Gogh and Gauguin to one particular roll of canvas and hence the same period. See Hoermann-Lister, Peres, and Fielder 2001.
5. The Thread Count Automation project was initiated in 2007 and is codirected by C. Richard Johnson Jr. (Cornell University) and Don H. Johnson (Rice University). See Johnson, Hendriks et al. 2009; Johnson, Johnson, Jr. et al. 2009; and Johnson, Johnson, Jr., and Erdmann 2013.
6. Agarose and a methylcellulose gel were also tested at various concentrations.
7. Archival research was kindly undertaken by Kim Clayton-Greene, The British Museum. The image was published as no. 40 in an exhibition catalog from the Nationalmuseum, Sweden. 1958. It is listed as in the collection of Hjalmar Gullberg. Gullberg's collection was sold at auction after his death, and the current location of the painting is unknown.

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THIS ARTICLE HAS NOT UNDERGONE A FORMAL PROCESS OF PEER REVIEW.

ALLISON LANGLEY, KEN SUTHERLAND, FRANCESCA CASADIO, and SONIA MACCAGNOLA

Fracture or Facture: Interpreting Intent during the Treatment and Analysis of Georges Braque's *Ajax*

ABSTRACT

Georges Braque's late painting Ajax *(1949/54) is a unique example of the artist's lifelong interest in exploring and manipulating artists' materials to achieve new surface effects. The painting was made with mixed media on paper attached to two stretched canvases. Braque repainted the composition several times between 1949 and 1954, even as the surface was showing signs of paint flaking and loss, as evidenced by contemporary photographs of the artist's studio. He incorporated select areas of paint loss in the final work yet covered others in later painting campaigns. A technical study of* Ajax *revealed new information about Braque's complex painting technique and unusual combinations of materials, and informed the treatment of the painting.*

1. INTRODUCTION

George Braque's (1882–1963) painting *Ajax* is unique among the artist's late works in size, materials, and subject matter (fig. 1). Braque reworked the painting repeatedly between 1949 and 1954, modulating the pigments and binding media to achieve subtle tonal and gloss variations. *Ajax* entered the collection of the Art Institute of Chicago in 1997 and was initially consigned to storage because of its poor condition. The unusual appearance of the work led to confusion about how to classify and care for it. The paint appeared to be mixed media; the paper support was adhered to two stretched canvases. The complex surface raised questions about the intended surface appearance and appropriate level of intervention. This article will present the recent conservation study of *Ajax*, including analysis of the pigments and paint media, and the treatment of the work.

It was Braque's practice to work on several pictures simultaneously, often returning to individual canvases months, or even years, after having begun them. His late works were in a constant state of development, and he would keep paintings artfully arranged and accessible in his studio, observing their interactions, with pots of paint and brushes at the ready should he be inspired to add to a surface. "I take years to finish them," Braque stated, "but I look at them every day. Arranged as they are, one next to the other, I have them constantly in front of me, I confront them" (Braque 1954, 21; Golding, Bowness, and Monod-Fontaine 1997, 73).

2. EXAMINATION OF THE PAINTING

Ajax is visible in a number of period photos of Braque's studio, prominently on display, a lone vertical figure in the company of his series of large studio paintings, bird paintings, and numerous small still lives and landscapes in various stages of completion.[1] He kept his paintbrushes meticulously organized. He had multiple palettes at the ready, coated and encrusted with paint, many placed on stands he made from wood picked up outside his home. Notably his studios were filled with dozens of cans for mixing paint.

The subject of *Ajax*, the striding mythological figure outlined in black and white, harks back to Braque's graphic work of the 1930s. In 1931 Braque illustrated an edition of the *Theogony* by Greek poet Hesiod, commissioned by the art dealer Ambroise Vollard, that was left unpublished. A renewed interest in the etchings in the late 1940s, and the subsequent publication of the series in 1955, led Braque to reflect upon his earlier fascination with mythological figures such as Ajax. (Golding, Bowness, and Monod-Fontaine 1997, Bowness 2000) Grandson of Zeus and cousin to Achilles, Ajax commanded his army with a shield and sword. In the Art Institute's painting, he is presented in profile. An adversary is implied by a leg disappearing off the right edge. The curvilinear outlines in black-and-white paint mimic the lyrical lines of the early etchings, including the stylized, simplified head and eye at the top of the figure.

Figure 1. Georges Braque, *Ajax*, 1949/54, oil on paper mounted on canvas, 179 × 71 cm, Bequest of Florene May Schoenborn, 1997.447, Art Institute of Chicago, © 2017 Artists Rights Society (ARS), New York/ADAGP, Paris

The support for *Ajax* is a tall, narrow piece of brown paper, adhered to two stretched canvases tacked to a stretcher. The surface of the paper is entirely covered by paint and ground; the tacking edges are covered by paper tape and little of the substrate is visible. The canvas additions, or linings, appear to be original, or at least to have been prepared with the artist's knowledge as the work is signed on the reverse of the second canvas: "GB." Also visible on the reverse is the artist's telling inscription: "NE PAS VERNIR" ("do not varnish"), a warning to anyone charged with care of the work.

3. ANALYSIS

The pigments used for the painting were characterized by instrumental analysis using XRF, FTIR, and Raman spectroscopy (Maccagnola, 2011).[2] The analyses indicated that *Ajax* began as a sketch on a thin, lead-white ground. Parallel lines of black and white outlined the figural form. The earliest paint layers were thin, lean, and matte and seem to have been largely blue and black. The blue remains visible along the left side and in the lower right corner primarily. It is a very thin artist's mix of Prussian blue with small amounts of ultramarine. The figural form was painted in entirely with a matte black paint containing predominantly carbon black. The initial paint layers have a gouache or tempera appearance, which led to speculation about Braque's use of water-based media. Analysis using pyrolysis gas chromatography mass spectrometry with thermally assisted hydrolysis and methylation (THM-Py-GCMS) indicated that all the paint layers on *Ajax*, including the ground, contain oil—probably linseed oil—in some cases modified with pine resin and/or plant gum in different proportions.[3] The early thin matte layers indeed contain greater levels of plant gum proportionately than the upper layers, and this may explain the distinct surface appearance and also perhaps their propensity to flaking. The blue and black layers seem to have had an adhesion problem early on and it can be speculated that this is one reason Braque reworked the surface.

Braque modified the surface with brushstrokes, drips and splatters of dense, medium-rich paint that filled in and obscured parts of the first painting campaign. Brushed and splattered red paint, as well as patches of dark green, light green, brown and gray, covered large portions of the initial blue and black composition, surrounding and partially covering the figural form, changing the palette and adding texture. A Mars red paint was brushed and splattered on the surface, with isolated areas of impasto and glossy patches visible. A light green paint made from a mixture of Hansa yellow and carbon black was applied upper right; it has a satiny sheen and an unusual wrinkled drying texture. A brown layer containing burnt umber was used in several parts of the composition. THM-Py-GCMS analysis detected nicotine in the brown paint, a possible nod to Braque's earlier interest in including nonartist's materials such as tobacco in his paints, or perhaps a consequence of his smoking in the studio. A dense gray paint containing an iron-based black was used in a number of areas on the upper torso of the figure.

Additional changes see the artist redefining parts of the figural composition on top of the upper paint layers that covered the early black outlines. Braque re-outlined the figure's proper right foot over an expanse of dark green, which contains a mixture of Prussian blue, chrome yellow and ocher. At some point a dense bone black paint layer was added around the edges of the composition to form a dark frame. Braque painted over an earlier aqua and tan "Ajax" inscription in the lower right corner with larger black and white letters. He also added looping white contour lines along the right side of the composition. The dense, matte white paint contains predominantly zinc and titanium oxides. Finally, bright Hansa yellow highlights were painted in select areas.

The painting's surface has a remarkably uneven sheen due to local applications of a fluid translucent coating. It is particularly evident top center and remains tacky in thicker areas of application. Long vertical drips run down the picture along the left side, where the oily material picked up underlying color as it moved down the surface. THM-Py-GCMS analysis of a sample from a drip mark located to the left of the figure identified the coating in this area as oil with a trace of pine resin; very pronounced levels of dicarboxylic acids were detected in the oil, a characteristic that has been associated with drying problems and separation in oil media (Corbeil, Helwig, and Poulin 2011; Bronken and Boon 2014).

4. TREATMENT

In his critical essay "Crimes Against the Cubists," art historian John Richardson recalled Braque's attitude toward surface sheen: "Later in his career, when Braque became more 'metaphysical' in his attitude toward reality…he played arbitrary games with the identities of objects by deliberately sending out confusing signals: making something shiny that should be matte, something opaque that should be transparent, and vice versa. It goes without saying that these subtle but crucial contrasts count for nothing if an ignorant collector or a dealer out to dress up his wares had a painting defiled with varnish" (Richardson 1983). This idea is supported by the artist's uneven application of surface coating and his "do not varnish" inscription on the reverse of the canvas.

During examination of *Ajax* it became clear that the painting had a history of instability and that the paint had begun flaking while still in the artist's possession. The early blue and black layers have poor adhesion to the ground, and although the use of mixed media may be a factor, the exact cause remains unclear. Braque covered many losses when he reworked the painting, but he seems to have accepted and incorporated others as part of the composition. Many losses are readily apparent in the upper torso of the figure, for example. On close examination the old exposed losses are splattered with dots of red and green from the later painting campaigns, indicating that they were present when the paint surface was reworked and that Braque intentionally left them visible. There are many of these splattered losses across the surface where they add an additional pattern to the busy composition: some of these, such as a loss on the figure's knee, are quite large.

It was also evident during examination that the older losses were accompanied by many areas of active flaking, cracking, and loss that were relatively recent. For example, the black that defined the figure's head showed active lifting flakes. More recent losses were also visible in the blacks and blues around the foot. Additionally, there were many areas of active cracking and flaking throughout the blue along the left edge.

Period photos of *Ajax* in the studio became a useful guide for interpreting Braque's intentions, and the appropriate level of intervention for treatment. The photos corroborated the physical evidence, indicating that many losses were present and apparent while the painting remained in the artist's position, and that he selectively incorporated these as a part of the surface texture. The photos also helped clarify the degree of flaking and surface change that had occurred in certain unstable areas of paint after the painting left the studio. With the help of high-resolution scans, the early appearance of *Ajax* in the photos could be examined in detail, and in some cases overlaid with a recent digital image of the painting for comparison.

An undated photo by Kurt Blum, in the collection of the Art Institute of Chicago, shows the painting in an unfinished state (fig. 2). The white figure-8-shaped form at the right edge was not yet painted in, for example. Of particular interest, the blue at the left edge of the composition appears intact in the photo, in contrast with the flaking blue visible on the paint surface, confirming that the extensive loss in this area was a more recent development. It is also interesting to note that in the photo, the painting already seems to have the surface coating and variable sheen visible on the finished *Ajax*, including the vertical drips along the left side. The glossy coating was not a final varnish layer apparently, but an aesthetic choice made during the process of painting that was embraced by Braque.

In a studio photo taken by Robert Doisneau, *Ajax* is conveniently positioned in the foreground of the image making for helpful comparison, although the left edge is cropped out.[4] The white figure-8-shaped form has been added to the right edge of the painting suggesting it is likely near completion. A number of losses in the torso are apparent in the photo, and many of these correspond with the splattered losses visible on

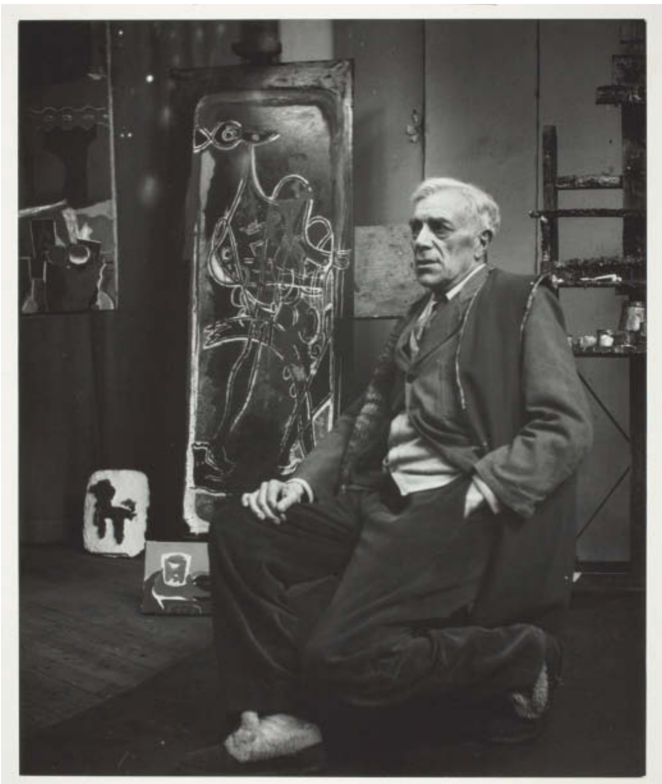

Figure 2. Kurt Blum, *Georges Braque*, n.d.; gelatin silver print, 35.5 × 29.5 cm, Gift of Eberhard Kornfeld, 1967.62, Art Institute of Chicago, © 2017 Artists Rights Society (ARS), New York/ProLitteris, Zurich

the painting's surface, indicating that they were present when the painting was still in the artist's possession. However, many of the tiny white losses and areas of flaking observed during recent examination were not present suggesting that some areas of the painting had deteriorated at a later date.

Ajax required extensive consolidation of the paint surface. Although it is an oil-based paint, the paint film is thin and matte in the areas prone to flaking, cracking, and loss, necessitating the selection of an adhesive that would impart sufficient strength to adhere lifting flakes and dry without darkening the paint or support or leaving a shiny residue. The painting was successively consolidated with ethulose (ethyl hydroxyethyl cellulose) a water-soluble, nonionic cellulose often used in paper conservation. Ethulose was applied in a 4 percent solution dissolved in a 50:50 water/ethanol mixture. Use of a hot-air tool during consolidation helped spread the adhesive and lower lifting flakes in areas where the paint was more pliable.

Recent losses, determined by close observation of the surface during treatment and information gathered from the archival images, as described previously, were inpainted with Gamblin Conservation Colors (paints formulated with a low-molecular-weight, aldehyde resin medium). The early losses, such as those in the black torso, which were clearly visible in the photos and filled with splatters of paint, were left untouched. The surface of *Ajax* was left unvarnished. Braque's subtle but crucial contrasts of matte and gloss remain readily apparent. The boldly striding figure is now more clearly delineated and areas of flaking paint no longer compete visually with the artist's uniquely textured surface.

5. CONCLUSION

Ajax is a prime example of Braque's life-long experimentation with complicated and unusual mixtures of traditional painting materials to achieve new effects. While Braque may be well-known for his addition of particulate matter into his paint: sand, ashes, tobacco, and wood shavings, among others (Richardson 1959); the study of *Ajax* reveals he was also able to create texture by varying the proportions of his paint media, differing the thickness and translucency of his paints, contrasting the means of application, and even accepting paint loss as part of the surface appearance.

Braque's late palette was diverse, featuring both traditional inorganic and modern synthetic pigments. On *Ajax* he used a variety of whites, blacks, yellows, blues, and two greens that interestingly feature no actual green pigment but are artist's mixtures of yellow with either blue or black. Late in his career Braque was clearly stirring and whipping up multiple mixtures of paint and pigment in the many cans covering his studio, combining techniques learned from his early training as a decorative painter, his famed cubist collaboration with Picasso, and the experience gained from decades of working in solitude in the studio, to devise paints that would meet his specific aesthetic needs.

Braque stated: "I work with matter and not with ideas, I mix and match. I've always been much occupied and preoccupied with matter because there is as much sensibility involved in the technique as in the rest of the picture" (Braque 1954, 16; Cooper 1973, 37).

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NOTES

1. Robert Doisneau, Alexander Liberman, Kurt Blum, and Mariette Lachaud took photographs of Braque at work in his studios in Paris and Varengeville in the early 1950s.
2. The elemental composition of the paints was determined using XRF. Pigment scrapings taken from the surface of the painting were further characterized with FTIR, Raman microspectroscopy, and FT-Raman spectroscopy at the Art Institute of Chicago. For detailed discussion of techniques and results see Maccagnola, S., 2011. The medium analysis will be described in detail in a separate paper (forthcoming).
3. For THM-Py-GCMS analysis, paint and varnish samples were placed in Frontier stainless steel sample cups and 2 μL of a 2.5 percent solution of tetramethylammonium hydroxide in water were added to the sample before insertion into a Frontier PY-2020iD vertical microfurnace pyrolyser, with the furnace at 550°C. The pyrolyser was attached to a Varian 3800 GC with Restek Rxi-5ms column (30 m, 0.25 mm i.d., 0.25 μm film), interfaced to a Saturn 2200 MS, transfer line temperature 300°C. The oven was programmed from 40°C, with a 2-minute hold, then increased at 20°C/min to 300°C, and held isothermally for 10 minutes; total run time 25 minutes. Helium was the carrier gas, with a constant flow of 1 mL/min, split ratio 1:10. The MS was run in scan mode (*m/z* 40-600) with the ion trap at 210°C. Data are on file in the Conservation Department, Art Institute of Chicago.
4. Robert Doisneau, *Georges Braque in His studio at Varengeville*, ca. 1957. Doisneau-Rapho. Reproduced in Zurcher, B. 1988, 292.

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A Wealth of Optical Expression: László Moholy-Nagy's Works in the Collection of the Solomon R. Guggenheim Museum

ABSTRACT

A systematic study of the Solomon R. Guggenheim Museum's collection of works by László Moholy-Nagy was carried out through a combination of microscopic observation of the surfaces, noninvasive and micro-invasive analysis, technical imaging, archival research, and replication of the artist's techniques. This research clarifies the composition of some of the artist's industrially sourced support materials and considers the particular qualities of the materials that interested him. Study of the Guggenheim's painted works has shown how he explored light, transparency and reflection using a complex range of paint application and incising techniques. The technical examination has been conducted in tandem with close attention to his extensive writings, investigating cross-pollination among mediums. This article focuses on painted works on plastic and canvas supports and explores how Moholy's materials and techniques furthered his lifelong quest to "paint with light."

1. INTRODUCTION

László Moholy-Nagy (1895–1946) was a pioneering artist of the twentieth-century avant garde. He worked in a wide range of mediums, including painting, sculpture, photography, industrial and stage design, and film, and he wrote prolifically about his artistic ideals. He was a passionate educator at the Bauhaus in Weimar and in Dessau, and subsequently directed the New Bauhaus (later called the School of Design and the Institute of Design) in Chicago, promoting Bauhaus pedagogical ideas and pursuing his utopian ideal of integrating science and technology into the arts.

Moholy holds a signifant place in the history of the Guggenheim Museum. He was one of the first 20th century artists collected by Solomon Guggenheim, who recognized Moholy's importance as a nonobjective painter and acquired a large group of his works in a range of materials that span most of his career. They include paintings on canvas, opaque plastic, highly polished aluminum and Plexiglas. There has been long-standing confusion about many of the unconventional, industrially sourced support materials and questions about appropriate presentation and storage. The collection offered a unique opportunity to study Moholy because it was relatively untouched, but some of the works needed treatment, which could not be undertaken without a better understanding of their materials and of the artist's intent.

A comprehensive retrospective, co-organized by the Guggenheim, the Art Institute of Chicago and Los Angeles County Museum of Art, provided the impetus for the first systematic technical study of the Guggenheim Moholy collection. In the most extensive analysis carried out to date on Moholy's painting materials, the compositions and states of preservation of many of the supports, pigments, and binders were characterized in depth.[1] The examination of related works in other collections and international archival research supplemented the research on the Guggenheim collection. The Guggenheim Conservation Department also conducted extensive interviews with the artist's daughter, Hattula Moholy-Nagy. Bringing together conservators, scientists, the exhibition co-curators, and prominent Moholy scholars for informal, interdisciplinary symposia helped to contextualize the technical findings and enabled the research to have a meaningful role in the planning of the retrospective. This article summarizes some highlights of the study; many of the analytical findings will be published in detail elsewhere.

In 1934, Moholy wrote to his second wife Sibyl: "…there are so few people who can really grasp [my paintings] in their reality…because they don't know anything about the effort put into their making and nothing about the overarching problems with which these paintings engage" (Tsai 2009, 146).[2] Although the complex works raise multifaceted issues, this systematic study has taken on the ambitious challenge of understanding how his materials and techniques furthered his artistic agenda.

A common thread that underlies much of Moholy's work was his desire to use light as a medium. Very early in his career, beginning in 1922, he began making cameraless photographic images, or photograms, by positioning objects in front of photographic paper and exposing them to light. He considered the photogram to be a form of painting that used light instead of pigments, and eventually became so impassioned about the photogram's potential that he declared that "manual pigment painting" had become antiquated and that it would "have to renounce its traditional valuation" (Moholy-Nagy [1929] 1985, 305). In the late 1920s, with revolutionary determination, he abandoned traditional painting with the dramatic proclamation that he would "paint with light" as his sole medium. Yet, after just a few years, concurrent to his work with photography, he returned to painting and continued to paint prolifically for the rest of his life. Why return to painting when he had exalted photography as "the way of the future to a more sublimated visual mode of expression" (Moholy-Nagy [1929] 1985, 306)? Our objective has been to study Moholy's painted works in the context of his large body of writings and his overall artistic production to understand how his paintings furthered his lifelong explorations of light, transparency, and reflection.

Studying the painted works under the microscope reveals a surprising degree of complexity and precision, even at a very fine scale. In his painting on canvas entitled *Leuk 4* from 1945, for example, there is a remarkable range of impasto (fig.1). Each area of paint on *Leuk 4* has a distinct texture, ranging from various styles of stippling to scribing into the paint with a blunt tool. This variety of surface is typical of most of his works after around 1930, including his paintings on plastics and metals.

At first glance, this attention to texture seems antithetical to Moholy's earlier disparagement of painting, but seen in the context of the Bauhaus, it makes much more sense. The study

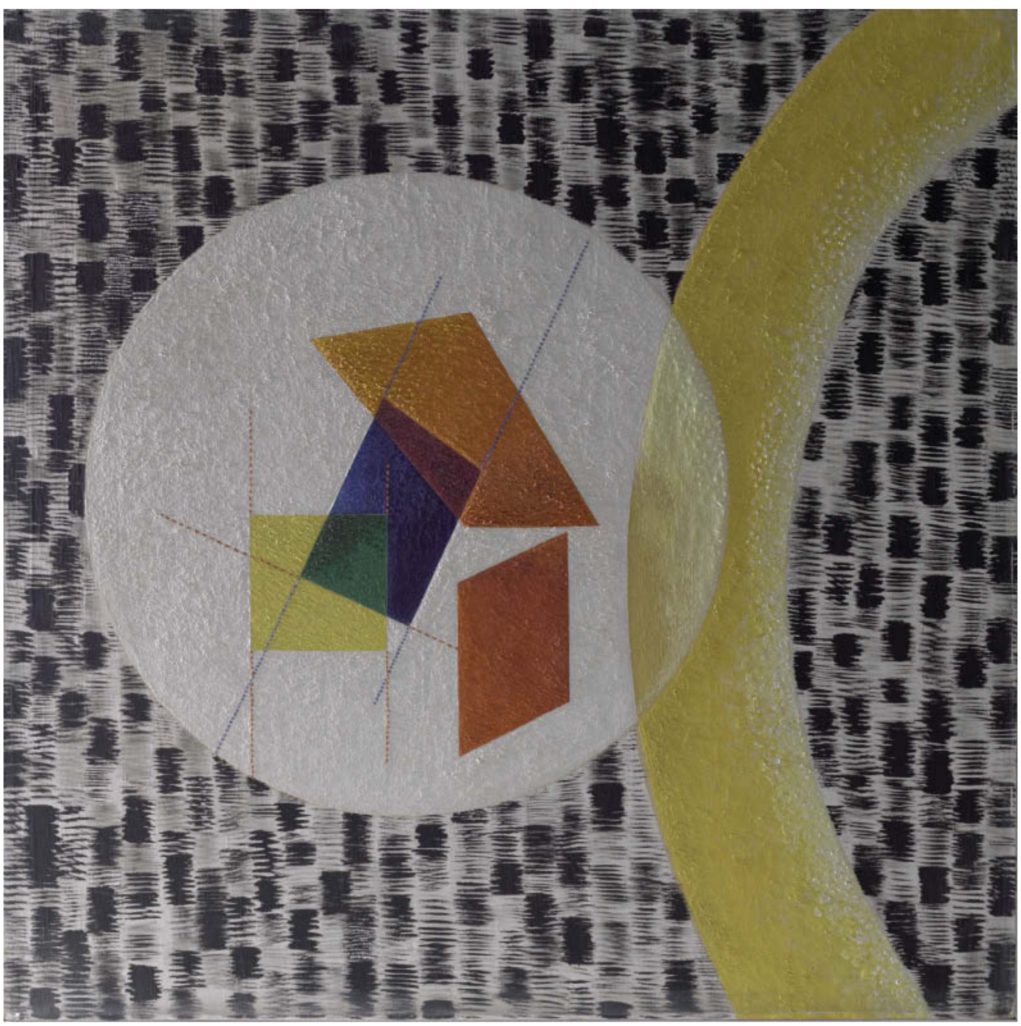


Figure 1. László Moholy-Nagy, *Leuk 4*, 1945; oil and graphite on canvas, 49 × 49 in. (124.7 × 124.7 cm), Solomon R. Guggenheim Museum, New York (48.1124); raking light image.

of surface treatments was a fundamental part of the Bauhaus curriculum, promoted most avidly by Moholy. Moholy reproduced examples of student work in his book *The New Vision* to illustrate the importance of experimenting with surface textures in every possible material, including wood and paper (Moholy-Nagy [1938] 2005). Seen in this context, it seems that Moholy's permutations of surface were one way of incorporating this pursuit into his own works. As usual, light may have been his focus: he used the varieties of paint surface to entrap and manipulate light and shadow. In *The New Vision* he clearly illustrated and described how different brushwork applied with the same oil paint generates different light effects, and even wrote (of the Impressionists): "surface treatments…had to be mastered if *light* was to be fixed on canvas" (Moholy-Nagy [1938] 2005, 72–4). Moholy also used the textural effects to differentiate between areas of overlapping forms and to suggest different degrees of translucency.

For Moholy, there was always cross-pollination across mediums and his own aerial photographs explored (among other things) a similar interest in surface texture and in the modulation and definition of materials by light and shadow. He captured the textures of ripples in the water, for example, or of chairs, umbrellas, and tables viewed from high atop the Berlin Radio Tower. Moholy also had an interest in scientific photography and an awareness of the textures of highly magnified materials from seeing illustrations in scientific journals. He published photomicrographs of paper, metal, and worm-eaten pine in *The New Vision* (Moholy-Nagy [1938] 2005). His interest in structure of materials at a magnified scale seems to affirm the relevance of very close scrutiny of his work.

Transparency and translucency fascinated Moholy from early in his career, and many of his early paintings depict overlapping translucent planes of color. The illusions of overlapping forms in his paintings are rarely accomplished through literal layering or mixing of paint. He drew the compositions accurately, typically with graphite pencil, and then painted each section with discrete pigment mixtures. At times, two areas of color will convey the illusion of overlap in space but the area of intersection will contain entirely different pigments, as evident from analysis performed on his 1924 painting *A II* (figs. 2, 3).[3]

Moholy's desire to bridge art and technology and his interest in light effects led him to experiment with new materials, often very soon after they entered the market; for example, he painted on early plastics like Rhodoid, Zellon, Celluloid, and Galalith (Tsai and Waentig 2015). In the Guggenheim's collection, there had been long-standing confusion about the supports of two paintings entitled *T1* (1926) and *Tp 2* (1930), which had been classified since their acquisition as either

Figure 2. László Moholy-Nagy, *A II*, 1924; oil and graphite on canvas, 45⅝ × 53⅝ in. (115.8 × 136.5 cm), Solomon R. Guggenheim Museum, New York (43.900)

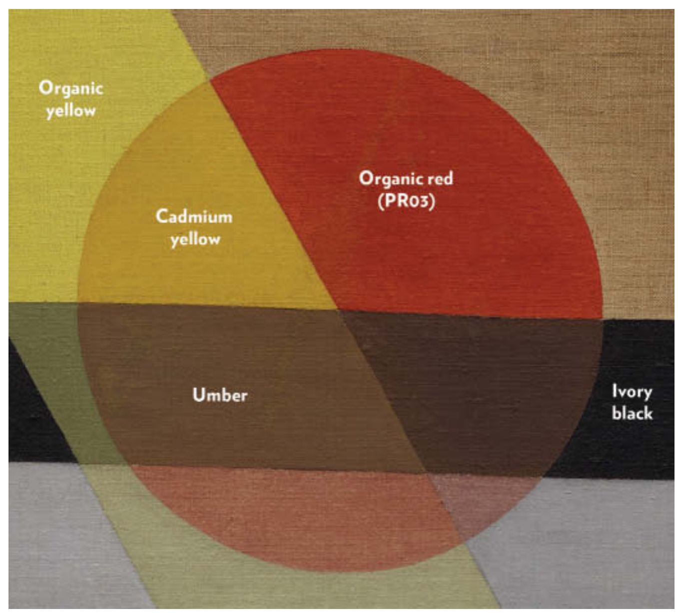


Figure 3. László Moholy-Nagy, *A II*, Solomon R. Guggenheim Museum, New York; detail showing principal pigments identified

Trolitan or Bakelite, both trade names for relatively stable phenol formaldehydes (figs. 4, 5). Analysis using a range of techniques has instead characterized this plastic as pigmented cellulose nitrate, and research has clarified that the highly polished opaque plastic was manufactured under the name Trolit-F at a plastics factory in Troisdorf, Germany (Hofmann

Figure 4. László Moholy-Nagy, *T1*, 1926; oil, sprayed paint, incised lines, and paper on Trolit, 55⅟₁₆ × 24¼ in. (139.8 × 61.8 cm), Solomon R. Guggenheim Museum, New York (37.354)

2014; Salvant et al. forthcoming). The blue and black backgrounds of these two paintings comprise the exposed, unpainted Trolit. In 1927, Moholy had explained his attraction to the material (in a footnote): "Valuable artificial materials are being produced today for the electro-technical industry… Experiments with painting on highly polished black panels (Trolit)…produce strange optical effects: it looks as though the color were floating, almost without material effect, in a space in front of the plane to which it is in fact applied" (Moholy-Nagy [1925] 1969, 25). A photograph of a room Moholy designed for the Paris Werkbund exhibition in 1930 shows Trolit wall panels, and advertisements promoted Trolit as a material for fabricating dials, lamp, and radio parts, calling it the "Handyman's joy" (Breuer 1930; Hofmann 2014).[4] Clearly, Moholy appropriated a material that had not been designed as a painting support.

Moholy adopted many new materials that allowed him to create dematerialized optical effects such as floating and hovering forms. Fortunately, in this case, the dematerialization has not extended to the actual plastic.[5] The Trolit panels are in surprisingly good condition for cellulose nitrate, probably because they are darkly colored and highly filled with materials—including gypsum and zinc oxide—that may have a stabilizing effect, and there is no visible evidence of plasticizer loss. Scanning electron micrographs show the high concentration of fillers, present along with ultramarine pigment in the blue plastic of *Tp 2* (fig. 6).

Moholy used complex techniques on the painting *T1* to enhance the impression of floating, including an early artist's use of sprayed paint on the circular forms. The top circle has a resist effect created by layers of red and black glossy paints; air bubbles appear to have formed in the glossy top black layer, and as they popped they exposed the underlying red layer (fig. 7a). In a letter to Galka Scheyer, Moholy referred to briefly sourcing suitable paints for his spraying apparatus from industrial firms around the time when he painted *T1* (Moholy-Nagy 1938).[6] This painting was too pristine to justify sampling, but the high level of gloss and the evidence of air bubbles suggest that this effect was achieved by spraying with industrial enamel paints. A former student of Moholy's remembered him stooping down to examine the highlights in the bubbles in saliva on the sidewalk (Kozman 1999); clearly, a similar attention to detail underlies this passage.

The very intricate smaller circle on *T1* has a more obvious use of layers of sprayed paint, as well as collaged paper and incised lines. The center of the circle consists of a 1-in. diameter disc of collaged paper with a smaller sliver of paper adhered around

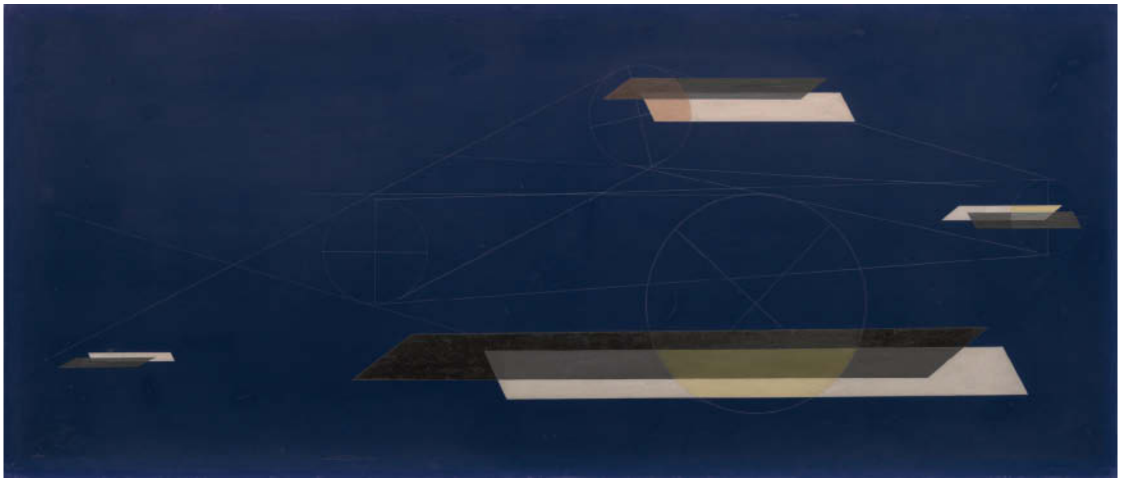


Figure 5. László Moholy-Nagy, *Tp 2,* 1930; oil and incised lines on Trolit, 24¼ × 56¾ in. (61.5 × 144.3 cm), Solomon R. Guggenheim Museum, New York (37.357)

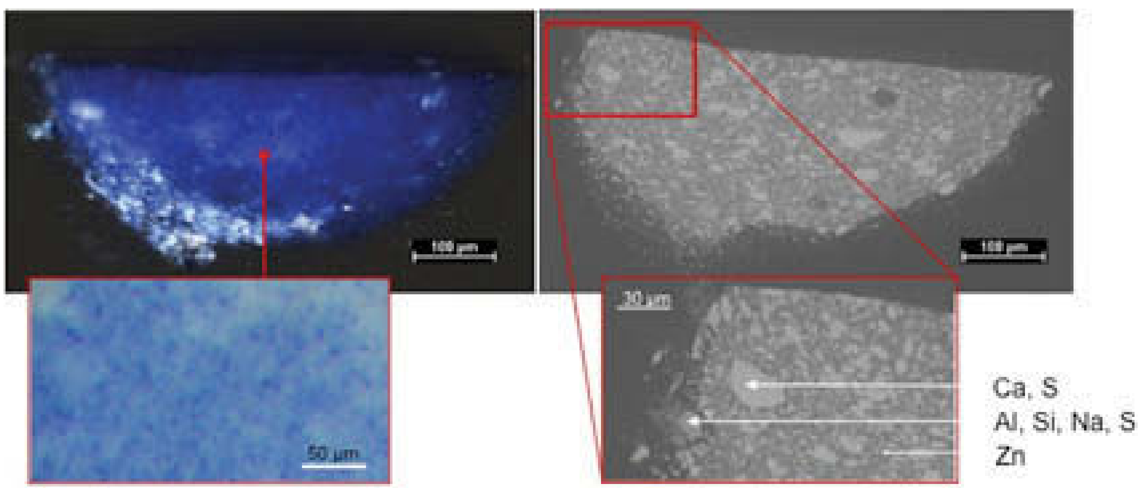


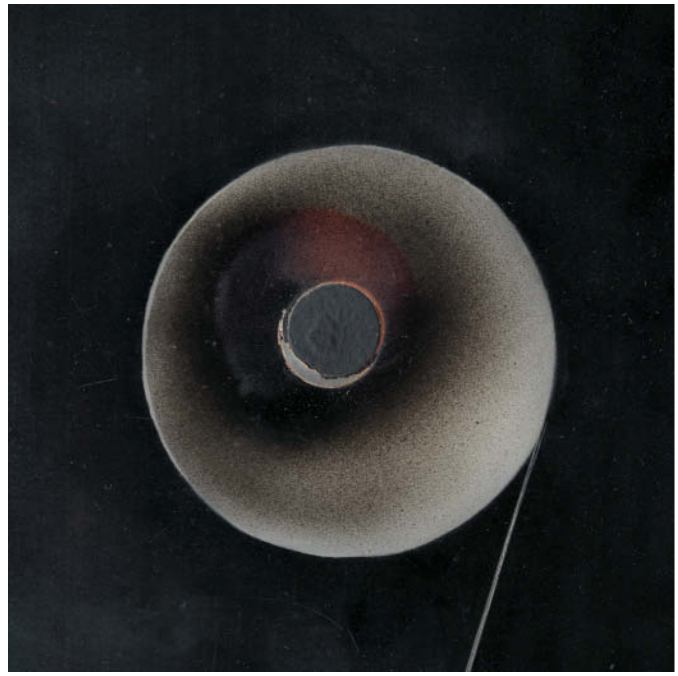
Figure 6. László Moholy-Nagy, *Tp 2,* Solomon R. Guggenheim Museum, New York. Visible light micrograph of a polished cross-section sample from the support along with detail of an unmounted sample (left), and backscatter electron SEM image of the cross section (right); elemental data from analysis by EDS are shown on the right corresponding to abundant particles of gypsum, along with ultramarine and zinc oxide.

part of the perimeter, again showing an acute attention to detail and texture (fig. 7b).

Moholy drew a parallel between the effects of the airbrush technique and the photogram in his book *The New Vision*, referring to similarities in their optical properties and the potential of both techniques to subordinate materials (Moholy-Nagy [1938] 2005, 85–6). The composition of *T1* seems to relate closely to a photogram dating several years earlier (see Heyne and Neusüss 2009, fgm 81, p.94), again demonstrating the influence one medium had on another in his work.

In 1934 Rohm and Haas began producing cast sheets of poly(methyl methacrylate) under the name Plexiglas (Waentig 2008, 272). Although it was marketed for industrial applications like airplane windshields, it was ideally suited to Moholy's explorations of transparency and reflection, and he quickly embraced it as a material for sculpture and painting. A number of the Plexiglas works

7a



7b

Figures 7 (a, b), László Moholy-Nagy, *T1*, Solomon R. Guggenheim Museum, New York; details of spraying technique (a, b) and collaged paper (b).

have tiny stamps in their corners that read, "Rohm & Haas Plexiglas" and state the month and year the supports were manufactured (fig. 8).

Moholy painted with oil on Plexiglas and suspended the supports with clips or rails several inches in front of white backings so that light would pass through the clear areas and

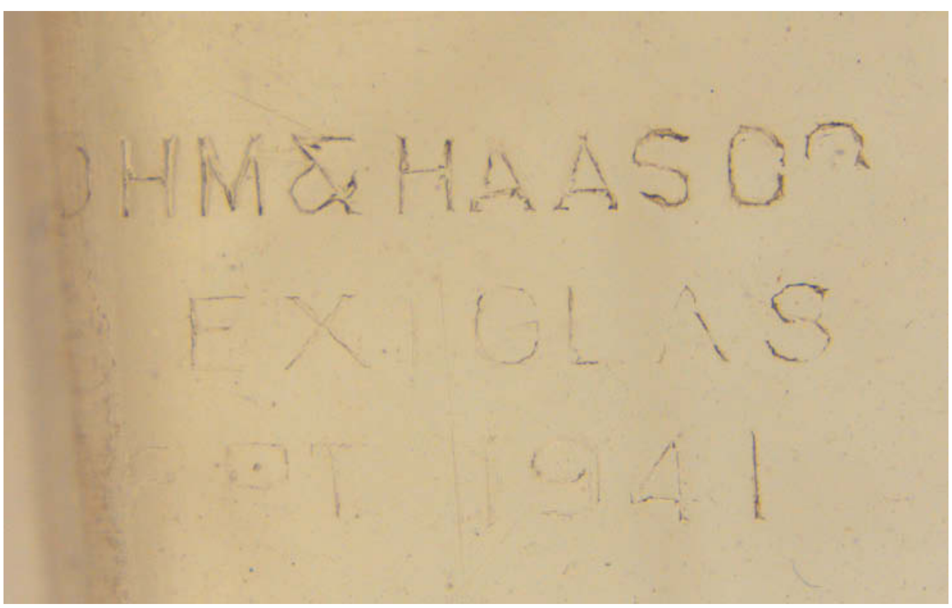


Figure 8. László Moholy-Nagy, *CH 4*, 1941; oil and incised lines on Plexiglas, 35⅞ × 35⅞ in. (91.2 × 91.2 cm), Solomon R. Guggenheim Museum, New York (48.1109); detail of manufacturer's stamp in lower right corner, 11 × 16 mm

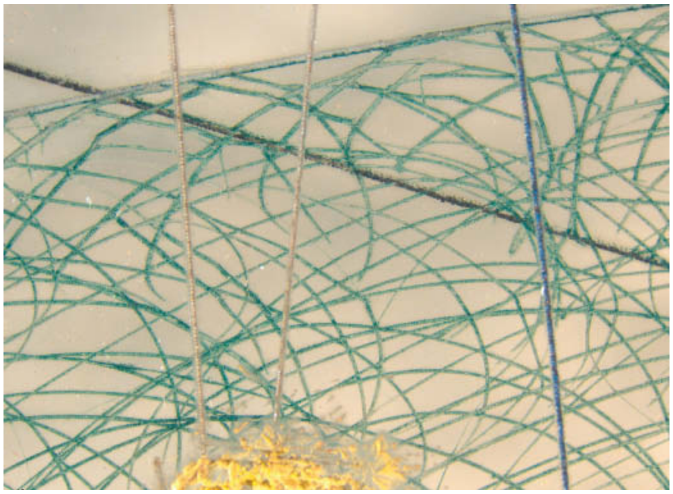
Figure 9. László Moholy-Nagy, *CPL 4*, 1941; oil and incised lines on Plexiglas, 23 × 36¼ in. (58.4 × 92.1 cm), The Hilla von Rebay Foundation, on extended loan to the Solomon R. Guggenheim Museum, New York (1970.132)

the painted areas would cast shadows (fig. 9). The paintings appear superimposed on the shadows they cast, and the shadows can be manipulated dramatically by the direction and intensity of the light sources. He painted the Plexiglas on both sides and created a complex interplay between recto and verso. These works engage Moholy's concept of "vision in motion," endlessly fluctuating in appearance with movements of light and the position of the viewer.

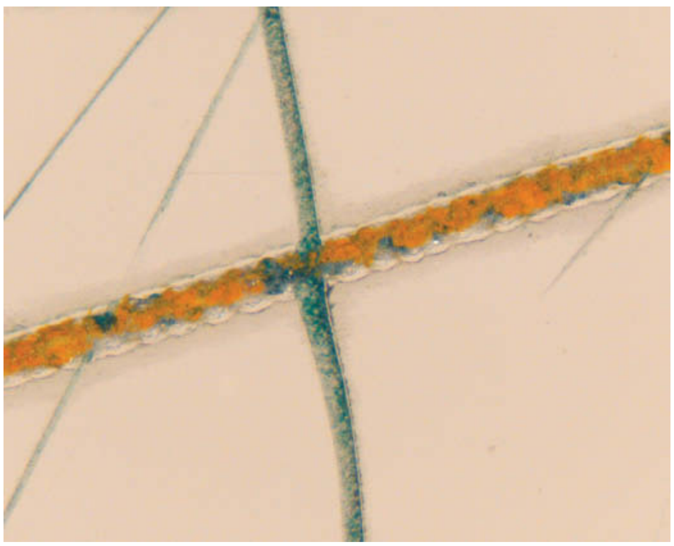
Moholy incised his compositions on the transparent plastic, using different sizes of pointed tools (figs. 10a, 10b). He created a variety of incisions, some on the front and some on the back. Some incisions contain paint and he left others unpigmented so that their edges catch light at certain angles and they cast softer shadows. The pigmenting of the incised lines is comparable to the inking of etched or engraved lines in printmaking: Moholy applied the paint and then carefully wiped it away from the surface, leaving it deposited only in the grooves. At times, adjacent or intersecting incisions are differently pigmented, indicating a remarkable precision and attention to detail. Some of the incisions have a beaded texture caused by "chatter" on the acrylic, and these hold the paint slightly more proud of the surface (figs. 10b, 10c).

Again, he makes a comparison with photograms: "There is a possibility of scratching the surface with fine lines of different density which throw shadows of varied gray values on the screen, similar to the fine gradations of grays in the photogram" (Moholy-Nagy [1947] 2005, 227). He used the word "screen" to refer to the backing board behind the Plexiglas, which he considered an integral component of these works.

Moholy also made denser networks of incisions beneath the more heavily painted areas. *Space Modulator* (1939–45) is one of the most complicated works in the Guggenheim's collection (fig. 11). Although he wrote of the need to score the smooth plastic so that the paint would stick to it (Moholy-Nagy [1947] 2005, 228), the wide range of incision styles beneath the thickly painted passages reveal that they became part of his language of drawing, rather than just a means of improving adhesion. As with many painted Plexiglas works, there is paint on the verso, meant to be viewed through the recto. The incisions under some painted areas are cross-hatched, while under others they are swirling lines. Clearly seen through the front, the incisions become another variation on surface treatment.



10a



10b

Figures 10 (a-c). László Moholy-Nagy, *CPL 4*, The Hilla von Rebay Foundation, on extended loan to the Solomon R. Guggenheim Museum, New York; details of (a) incisions with paint, 20 × 28 mm; (b) incisions with different widths, textures, and paints, 3 × 5.5 mm (c) paint in an incision with "chatter," 2 × 2 mm.

10c

Figure 11. László Moholy-Nagy, *Space Modulator*, 1939–45; oil and incised lines on Plexiglas, Solomon R. Guggenheim Museum, New York (47.1064); lit with a bright spotlight to create dramatic shadowing that shows the flaws in the Plexiglas.

Some of the intricate interrelationships between recto and verso are so complex that they can only be fully understood under magnification. Moholy precisely calculated very complex details to be seen through the front by elaborate layering of incisions and paint from the back. Pigmented incisions on the recto cast shadows on the painted areas of the verso; clearly he took advantage of the thickness of the Plexiglas to enable this kind of effect (fig. 12).

Another work on Plexiglas, *Space III* (1940), also illustrates a complex recto/verso interplay, with a range of incisions, some pigmented and some not, some drawn free hand and others ruled, and again there is shadowing both on the verso and on the backing (fig. 13).

Figure 12. László Moholy-Nagy, *Space Modulator*, Solomon R. Guggenheim Museum, New York. Detail of recto showing complex recto/verso interplay between incisions, paint, and shadows, 21 × 28 mm. Only the five vertical incised and red-pigmented lines are on the recto. Crosshatched incisions beneath the yellow paint on the verso both improved paint adhesion and serve as a drawing element.

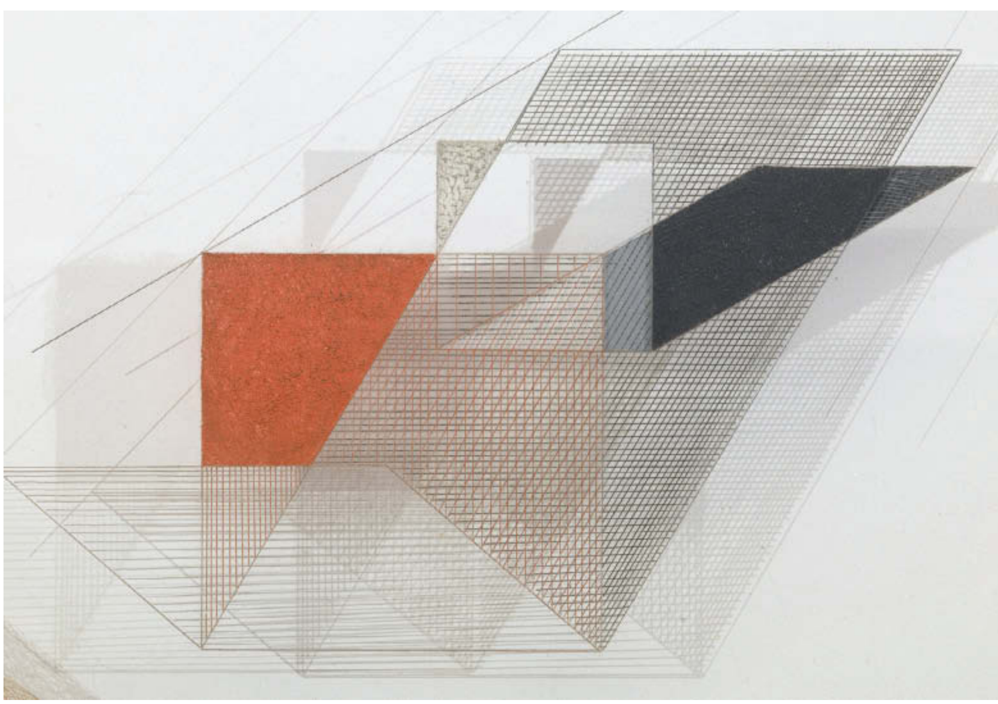


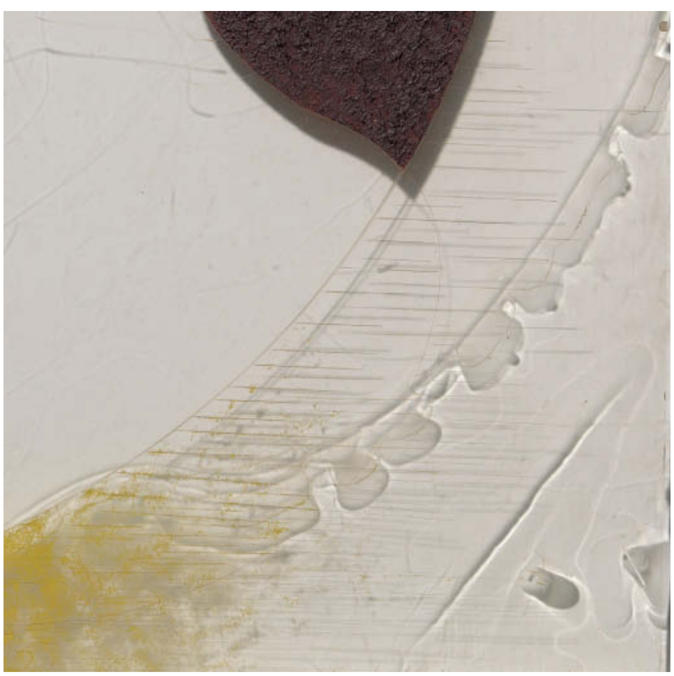
Figure 13. László Moholy-Nagy, *Space III*, 1940; oil and incised lines on Plexiglas, 48 × 36 in. (121.9 × 91.4 cm), The Hilla von Rebay Foundation, on extended loan to the Solomon R. Guggenheim Museum, New York (1970.41); detail showing complex incising and painting of Plexiglas on recto and verso and the dramatic shadows cast when the work is lit with a bright light.

There is a striking consistency of vision within Moholy's body of work, spanning across very diverse mediums. For example, his 1931 set design for *Madame Butterfly* and his 1926 photograph *Dolls on the Balcony* evoke the painted Plexiglas works, exhibiting a similar interplay between solid forms and their cast shadows.

Some of the most fascinating effects are those Moholy achieved using sheets of Plexiglas with flaws. On *Space Modulator* linear imperfections radiating from the top edge had been misconstrued as cracks and the organic, bubbly shapes on the right were perplexing until the work was very closely studied in consultation with experts in plastics conservation and from the plastics industry (figs. 14a, 14b). Research confirmed that the overheating of the PMMA mass during polymerization would have caused these kinds of bubbles, distortions, and arrays of linear imperfections to form as the original sheet was manufactured (van Oosten and Marques 2014, pers. comm.). It is important to recall that the work dates to quite early in the history of Plexiglas. Moholy embraced and accentuated these defects because of their ability to cast exquisite shadows. As bright light filters through the defects, the flawed material dissolves into watery shadows and reflections that are infinitely variable and difficult to distinguish from the solid plastic. An inscription on the back of the original frame reads, "this work requires a very strong spotlight," leaving little doubt about the central role played by light. Moholy painted at least two other works on similarly flawed sheets of Plexiglas.[7]

Moholy also realized that he could take advantage of the thermoplasticity of Plexiglas and introduce his own distortions. On *B-10 Space Modulator* (1942) he heated the Plexiglas in his kitchen oven (Hattula Moholy-Nagy 2014), and then molded it by hand, probably after painting it.[8] A comparison of the work, photographed at the same scale but under different lighting conditions, demonstrates how light dramatically transforms it and some of the variable effects that can be achieved. The work can be made to expand on the wall by manipulating the number and direction of light sources; the perceived boundaries between physical material, reflection, and shadow dissolve and merge (figs. 15a, 15b).

The desire to create dematerialized light effects that began with the photogram permeates much of Moholy's subsequent work. Ironically, it has taken a study of materials and painting techniques to begin to elucidate how Moholy-Nagy truly did "paint with light."



14a

14b

Figures 14 (a, b). László Moholy-Nagy, *Space Modulator*, Solomon R. Guggenheim Museum, New York; details of flaws in Plexiglas.

15a

15b

Figures 15 (a, b). László Moholy-Nagy, *B-10 Space Modulator*, 1942; oil and incised lines on Plexiglas, Solomon R. Guggenheim Museum, New York (47.1063); lit with a single, central light source (a) and with two lateral lights (b) to show variability of perceived size of work.

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NOTES

1. Materials analysis was performed using a complement of analytical techniques including in–situ X-ray fluorescence (XRF) spectroscopy and Fourier transform infrared (FTIR) spectroscopy in reflectance, along with transmitted FTIR and Raman spectroscopy, Scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), nanoindentation, and Pyrolysis gas chromatography mass spectrometry (Py-GCMS) on a small number of samples. Detailed results will be presented in separate publications.
2. October 9, 1934 letter, quoted and translated by Tsai.
3. Pigment analysis was conducted in situ, noninvasively using XRF and FTIR in reflectance. Only the main pigments identified have been noted in figure 3.
4. Advertisement for Trolit is from Heimatblätter Sieg-Kreis, July 1928, reproduced by Hofmann.
5. A number of works by Moholy on cellulose acetate have deteriorated quite severely and are no longer exhibitable.
6. The letter discusses the painting *A3* (1926); "…it was on my first or second aluminum picture that I tried to use a spraying apparatus."
7. *Papmac*, 1943 (private collection), and *Untitled*, 1942 (Museum of Modern Art, New York, 526.1961) are also painted on Plexiglas with flaws.

8. Fine cracks in the paint are visible in several areas under magnification along the folds of curves, suggesting that the shaping occurred after the paint was applied. Northwestern University's Research Experience for Undergraduate (REU) student Amy Gonzales was able to replicate the process of heating and forming the Plexiglas sheet after painting on it with oils. (For more on her observations see her blog at http://www.nuaccess.northwestern.edu/blog/index.html.)

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BRADFORD A. EPLEY and CORINA E. ROGGE

Response and Interplay between Artist and Materials in the Late Paintings of Barnett Newman

ABSTRACT

Barnett Newman's late paintings (1965–70) document his transition from oil to acrylic media. Visual examination of the works in conjunction with mockup studies using historic Bocour Aqua-tec acrylic paints and media suggest that Newman developed new methods of paint application involving both rollers and brushes, and may have modified his paints with the addition of acrylic media and varnish to create gloss differences. Comparative pigment analysis suggests that Newman was choosing not to utilize off the shelf Aqua-tec paints, rather he had made to order the colors desired or perhaps mixed them himself.

1. INTRODUCTION

"Anyone who knows anything about art techniques knows that to paint the large areas I do in free space in terms of the whole image requires the greatest skill and artistry" (Newman 1957).

The paintings of Barnett Newman (1905–1970) have come to define the spiritual aspirations and material innovations of American painting in the mid-twentieth century. Large and bold vertical planes of color, with thin upright lines that came to be known as "zips," characterize Newman's pictorial vocabulary. In contrast to the horizontal compositions that define the landscape tradition in Western art, Newman's work reflects the upright posture of the human body. For the artist, this reorientation was deeply political. He felt it could free painting from the past and allow an entirely new sense of self-awareness for the viewer through the ineffable experience of standing in front of his paintings. Initially, for his larger paintings, Newman provided specific viewing-distance instructions, recommending viewers stand closer to the paintings than intuitively inclined to do so to enhance their sense of envelopment by the painting thereby increasing their emotional response (O'Neill 1990).

Newman's sudden death on July 4, 1970, left his studio frozen in time—paintings hung on Kraft-paper-covered walls, paint jars, tools, and other supplies neatly stacked on shelves—all documented photographically by Alexander Liberman, Paulus Leeser, and filmmaker Emile de Antonio (fig. 1). This photodocumentation provides an intimate look into Newman's working method, because although Newman was interested in new materials and how to best utilize them, and loved to "talk shop" with artist colleagues (Siegel 1971; Mancusi-Ungaro 2004), he never wrote about his own technique. He was also notoriously private about his painting process. Not even Newman's wife, Annalee, was permitted to see him at work on anything beyond the initial preparatory steps (Murray 2015). Because of the lack of the direct evidence mentioned earlier and because Newman did not make preparatory sketches or studies, the images of the studio, preserved materials, and, in particular, the unfinished works that were present provide unique information about Newman's process.

One of the prime motivations for the exhibition *Barnett Newman: The Late Works*, March 27–August 5, 2015, at the Menil Collection, Houston, Texas, was the opportunity for in-depth analyses of Newman's late paintings, which reveal the remarkable innovations and transformations including the shift from oils to acrylics that took place in Newman's work between 1965 and 1970. The research focused around a core of eight paintings held by the Menil Collection, a corpus that includes three unfinished works donated to the museum by Annalee Newman. In addition, sampling and analysis of Newman's paints, which included both Liquitex and unlabeled jars, was permitted by the Harvard Art Museum Center for the

Figure 1. Painting supplies in Barnett Newman's studio, 1970. Courtesy of Alexander Liberman. The Getty Research Institute, Los Angeles (2000.R.19)

Technical Study of Modern Art (CTSMA). Other samples of Newman's paints, including Bocour Hand Ground Oils, Bocour Artist Oils, Bocour Magna, and unlabeled jars of paint, were donated to the Menil Collection by Robert Murray. This permitted direct comparison between paints found on the paintings and paints present in Newman's studio at the time of his death. Historic Bocour Aqua-tec acrylic paints in the Art Materials Research and Study Center of the National Gallery, Washington, DC (NGA), were also analyzed as Aqua-tec paints were present in Newman's studio (as revealed by the aforementioned photographers), and receipts and historical accounts indicated Newman favored that brand of acrylic paints (Mancusi-Ungaro 2004; BNFA 1970). In dialogue with his early works from the late 1940s through to the early 1960s, the late paintings also provide a way of better understanding the formal developments in Newman's painting process, including the extent to which new paint and roller-application techniques permitted Newman to achieve his late large works of increasing visual subtlety.

2. ANALYSIS OF THE PAINTS

Two late works in the Menil Collection, *Unfinished Painting [Red & White 1970]* (1970) and *Unfinished Painting [Blue & Brown 1970]* (1970) (figs. 2, 3) both display bright red paints, in the latter case as a subsurface layer partially exposed on turnover edges. XRF analysis[1] suggests that the primary pigment in both cases is likely a cadmium sulfoselenide red with no detectable amounts of barium sulfate present. A sample of Liquitex cadmium red light paint from Newman's studio and now in CTSMA's collection is clearly labeled as being "coprecipitated with barium sulfate" and indeed high levels of barium are detected in the sample (fig. 4). Likewise, samples of Bocour Aqua-tec cadmium red light, cadmium red medium, and cadmium red deep from the NGA collection exhibit high levels of barium. However, three jars of unlabeled red paint from Newman's studio, now preserved at CTSMA, contain only trace amounts of barium, suggesting that they may be similar to the paint used on the unfinished

Figure 2. Barnett Newman, *Unfinished Painting [Red & White 1970]* (1970), acrylic on canvas, 243.8 × 548.6 cm, The Menil Collection, Houston (1986–37)

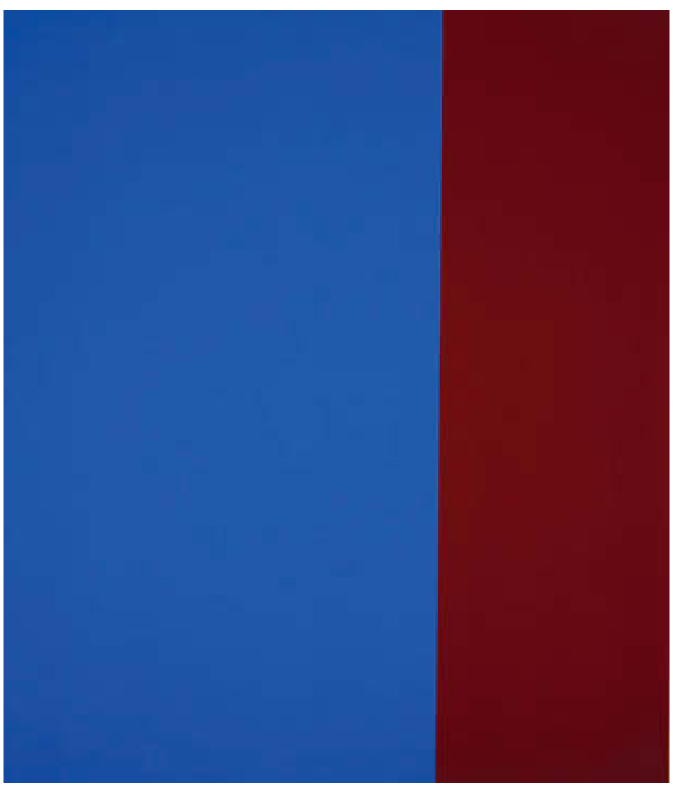
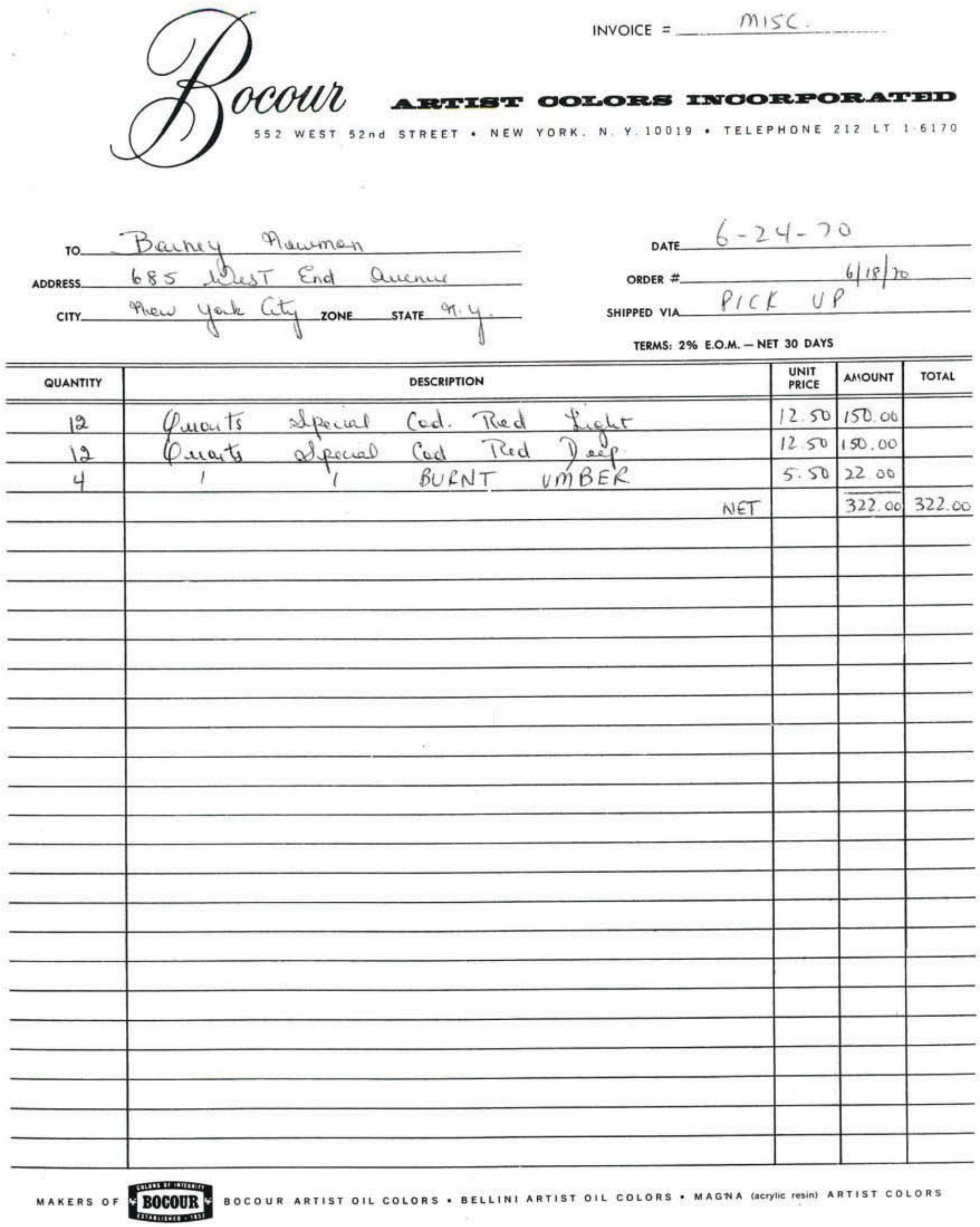


Figure 3. Barnett Newman, *Unfinished Painting [Blue & Brown 1970]* (1970), acrylic on canvas, 213.4 × 193 cm, The Menil Collection, Houston (1990–14)

Figure 4. A sample of Liquitex cadmium red light paint from Newman's studio. Courtesy of the Center for the Technical Studies of Modern Art (CTSMA), Harvard Art Museums



INVOICE # MISC.

Bocour ARTIST COLORS INCORPORATED

552 WEST 52nd STREET • NEW YORK, N. Y. 10019 • TELEPHONE 212 LT 1-6170

TO Barney Newman

ADDRESS 685 West End Avenue

CITY New York City ZONE STATE N.Y.

DATE 6-24-70

ORDER # 6/18/70

SHIPPED VIA PICK UP

TERMS: 2% E.O.M. — NET 30 DAYS

QUANTITY	DESCRIPTION	UNIT PRICE	AMOUNT	TOTAL
12	Quarts Special Cad. Red Light	12.50	150.00	
12	Quarts Special Cad Red Deep	12.50	150.00	
4	" " BURNT UMBER	5.50	22.00	
	NET		322.00	322.00

MAKERS OF BOCOUR BOCOUR ARTIST OIL COLORS • BELLINI ARTIST OIL COLORS • MAGNA (acrylic resin) ARTIST COLORS

Figure 5. Receipt from Bocour Artist Colors Incorporated for 12 quarts of "special" cadmium red light and 12 qt. of "special" cadmium red deep paint made out to Barnett Newman and dated 6-24-1970. Courtesy of the Barnett Newman Foundation

paintings. This implies that the unlabeled jars of paint are not commercially available Aqua-tec or Liquitex cadmium reds, but are instead either paints mixed by Newman himself or made on his behalf by another, perhaps Leonard Bocour. Bocour was willing to formulate paints for other artists, including Morris Louis and Kenneth Noland (Upright 1985), and a receipt from Bocour Artist Colors Incorporated in the Barnett Newman Foundation Archives dated June 24, 1970, indicates the purchase of 12 qt. each of "Special Cad. Red Light" and "Special Cad. Red Deep" (fig. 5). The adjective "special" suggests a custom formulation made specifically for Newman.

If the unlabeled jars of red paint and the paint on the unfinished works are custom Bocour acrylic paints, the question of why Newman requested a special formulation necessarily follows. Newman was concerned about the quality of the materials he used and evidently exquisitely sensitive to color. Mark Golden recounted to Carol Mancusi-Ungaro that one time his father, Sam Golden, who then worked for Bocour, was unable to obtain cadmium red pigments and so substituted other colorants instead, theoretically obtaining a color match through the use of a spectrometer (Mancusi-Ungaro 2004). Upon receipt of this paint Newman immediately phoned to complain that the colors "weren't cadmium." Raman analysis[2] of the commercial Aqua-tec cadmium red series from the NGA collection revealed that in addition to the cadmium pigments, an organic colorant—likely PR3—is also present as a color enhancer. It is possible that Newman could visually detect the presence of the dye and requested paints made without it, or that he was told by Bocour that the commercial paints contained this light sensitive pigment and so requested that a more stable formulation be made. Bocour may have eliminated the barium sulfate filler/extender from the custom paints to achieve the same level of pigmentation in the absence of the dye.

In addition to red, the other prevailing color found on paintings in Newman's studio was blue. The blue paint on *Unfinished Painting [Blue & Brown 1970]*, which serves as a ground layer, contains calcium, titanium, and copper. Raman spectroscopy confirmed the presence of copper phthalocyanine blue, and FTIR[3] suggested that calcium carbonate and kaolinite are also present in this paint. Bocour sold phthalocyanine-pigmented Aqua-tec paint under the name "Bocour Blue." However, analysis of a sample of historic Bocour Blue from the NGA collection showed only trace levels of titanium and calcium and relatively high levels of lead, perhaps as a biocide. This indicates that the phthalo blue paint on *Unfinished Painting [Blue & Brown 1970]* is likely not pure Aqua-tec Bocour Blue paint. A historic Liquitex phthalo blue paint has thus far not been analyzed; however, given the light tone of the blue on the painting, it is likely that it is a mixed paint created either by Newman himself or as a custom paint from Bocour. None of the three unlabeled jars of blue paint in the Harvard collection has phthalo blue as a colorant, and thus far, no receipts in the Newman archives for "special" blues have been found, so it may be that Newman himself created this color.

Whatever the origin and nature of this blue paint, *Unfinished Painting [Blue & Brown 1970]* is not the only late painting that it appears on. *Untitled I (1970)*, held by SFMOMA, was also found in Newman's studio at the time of his death. The painting contains a broad field of blue bracketed on either side by passages of white of unequal width. There are actually two layers of blue paint present, implying that Newman revised his color choice, altering the tonality of the blue passage. The subsurface blue, exposed on turnover edges, contains cobalt, chromium, and tin suggesting the presence of cobalt stannate and cobalt chromate cerulean blues. The surface blue closely resembles the blue on *Unfinished Painting [Blue & Brown 1970]*, with high levels of calcium, titanium, and copper. Unfortunately, there is no way to determine if the phthalo blue paint was created for *Untitled I* and then also used for *Unfinished Painting [Blue & Brown 1970]*, or if Newman mixed the blue paint for *Unfinished Painting [Blue & Brown 1970]* and then liked the color so much that he used it to overpaint the original blue of *Untitled I*.

3. ASPECTS OF NEWMAN'S TECHNIQUE IN HIS LATE PAINTINGS

As a general rule, Newman's material choices were not as radical as the pictorial ends to which he utilized them. Newman used primarily oil paint up through the mid-1960s, at which time the proportion of his output executed in this medium diminished. Newman did experiment with new materials, but he was highly selective, utilizing those that were developed specifically for artists rather than appropriating commercial materials, such as the oil and alkyd-based house paints favored by some of his contemporaries. Newman's adoption of new artists' materials tended to coincide with the earliest dates of their introduction, evidencing his awareness of and engagement in the developments and experiments with materials at the time. As mentioned earlier, Newman relied heavily on the paint products of Leonard Bocour, whose initial artist oil paint company Bocour Artist Colors Incorporated expanded into paints based on synthetic media: Magna in 1950 and Aqua-tec in the mid-1960s.

Between 1958 and 1966 Newman created his large painting series, *The Stations of the Cross: Lema Sabachthani*, utilizing bare cotton canvas and a grisaille palette of varying media. It was during the *Stations of the Cross* series that Newman settled into a reliance on acrylic emulsion paint and a corresponding tendency toward a flat impersonal paint surface. In these paintings, his process came to include the canvas in a much more fundamental way. He manipulated it almost as much as the paint itself through a ritual act he had of washing, shrinking, and scrubbing sizing into the canvas to "get rid of the beautiful mysterious quality that raw canvas can have" (Newman 1963). For Newman, the material became both canvas and color, simultaneously transcending and reinforcing itself. The later 12th through 14th stations show the paint application approaching neutrality similar to that of the raw canvas. It is through this increased utilization of acrylic emulsion paints over larger and larger areas in these painting that we see Newman replicating with paint what he had already achieved with canvas. The characteristics of the canvas as an expanse of color—uniformity, stillness, and radiance—were translated into the paint as well.

In terms of paint application, before 1965 Newman tended to rely almost exclusively on brushes, with two documented exceptions. Early in the 1950s, Newman did experiment with applying paint with a spray gun, but however beautiful the result, the experience was not pleasant for the artist. He described the use of the spray gun as "dangerous, messy and more trouble than using a brush" (Penn 2005). What it does point to, however, is Newman's early interest in a surface effect other than the brushstroke, which he would revisit later on once the invention of new media—in the form of acrylic emulsion paints—and implementation—in the form of the paint roller—allow him to do so in a way that better suited his painting sensibilities.

There are conflicting statements about Newman's use of a roller. Scholars and Newman's contemporaries have stated that he used a roller only in the preliminary steps of creating a painting, but always finished with a brush (Hess 1971; Siegel 1971). However, mockups created in the course of research demonstrated difficulty in detecting subtle surface differences between layers applied with a very smooth roller and one finished by rolling and tipping. As the nap of the roller was not necessarily smooth, evidence indicates that Newman would sometimes modify the final surface with a brush, lightly brushing the surface of the still wet paint with the tips of a dry brush, as seen in figure 6, a detail from *Midnight Blue* (1970). While this final pass over the surface can be seen as a pragmatic attempt to diffuse the roller texture, conceptually it may also be the last vestiges of a committed abstract expressionist.

It is important to see Newman's use of a roller not as a diminution of his involvement in the act of painting but rather as his adoption of a compelling and responsive

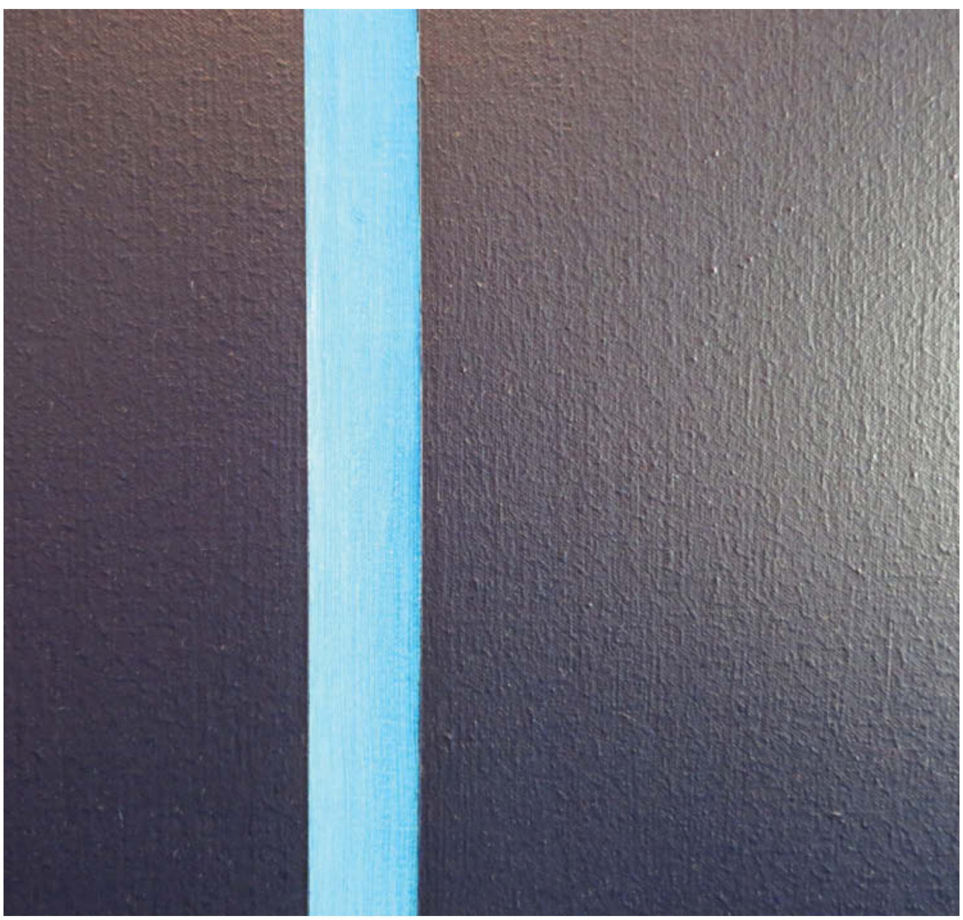


Figure 6. Detail, from Barnett Newman, *Midnight Blue* (1970), acrylic and oil on canvas, 193 × 238.8 cm, Museum Ludwig, Cologne, Germany. Courtesy of the Museum Ludwig, Cologne

instrument for the conveyance of the new medium of acrylic emulsion paint. Newman's use of the roller should be seen as akin to Jackson Pollack's appropriation of sticks and brush handles to propel his paint from can to canvas. No one who approached the act of painting with the emotional weight and sense of ritual that Newman did would seek to diminish his involvement in the act of painting. The moment of that act was everything for Newman. Like his manipulation of the canvas, the roller was part of Newman's efforts to liberate painting from the psychological weight of centuries of artistic practice and convention, "freeing ourselves from the impediments of memory, association, nostalgia, legend, myth or what have you, that have been the devices of western European painting (Newman 1948)."

In addition to providing different handling properties, acrylic paints also display very different optical characteristics from oils. Early acrylic paints could not contain the same density of pigments available to oils, so to achieve the same intensity of colors, acrylics needed to be either applied more thickly or in multiple layers. To overcome this pigmentation shortcoming, Newman's late acrylic works tend to contain multiple layers of the same color or very similar colors to achieve the dense and opaque colorful fields. Although Newman utilized thin layers of highly pigmented oil paints in his early work to create a palpable sense of atmosphere and depth, in the late acrylic works, the color is bound to the surface both conceptually and materially in an integrated singularity of surface and hue. It is the subtle difference between the quality of light found in the early and late paintings that was absolutely critical for Newman. In the earliest work, the sense of light flickering and shimmering off of or throughout the surface is the result of a very specific optical property of oil paints applied by brush. Evidence of application—the varied stroke length, the adjacency of matte and glossy areas—remain in the image for Newman's early work. For the works executed in acrylics, the optical quality of the color is distinctly different. The passive reflectivity of the early works is replaced by an almost incandescence in the late works and, combined with a neutral application technique, results in paintings with an astounding sense of presence and self-creation.

Similarly, the clarity of the interfaces found in the later paintings may also have been a consequence of the new medium. Pressure sensitive adhesives found in masking tapes are usually a combination of natural and synthetic rubbers, which dissolve much more readily in hydrocarbon-based solvents, such as turpentine, than they do in water. While the rippling bleed of the paint edges seen in Newman's earlier paintings arise from his conscious aesthetic choices, he was also much more likely to have surprising bleed effects when using oils rather than with acrylic emulsion paints, where the tape adhesive was not undermined as easily. This difference can easily be seen in the two paintings *Ulysses*, created in oils in 1952 and *Unfinished Painting [Blue & Brown 1970]* painted in acrylics in 1970 (figs. 7, 8).

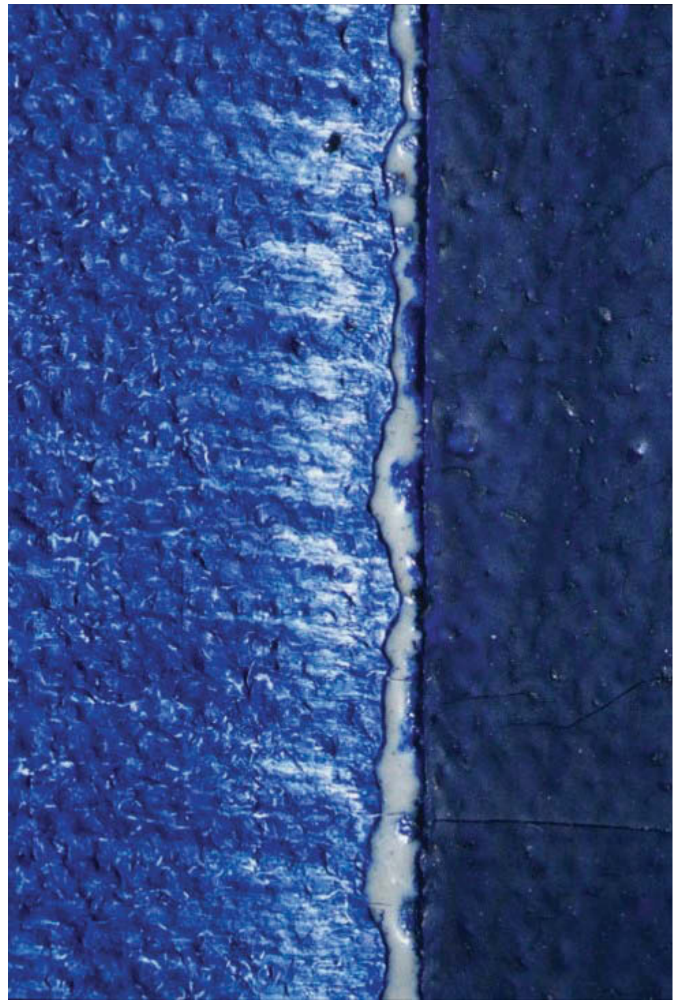


Figure 7. Detail, from the zip of *Ulysses* (1952) oil on canvas, 335.3 × 127 cm, The Menil Collection, Houston, formerly in the collection of Christophe de Menil. Courtesy of the Menil Collection, Houston

4. CONCLUSION

Between 1948 and 1970, the years bracketing his artistic career, Newman's painted surfaces demonstrate his gradual compression of the expressive movement of the brush on the canvas into the still intensity and radiant color characteristic of the works completed between 1965 and 1970. At the same time three unfinished paintings in the Menil

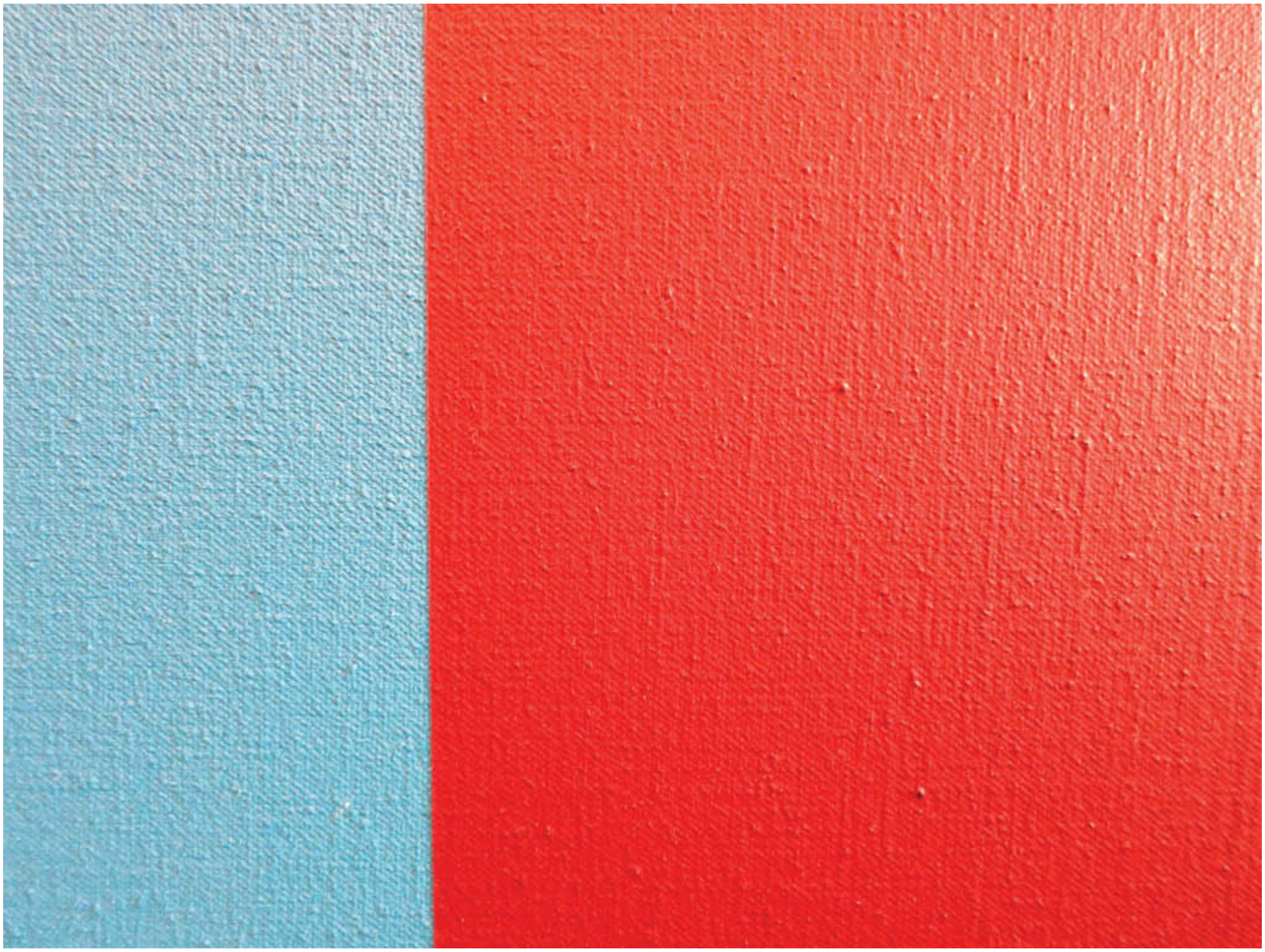


Figure 8. Detail, from the zip of *Unfinished Painting [Blue & Brown 1970]*. Courtesy of the Menil Collection, Houston

Collection, discovered in Newman's studio after his death, offer a unique glimpse into the states of an evolving painting and the latent evidence of the "surprising and daring" possibilities of which Thomas Hess, Newman's friend and advocate spoke. Technical clues enabled inferences about the paintings' material attributes, the shift to acrylic medium in the mid-1960s, and the artist's process—the order in which layers of paint were laid on the support, how masking tape was applied or lifted from the paint to create an edge, and whether a roller or brush was used. The final state of the three unfinished paintings remains unknowable; however, their context among finished works left in the studio and their varying degree of completion offer tantalizing glimpses of the artist looking both ahead and backward, experimenting and revisiting.

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NOTES

1. X-ray fluorescence spectra were collected using a Bruker Tracer III-SD handheld energy dispersive x-ray spectrometer equipped with a Peltier cooled XFlash silicon drift detector (SDD) with a resolution of 145 eV. The excitation source was a rhodium (Rh) target x-ray tube, operated at 40 kV and 10 μA current, or 15 kV and 10 μA current with the vacuum pump attachment. Spectra were collected over either 120 or 180 seconds (live time). Spectral interpretation and peak integration was performed using the Bruker Artax Spectra 7.4.0.0 Software.
2. Dispersive Raman spectra were collected on an InVia Raman microscope (Renishaw) using a 785 nm excitation laser operating at 5–50 percent power. A 50x objective was used to focus the excitation beam to an analysis spot of approximately 1 mm directly on the sample supported on a glass microscope slide. The resulting Raman spectra are the average of 1 to 7 scans of 10-second duration. Spectral resolution was 3–5 cm^{-1} across the spectral range analyzed. Sample identification was achieved by comparison of the unknown spectrum to spectra of reference materials and to those published in the literature.
3. Infrared spectra were collected using a Thermo Continuum microscope coupled to a Nicolet Nexus 670 FTIR spectrometer (Thermo Scientific). Samples were prepared by flattening them in a diamond compression cell, removing the top diamond window, and analyzing the thin film in transmission mode on the bottom diamond window (2 × 2 mm surface area). An approximately 100 × 100 μm square microscope aperture was used to isolate the sample area for analysis. The spectra are the average of 64 scans at 4 cm^{-1} spectral resolution. Sample identification was aided by searching a spectral library of common conservation and artists' materials (Infrared and Raman Users Group, http://www.irug.org) using Omnic software (Thermo Scientific) and through comparison with authentic Bocour paints.

   ATR spectra were collected using a Lumos FTIR microscope equipped with a motorized germanium ATR crystal with a 100-μm tip (Bruker). Samples were placed upon glass slides and analyzed using the built-in 8x objective and a medium ATR crystal pressure. An approximately 150 × 150 μm square microscope aperture was used to isolate the sample area for analysis. The spectra are an average of 128 scans at 4 cm^{-1} spectral resolution. An ATR correction was automatically applied by the Opus 7.0 instrument control and data collection software.

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THIS ARTICLE HAS NOT UNDERGONE A FORMAL PROCESS OF PEER REVIEW.

SAMANTHA SKELTON, CORINA ROGGE, and ZAHIRA VELIZ BOMFORD

Testing the Limits: The Theoretical Development and Practical Reality of a Large-Scale Agarose Gel Treatment for a Discolored Morris Louis

ABSTRACT

The raw canvas paintings of Morris Louis and similar color fieldworks, with their extreme vulnerability to staining and structural damage, present a challenge for safe and successful treatment design, often testing the bounds of our abilities as conservators while providing avenues to expand our range of treatment options. These paintings are physically akin to textiles, though their functional value lies almost exclusively in their aesthetic impact. Treatments focus primarily on restoring the work to the appearance intended by the artist, a goal outside the normal parameters of textile conservation, where signs of use and natural degradation are often considered historically important and aesthetically acceptable. Straddling this bridge between specialized textile and painting conservation techniques, and understanding their long-term implications and impact on aesthetic perception, becomes an essential skill for the conservator. A large 1960 *Morris Louis, Untitled (Floral)*, in the study collection of the Museum of Fine Arts, Houston provided an ideal example to explore the intersection of minimally interventive treatments with the need for aesthetic perfection. The moribund painting—coated at some point in the 1970s with a poly(vinylacetate) coating that had become extremely discolored and layered with grime—was deemed irretrievably damaged, and has been held by the museum outside of the permanent collection for research purposes since its 2004 donation. Although the chosen treatment, an innovative application of a rigid gel cleaning system, was ultimately successful, many issues were encountered in the shift from theory to practice. This research explored the challenges related to the realistic treatment of large works, scaling up from small cleaning tests to full-scale treatments, and the ethical aspects of treating works that function as "conservation cadavers." The practical knowledge gained from the treatment, including many observations on the mechanics of agarose gel, and new methods of application relevant to paintings, textile, and paper treatments, were described.

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From Spit to Space: The Use of Traditional and New Techniques to Conserve a Fire-Damaged Collection

ABSTRACT

Fire damage to an artwork can result in complex condition issues including soot accumulation, blistered paint, and the tenacious odor of smoke. Modern Art Conservation's work with a private art collection caught in an apartment fire unveiled remarkable variation and severity from piece to piece. The collection is presented as a case study exploring the variables inherent to fire-damaged artworks conservation and the efficacy of traditional and nontraditional treatments ranging from "spit cleaning" to using materials introduced in the Cleaning Acrylic Painted Surfaces workshops to atomic oxygen treatments executed in collaboration with the National Aeronautics and Space Administration.

1. INTRODUCTION

In July 2010, Modern Art Conservation was called by a gentleman whose apartment had recently been damaged by fire. Initially, he asked for a proposal to restore a single painting by Joan Mitchell. Upon arrival at the apartment, conservators found extensive damage to what had once been a well-appointed and art-filled duplex on New York's Park Avenue. The blaze had been sparked by faulty wiring in the kitchen, on the opposite side of the wall where the Mitchell hung.

The effects of the fire were most severe in the adjoining living room, but no room in the home had been spared from damage. Every surface was blackened with soot, and drips of an unknown material that aided in putting out the fire coated the walls (fig. 1). Luckily, the octogenarian couple and their poodle had escaped, but their belongings were nearly destroyed.

The day conservators first visited was hot and humid, the apartment windows were wide open, and there was no air conditioning. The owner explained what had happened and provided a handwritten list of artists compiled from memory. Although his art insurance had lapsed two years prior, midway through the visit, he realized he wanted the studio to restore not just the Mitchell, but rather everything possible from the collection at his expense. At the time, it wasn't yet clear how much the collection reflected this couple's many years together. The artworks were not only monetarily valuable; they were markers of memories from a lifetime of adventures.

Figure 1. Fire-damaged artworks by Hans Hartung and Pol Bury hanging in the apartment

2. EMERGENCY RESPONSE

It quickly became apparent that the works needed to be removed from the apartment as soon as possible given the climate conditions. With the help of the Emergency Response Team at Crozier Fine Arts,[1] the collection was carefully packed and transported to their facility in Newark where a room was designated for an initial examination of the works.

The first course of action was to separate the art objects by type. A long day was spent unframing, unglazing, and cataloguing the collection. The owner had often taped newspaper clippings to the reverse of the works with information about the artist, which helped identify many of the pieces. Soon after he also provided a file box containing records of his purchases. From these documents, an inventory was compiled of 20 paintings, 29 works on paper, 10 sculptures, 32 ethnographic objects, and 2 textiles.

3. GENERAL TREATMENT PROTOCOLS

Once the flat works had been triaged and inventoried, they were transported to Crozier's facility in Chelsea, located just a few blocks from the conservation studio. An initial cleaning phase was performed to remove as much of the soot as possible and any chemical contaminants from the fire extinguishers. If safe for the artwork, a HEPA vacuum was used to carefully remove any loose soot deposits. Where possible, vulcanized rubber sponges were used for additional dry cleaning, avoiding driving soot further in to the painted surface. On some works, small tests were done with saliva and other aqueous materials to indicate the scope of further cleaning that might be required.

The paintings then came to the conservation studio, and the real challenges began. The studio's approach to treatment was much influenced by the paper "Up in Smoke: New Solutions for Treating Soot Damaged Paintings," presented by Rustin Levenson Art Conservation Associates at the AIC Annual Meeting just two months before the New York fire (Romero, O'Neill and Levenson 2010). Their findings and shared expertise could not have been more timely for the treatment of this collection.

This article presents a selection of case studies from the collection to illustrate the range of chemical and physical damages encountered, from light soot accumulation to discolored varnish to severely blistered and charred paint surfaces. Though the collection encompassed objects made of various organic and inorganic materials, this article will focus on the treatment of paintings. Even within this narrowed selection, the variety of condition issues was vast and called for many creative conservation solutions, from spit to solvents to space engineers.

Discussion of the following treatments includes only the most relevant details, rather than full step-by-step processes. As a general rule, all works in the collection were HEPA vacuumed many times. Components that were not original or integral to the works were removed and discarded, including frames, mounts, backings, and occasionally stretchers. During treatment, the collection was kept in a separate room in the studio with a HEPA air purifier. Works were stored unwrapped in lightly covered bins in which small containers of kitty litter were placed and changed frequently to help absorb the smoke odor. Over the course of more than two years of treatment, these steps were sufficient to greatly reduce, if not completely eliminate, any lingering odor of smoke.

3.1 Treatment Case Studies

A small acrylic and oil stick on panel by Hans Hartung (figs. 2a-b) initially appeared to be one of the most severely damaged in the collection. The wooden frame was charred and the plexiglass glazing blackened and melted, making it impossible to discern the artwork inside. It was identifiable only by a charred newspaper article taped to the reverse. Once unframed, the painting was found to be nearly pristine due to the protection provided by the frame and glazing. The only intervention required was some minimal cleaning with dry sponges and saliva-dampened swabs.

Fortunately, most of the glazed works in the collection sustained little damage. Paintings without the protective benefits of glazing, on the other hand, presented various levels of soot deposition and damage from heat exposure. For some paint surfaces, aqueous cleaning was sufficient to remove surface soiling. A small kinetic work by Belgian sculptor Pol Bury (fig. 3) was heavily discolored, and it was uncertain whether the electrical components had been damaged by heat.

The first step was to remove as much particulate soot as possible with dry cleaning sponges. The mechanical components on the reverse were cleaned as possible with saliva. Spit was also effective on the painted surface, but further testing revealed that a 2% aqueous solution of dibasic ammonium citrate, a chelating agent, more thoroughly removed the discoloration. A small digital image found online from an auction 10 years prior served as an invaluable guide in returning the work to its original appearance. Cleaning results on the painted surface were dramatic. With some trepidation, conservators plugged in the cord and fortunately the mechanical elements were in perfect working order. For this painting and a number of others, dry cleaning followed by aqueous cleaning was straightforward and effective on the accumulated soot.

For an abstract painting by Larry Zox, however—with exposed, raw canvas and sensitive, matte paint—dry cleaning was the only possibility. It had been hanging upstairs, away from the source of the fire, resulting in a comparatively light deposition of soot.

2a

2b

Figure 2. (a) The frame and glazing were blackened and charred by the fire; (b) the painting inside remained protected and nearly pristine; Hans Hartung, 1977, acrylic and oilstick on panel, 9 × 7½ in.

Figure 3. During aqueous cleaning to remove accumulated soot. Pol Bury, 1962, oil on masonite, monofilament, and electric motor, 9 ½ × 9 ½ × 6 in.

Vacuuming reduced the accumulated soot but some particulate matter remained caught in the weave. Pressure applied with dry cleaning sponges and eraser crumbs seemed to drive the soot further into the raw canvas, and the paint film was easily burnished. The surface proved too porous and absorptive for aqueous cleaning. Cleaning with bread, a technique that had generally fallen out of favor but was reintroduced for cleaning raw canvas works in the Museum of Modern Art (MoMA) paintings conservation lab proved successful in this case. Baked from a recipe developed by James Bernstein and shared by MoMA, a loaf of bread consisting of only flour, yeast, and water with no salt or fat was broken into small handfuls and gently rubbed over the surface of the artwork. Bread cleaning works similarly to eraser crumbs, but also introduces a controlled amount of moisture to help lift away the surface soiling. The weave of the canvas was dense enough that the bread remained on surface, but to be certain no crumbs were left behind, the painting was vacuumed thoroughly after the treatment. In addition to lifting off the soot, the bread poulticed out some of the yellowed degradation products in the raw canvas, improving the overall contrast and returning the work to a state much closer to its original appearance.

For more traditionally painted works on canvas—especially those exposed to high heat—varnish served as an invaluable barrier layer. When heat exposure nears the glass transition temperature of a paint film, the paint will soften allowing soot and other particulates to become permanently embedded. For uncoated paintings, this can potentially result in permanent discoloration. When soot bonds with a varnish layer, however, a traditional solvent cleaning may be very effective in restoring the work to its original appearance.

Such was the case with a large oil on canvas by José Guerrero (fig. 4). Initial cleaning tests were conducted with various aqueous solutions, including chelating agents and surfactants, many of which were introduced at the first CAPS (Cleaning

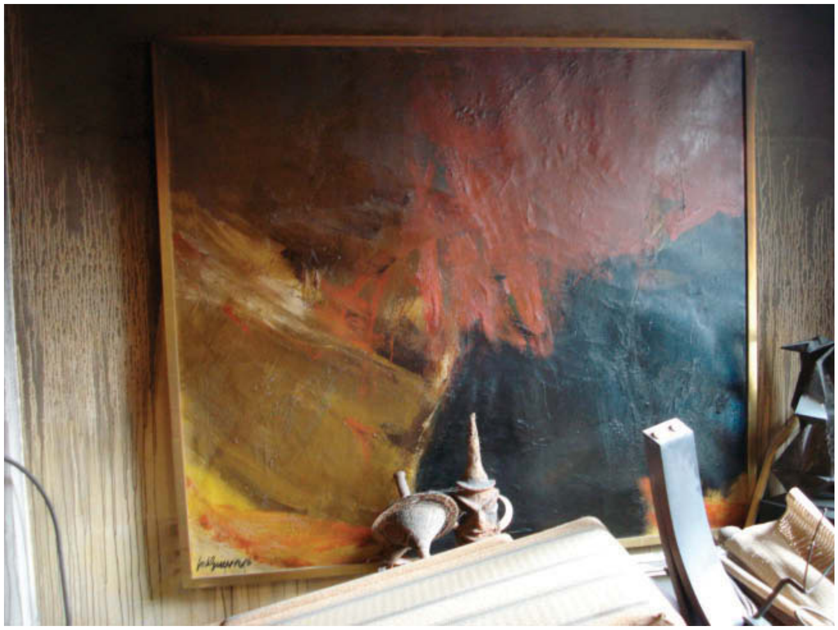

Figure 4. Installation view, post-fire; José Guerrero, 1960, oil on canvas, 52 × 60 in.

Acrylic Painted Surfaces) colloquium hosted by The Getty in 2009.[2] Unfortunately, these proved ineffective, as the soot had become chemically bonded with the varnish layer. Testing progressed to various solvents, using the methodology taught in the Modular Cleaning Program workshop as a guide.[3] Fortunately, the heat had not caused the varnish to bond with the paint layer. A mixture of odorless mineral spirits, acetone, and isopropanol effectively removed the discolored varnish (fig. 5).

Figure 5. During varnish removal; José Guerrero, 1960, oil on canvas, 52 × 60 in.

6a

6b

Figure 6. (a) Detail of blistered paint before treatment and (b) after injecting blisters with sturgeon glue and setting down with gentle heat; José Guerrero, 1960, oil on canvas, 52 × 60 in.

In addition to soot damage, the painting had developed blisters in the upper third of the composition (figs. 6a–b). Fortunately, the blisters retained enough plasticity to be set back down without rupturing the paint film, but the thick canvas and ground were difficult to penetrate with a local infusion of adhesive from the reverse. Using careful measurements and a tiny syringe, each blister was injected with sturgeon glue from the reverse and the paint layer coaxed flat with a heated spatula applied from the front. The painting was then revarnished.

For a small oil on panel by Joaquin Torres Garcia (fig. 7), several cleaning stages were necessary to unlock the layers of soot and discolored varnish. Dry cleaning reduced the soot somewhat, but the painting remained discolored. Aqueous cleaning tests with saliva, carbonated water, chelating agents, and surfactants provided little result. Solvent cleaning options were explored next. Various solvent combinations and emulsions from the Modular Cleaning Program were tested, but mechanical action of the swab always disturbed the paint. However, when applied by rolling a swab over Japanese tissue, acetone poulticed away

7a

7b

Figure 7. (a) Before treatment; (b) after treatment; Joaquín Torres-García, 1942, oil on wood panel, 7 ¾ × 10 in.

8a

8b

Figure 8. (a) Detail, after solvent cleaning to remove darkened varnish; (b) detail, after subsequent aqueous cleaning with dilute mixture of chelating agent and surfactant; Joaquín Torres-García, 1942, oil on wood panel, 7 3/4 × 10 in.

much of the oxidized varnish without disturbing the paint. Though much improved by solvent cleaning, a darkened residue remained pooled in the texture of the brushwork, giving the painting an uneven, dirty appearance. It appeared that the painting had been treated before, resulting in several oxidized layers with varying solubilities. Given the sensitivity of the paint, gentle aqueous cleaning was revisited to see if further improvements could be made. A dilute mixture of ammonium citrate and surfactant in water proved very effective for reducing the residual discoloration (figs. 8a-b). In particularly textured brushstrokes, a blunted paintbrush was used to work the solution into the furrows, which were then rolled over with a water-dampened swab several times to clear. The result was a drastic improvement (fig. 7b).

In both cases described above, varnish served as a sacrificial layer that allowed the soot damage to be removed while leaving the paint surface intact. Removing and replacing varnish (when appropriate) often left the works looking even better and brighter than before the fire.

Unvarnished paintings proved more of a challenge. An unvarnished oil on canvas by Gerard Schneider had been exposed to extremely high levels of heat. It was severely discolored, and the white paint was so charred that it crumbled at the slightest touch. It quickly became evident that the work was damaged beyond repair. Though unfortunate, the situation provided conservators with an invaluable opportunity when the client agreed that the work could be used as a test surface on which to experiment with both traditional and untested materials, including proprietary cleaning products for which little or no chemical information is available.

Tests of a given cleaning agent were performed on both the upper and lower edges of the painting for a comparison of effectiveness on lightly soiled versus heavily charred areas, and detailed notes were taken for reference (figs. 9a-b). These experiments guided future decisions that resulted in the restoration of at least one painting that otherwise might have been unsalvageable: an unvarnished oil on burlap by Jean-Michel Atlan. Testing on this painting had progressed through dry and aqueous cleaning methods. Minimal improvement was made with ammonium citrate, but only at concentrations suspected to be too high for full clearance. Surfactants were ineffective. Testing with solvents and solvent gels showed some promise, but ultimately the improvement was limited to blue and green passages, while the lightest areas remained significantly discolored. When all other possibilities had been exhausted and it appeared the work might be a total loss, several proprietary cleaners that had shown promise in experimental tests were revisited. The soot layer was finally unlocked with Formula88 Cleaner and Degreaser, a commercial product that was also used with success by Rustin Levenson's studio for cleaning soot-damaged paintings. The key ingredient listed on the MSDS sheet is ethylene glycol monobutyl ether, a common additive in coatings, cleaners, and inks with surfactant properties and fairly low human toxicity (Romero, O'Neill and Levenson 2010).

Two paintings that had both sentimental and monetary value were found to be too porous to treat with any method available

9a

KEY TO SCHNEIDER TESTS

BETTER RESULTS

TEST	SOLUTION OR SEQUENCE (→)
0	vulcanized rubber sponge
1	water
2	mild enzymatic solution (saliva)
3	carbonated water
4	1% ammonium citrate in water
5	2% ammonium citrate in water
6	**1:6 Vulpex/water, cleared with water**
7	Naphtha emulsion cleared with water
8	Greenworks Glass & Surface cleared with saliva
9	Greenworks Glass & Surface cleared with water
10	Greenworks All-Purpose cleared with water
11	Mr. Clean Magic Eraser
12	Mr. Clean Magic Eraser Extra Power
13	VM&P Naphtha
14	1% ammonium citrate cleared with water → naphtha
15	water → naphtha → 1% ammonium citrate cleared with water
16	naphtha → 1% ammonium citrate cleared with water
17	**acetone → ethanol → water**
18	acetone/water 1:1
19	acetone/water 2:1
20	**saliva → naphtha**
21	**1:6 Vulpex/water : naphtha (1:1)**
22	**1:6 Vulpex/water : naphtha : acetone (1:1:1)**
23	1:6 Vulpex/water : acetone (1:1)
24	water-dampened PVOH sponge
25	1:6 Brij700/water → saliva
26	Goo Gone cleared with water
27	**Formula 88 cleared with water**
28	**Formula 88 : water (1:1) cleared with water**
29	Formula 88 : water : 1:6 Vulpex/water (1:1:1) cleared with water
30	Formula 88 : naphtha (1:1) cleared with water
31	Formula 88 : naphtha : 1:6 Vulpex/water (1:1:1) cleared with water
32	**Formula 88 : 1% ammonium citrate (1:1) cleared with water**
33	**Formula 88 : acetone (1:1) cleared with water**
34	acetone: naphtha (1:1)
35	**isopropanol**
36	**ethanol**
37	**Sentinel Carbon & Soot 510: water (1:3) cleared with water**
38	**Sentinel Carbon & Soot 510: water (1:1) cleared with water**
39	**Sentinel Carbon & Soot 510 (pure) cleared with water**
40	**Sentinel Smoke & Odors 522 (pure) cleared with water**
41	**Sentinel Smoke & Odors 522: water (1:1) cleared with water**
42	**Grez-Off (pure) cleared with water**

9b

Figure 9. (a) Test painting, annotated image and (b) chart recording the results of various cleaning tests; Gérard Schneider, oil on canvas, 25 1/2 × 31 3/4 in.

in-studio: the oil on canvas by Joan Mitchell and an acrylic on canvas by Simon Hantaï, both with large areas of exposed ground incorporated into the compositions. The nature of the materials used by these artists, along with the heat and soot exposure, made them impossible to touch with a swab, sponge, or brush. Any physical contact drove the soot farther in and the amount of intervention needed to get results began to remove the paint. Another solution needed to be found for the works not to be total aesthetic and financial losses.

4. COLLABORATION WITH NASA

Conservators at Modern Art Conservation were aware of NASA's work cleaning lipstick from a Warhol (Miller, Banks and Waters 2004) as well as soot from fire-damaged paintings using atomic oxygen (Rutledge et al. 1998). Articles published on atomic oxygen treatments were researched and contact was established with Bruce Banks, Senior Physicist and Sharon Miller, Senior Engineer at NASA's Glenn Research Center in Cleveland.[4] These discussions provided new hope of finding a way to save the paintings by Hantaï and Mitchell.

The clients were willing to send the smaller Hantaï canvas to NASA as a test, with hopes of saving the Mitchell painting if successful. Since the material characteristics and levels of soot deposition were similar for both paintings, it made sense to try the treatment on the less valuable work.

The NASA treatment utilizes the properties of free atomic oxygen. On earth, oxygen exists primarily as a diatomic molecule. In outer space, however, UV radiation from the sun causes molecular oxygen to disassociate into single atoms. Atomic oxygen is highly reactive and has the ability to break carbon and hydrogen bonds. It will not exist naturally for long in Earth's atmosphere, but in low-earth orbit it is the predominant species and it attacks spacecraft materials by oxidizing and eroding polymers. NASA has developed land-based methods of generating atomic oxygen for testing the degradation of materials used to construct low-earth orbiting satellites (Banks, Rutledge and Norris 1998). In the lab, atomic oxygen is produced in a vacuum chamber with radio frequency, microwave radiation, or electron bombardment. For more targeted applications of a few millimeters in diameter, atomic oxygen can also be generated as a beam at atmospheric pressure. The environment must be rich in helium, which separates the oxygen atoms and prevents them from recombining (Rutledge, Banks and Chichernea 2000).

When atomic oxygen encounters carbon-based organic materials it bonds to form volatile species such as alcohols, water, carbon monoxide and carbon dioxide. During NASA's studies of the destructive power of atomic oxygen, it became apparent that in a different application the effects of atomic oxygen's reactivity could be beneficial.

For paintings applications, this means that cleaning soot from the surface may be possible with no physical contact. As most pigments are inorganic or highly oxidized, in theory, they remain unaffected by atomic oxygen. It is worth noting, however, that overexposure to atomic oxygen can remove varnish layers and even the organic binder between pigment particles. The treatment must be administered carefully to avoid overexposure (Miller, Banks and Waters 2004).

Prior to working with Modern Art Conservation, it had been NASA's protocol to apply a layer of varnish following the treatment to replace any lost binder. Although the varnishes used are marketed as reversible, in practice it would prove incredibly difficult for a conservator to remove the resin from an underbound paint surface. Further, for the modern works being treated, a varnish coating would not have been sympathetic to the original and intended aesthetic. For these reasons, it was particularly important to communicate the studio's objectives and to consistently monitor treatment progress. However, travel from New York to NASA's Glenn Research Center in Cleveland for each stage of the treatment was not practical. Instead, the studio engaged Per Knutas, now chief conservator at the Cleveland Art Museum, to monitor the project.

Figure 10. The painting masked with polyimide film in preparation for atomic oxygen cleaning tests; Simon Hantaï, 1973, acrylic and exposed ground on canvas, 29 3/4 × 30 1/4 in. Courtesy of NASA

To allow for comparison before and after cleaning, half of the Hantaï painting was masked with DuPont Kapton HN polyimide film with the upper edge rolled back to prevent too sharp a line from forming (fig. 10). The painting was then installed in the vacuum chamber and exposed to atomic oxygen in five-hour increments, checking the progress after each session. After two sessions in the vacuum chamber, the results were dramatic (fig. 11). The soot had been lifted off the surface, leaving the exposed ground and painted areas intact and significantly brightened. The decision was made to proceed with full treatment of the painting.

Once the work returned to the studio, there was little for conservators to do aside from some minor inpainting. An added benefit of the atomic oxygen treatment was a significant reduction in smoky odor. The clients were thrilled and enthusiastically agreed to move forward with atomic oxygen treatment for the Mitchell painting as well.

The Mitchell was documented and discrete areas of lifting impasto were consolidated with BEVA-371 to make the work safe for transport. Due to the size limitations of NASA's equipment, the multicanvas work was dismantled and each section was treated separately in the vacuum chamber (fig. 12).

Figure 11. After two five-hour treatment sessions in the atomic oxygen chamber; Simon Hantaï, 1973, acrylic and exposed ground on canvas, 29 3/4 × 30 1/4 in. Courtesy of NASA

Figure 12. One panel of the multipart painting installed in the atomic oxygen chamber at the Glenn Research Center; Joan Mitchell, 1971, oil on canvas. Courtesy of NASA

In Figure 13a, one can see the deposition of soot gradated from light at the bottom to very dark at the top. The fire began in the kitchen, and this work hung directly on the other side of the kitchen wall, so the painting's heat exposure was very high. As the work was being treated with atomic oxygen, it became clear that many of the darkened white passages had altered. NASA suspected there was some lead conversion occurring from the treatment, as this is a known phenomenon. In cases where lead is present, white lead carbonate may convert to brown lead oxide. Although NASA was willing to halt the treatment, the conservators decided to move forward as atomic oxygen seemed to be the only viable option for having the soot and odor removed.

Once the work returned to the studio, the canvases were reassembled. Lead tests proved negative and any attempts at reconversion brought no change. The areas of darkening corresponded closely to the most soot-coated and most heated

13a 13b

Figure 13. (a) Detail, one panel of the multipart painting, before treatment; (b) detail, after treatment; Joan Mitchell, 1971, oil on canvas

areas. At this point, the conservators and clients made a decision to "restore" the work. Given that the soot was removed and the underlying paint no longer matched images of the original state, the only remaining option was to tone the discoloration. The studio's experience treating other works by Mitchell aided in finding an appropriate level of toning (fig. 13b). The compensation phase was fully documented and was carried out in gouache so as to be readily reversible. Although some might disagree with the decision, toning back the residual discoloration was the only way to make conservation work for the life of this painting and for the clients.

5. CONCLUSION

About two years after the fire, the couple was settled in a new apartment and living again with their artworks. With great pride and pleasure they invited the conservators to visit. It was immediately apparent how much the studio's efforts meant to them and to the story of their life together. In a private studio that treats the types of works Modern Art Conservation does, artworks often have extremely high monetary value though sometimes little personal meaning for an owner. The case was the exact opposite, and brought a great sense of accomplishment to all who worked on the project.

In order to make conservation work for this collection, the studio adopted a problem-solving approach. It was often necessary to think both inside and outside the box; some treatments were unorthodox and perhaps not all will stand the test of time. But for a couple in their eighties, having a beloved art collection restored to their home made the leaps of faith and technology well worthwhile.

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NOTES

1. For more information on emergency planning and response, visit http://crozierarts.com/fine-arts/emergency-planning-and-response
2. For more information on the CAPS program at the Getty Conservation Institute, visit http://www.getty.edu/conservation/our_projects/education/caps/index.html
3. For more information on the Modular Cleaning Program, see Stavroudis, Doherty and Wolbers, 2005.
4. For more information on the Space Environment and Experiments Branch of the NASA Glenn Research Center, visit http://www.grc.nasa.gov/WWW/epbranch/index.htm

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THIS ARTICLE HAS NOT UNDERGONE A FORMAL PROCESS OF PEER REVIEW.

NINA L. ENGEL and SUZANNE SIANO

Airbrushing in the Conservation of Modern and Contemporary Painted Artworks

ABSTRACT

This article provides an overview of the versatile uses of the airbrush in modern and contemporary art conservation, particularly for paintings and painted surfaces. It gives basic technical information on the airbrush tool itself and discusses requirements for the choice of paints and media. It also introduces the problem of overspray and the solution through different masking options. Case studies will illustrate the airbrush's use as a tool not only for inpainting on monochromatic artworks but also to adjust sheen and for subtle consolidation of underbound paint layers. In conclusion, it discusses the advantages and disadvantages of using an airbrush.

1. INTRODUCTION

At Modern Art Conservation, a private conservation studio in New York, the authors specialize in the treatment of modern and contemporary paintings and painted artworks. Modern and contemporary art often features a monochromatic paint layer and/or an industrially applied coating. Damage in these "pristine" surfaces catches the eye and can significantly diminish the artist's intention or readability of the artwork. The simpler the composition and the more limited the palette, the more distracting is even the smallest disruption or damage. When it comes to inpainting larger areas of loss in monochrome surfaces, conservators often struggle with traditional retouching methods. The same applies to scuffs, burnishes, or other alterations in the sheen of a work of art.

Current conservation practices offer different approaches to compensation of loss or damage in monochrome surfaces. According to Blumenroth (2008, 12–18), there are four options:

- traditional inpainting by brush
- inlays
- inpainting by airbrush
- re-painting in collaboration with the artist (if possible)

This article focuses on the use of the airbrush for compensation. Used correctly and judiciously, it has become an invaluable addition to the conservator's options for inpainting.

The main advantage of using an airbrush over a traditional paintbrush on modern and contemporary artworks is its ability to produce a monochromatic paint or varnish layer without leaving any brush marks or other texture. Because of the airbrush's ability to produce very thin layers, conservation intervention can be kept to an absolute minimum when using it (Blumenroth 2008, 17). In many cases, the finest mist of inpainting material will suffice to reintegrate a damaged area.

2. AIRBRUSHING

2.1 The Airbrush Tool

An airbrush is a small air-operated tool that sprays various media—most often paint—by a process of nebulization. It consists of a metal body into which a valve is inserted to let in air and a reservoir to let in the paint. Powered by a compressor, air and paint are combined in a fine spray, which is expelled through a nozzle (Parramon-Paidotribo 2012, 24–5). The invention of the airbrush (in the 19th century) soon led to the development of the spray gun—a similar device that typically delivers a higher volume of paint and is used for painting larger areas or industrial coatings (Parramon-Paidotribo 2012, 24–5). Conservators most often use spray guns for varnish application.

Airbrush tools can be divided into single- and double- or dual-action air guns. With single-action air guns, the amount of air and paint building the spray is controlled simultaneously by pulling back the lever, whereas with a double-action model, the quantity of air and paint can be controlled separately (fig. 1). Pushing the lever up and down regulates the amount

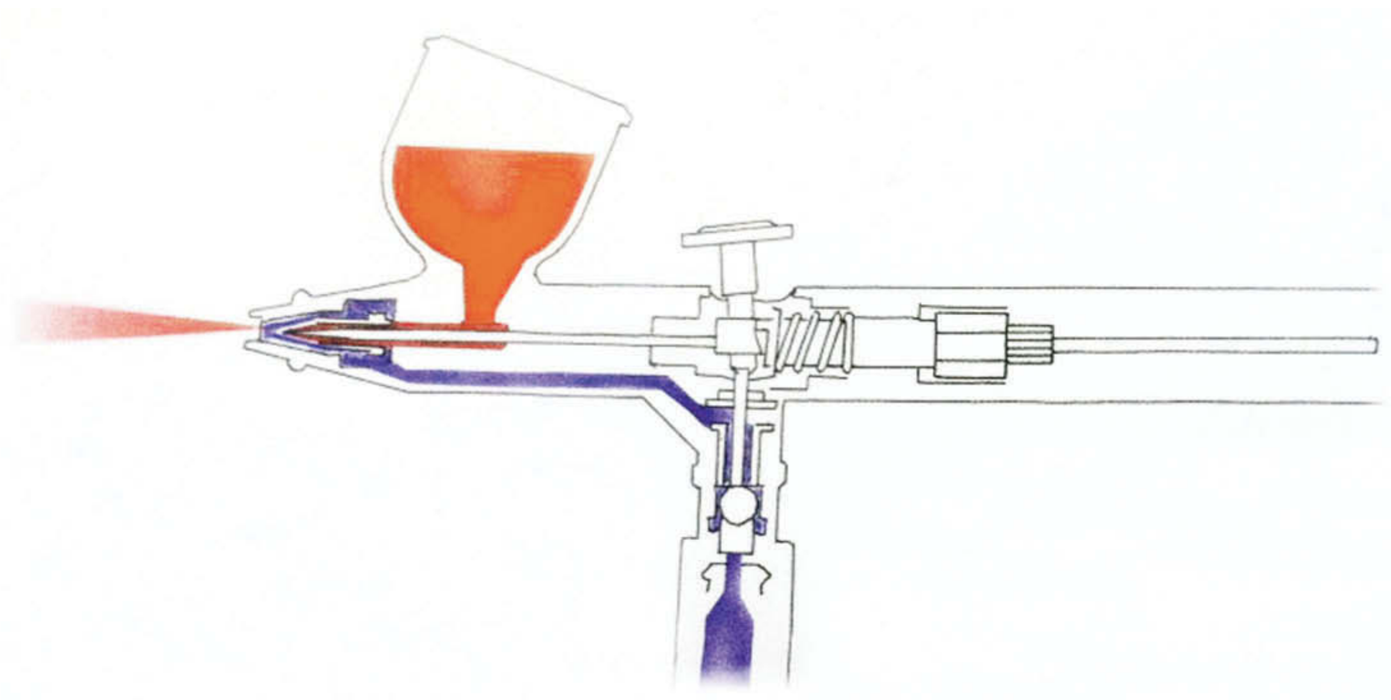

Figure 1. Double action airbrush with dual action trigger that controls paint and air flow separately (Parramon-Paidotribo (2012, 26)

of air; pushing the lever back opens the paint supply. The thickness of the applied paint layer can also be controlled by air pressure (controlled through the compressor), the size of the nozzle, and the actual amount of paint applied (Parramon-Paidotribo 2012, 28–9).

Single-action airbrushes are used for varnishing or for large-scale work as well as high-viscosity paints. There are more viscosity options with a single-action airbrush but less variance in the spray pattern. Double-action models are used for fine detailing and precise work as would be needed for conservation inpainting projects. They offer more variation in application than the single-action models (Parramon-Paidotribo 2012, 28–9).

2.2. Protection while Airbrushing

When working with the airbrush using any medium—not only when using solvent-based paint or varnish—it is important to use a fume extractor and a solvent or a particle mask. Furthermore, the spraying should be executed in a properly ventilated area. Small paint particles can be inhaled and are a potential health hazard.

To prevent the fine airbrush mist from spreading across the studio, it is important to work in a spray booth. For temporary use, a spray booth can be built with adjustable poles[1] and plastic sheeting (fig. 2). For small-scale work or testing, a small booth made out of cardboard is sufficient (fig. 3).

2.3 Paints for Conservation Airbrushing

Generally, almost any paint can be used for airbrushing as long as:

- it offers the right viscosity
- the pigments contained in the paint are ground finely enough so as to not clog the nozzle
- the material the airbrush gun is made of is compatible with the solvent that is used to dilute the paint. Some airbrushes are made of plastic and could be affected by certain solvents (Schönburg 2006, 3)

The most common paints used in conservation airbrushing are watercolors, gouache, and acrylic paints (emulsions). Synthetic resin paints such as Gamblin Conservation Colors, Paraloid, Mowilith (AYAB), MS2A, etc., can be used with the airbrush as well. The paint market also provides versions of several media that are specifically intended for airbrush application. Golden Artist Colors Inc., for example, offers an acrylic paint that is modified to meet all the requirements for airbrushing (Golden Airbrush Colors and Golden High Flow Acrylics). As in traditional inpainting, it is advisable to use high-quality artist's paints because they contain less extenders and, in many cases, the pigments are more finely ground. In general, most paints require thinning before use with the airbrush to avoid clogging the nozzle.

2.4 Masking

To limit the airbrush inpainting to a precise area, a mask should be made. Masking off the area to be treated will allow for very

Figure 2. Temporary spray booth built in the studio with adjustable poles, plastic sheeting "walls" and paper protecting the floor

Figure 3. Mini-spray booth built of cardboard for testing or small-scale projects

local and precise work with minimal intervention. Before masking the inpainting area, it is important to cover the whole object or painting with a protective material such as Dartek or other plastic because paint mist will spread in the air and onto the exposed painting's surface. After covering the whole object or painting, a window is cut in the protective layer so that the area to be treated is accessible (fig. 4). A mask can be applied over the cut out window to further narrow the area to be sprayed and protect the original paint surrounding the damage.

A variety of masks and masking materials are commercially available, most of which are designed for artist's use when making an artwork. These materials are not always appropriate for use in direct contact with an artwork undergoing conservation treatment. It is important to test the masking material before application to the painting being treated.

2.4.1 Masking options

Some of the masking options are as follows:

- self-adhesive masking film—most often made of polyester (e.g., Iwata Art Mask Frisk Film, Artool Art Mask, or Dura-Lar)
- loose templates that are not attached to the painting/object (e.g., paper, cardboard, Holytex, Reemay, Japanese tissue, etc.)
- cyclododecane,[2] a saturated cyclic hydrocarbon that can be applied by brush or sprayed on the original paint layer and will sublimate spontaneously given time (Schönburg 2006, 6–7)

The depth of the masking material plays a role in how defined the spray edge will be. When making a mask, the thicker the template (meaning the farther the upper edge of the mask is from the surface to be sprayed), the more diffuse the sprayed outlines. Loose templates that "float" above the surface of the artwork (such as those made with cardboard or Reemay®)

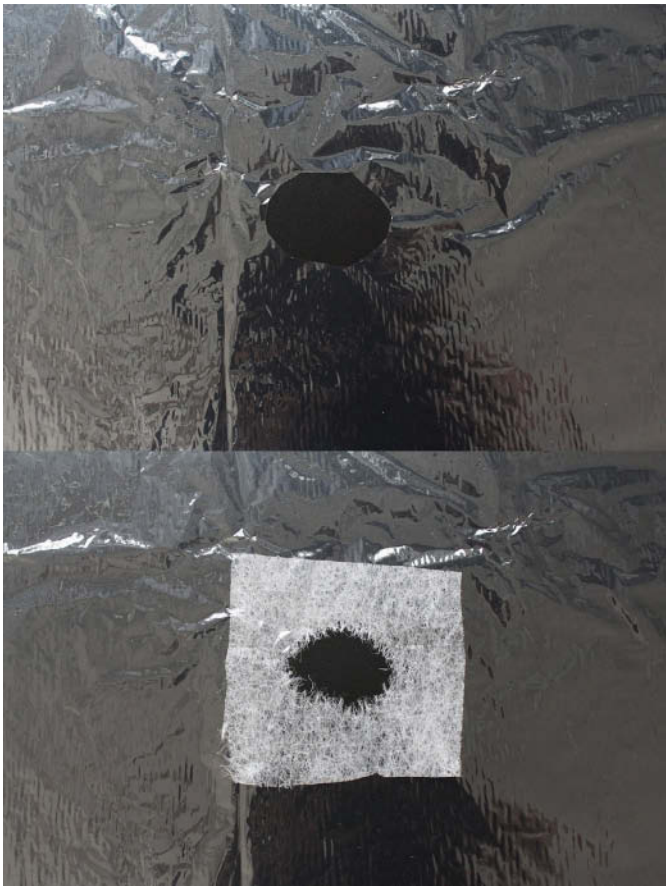

Figure 4. Dartek window (top), Dartek window with fringed Reemay template on top (bottom)

tend to produce diffuse rather than sharp edges when the paint is airbrushed.

2.5 MockUps and Tests

Before spraying an object or painting, it is very important to initially test the masking material, the paint, and the application method (number of spray layers required and distance from the surface). Brushed paintouts can show very different results in hue and gloss than a sprayed layer, therefore it is crucial to test-airbrush any color before working on the actual artwork (fig. 5). Because the underlayers affect the tone of the airbrush layer, it is helpful to prepare mockups that show a similar layer structure as the original. It is important that the color matches perfectly before spray application. Mixing and matching as done with traditional brush inpainting is possible but limited; layering can change the gloss and tone of the airbrush layer significantly and thus should be tested in advance. Preparing mockups and testing is time consuming and should be taken into account generously when writing a proposal for or planning an airbrush project.

3. CASE STUDIES

The projects described subsequently display the versatile applicability of an airbrush in conservation of modern and contemporary artworks. These case studies illustrate treatments carried out at Modern Art Conservation's studio in which the airbrush was used very successfully. Because of the confidential nature of private conservation work, it is not possible to provide detailed artwork information or overall pictures. For context, however, the airbrush should be considered a viable tool when treating works by artists whose works display even, monochromatic, sprayed, or mechanically applied paint layers such as Takashi Murakami, Andy Warhol, Richard Prince, Ugo Rondinone, Keith Haring, Rashid Johnson, Sterling Ruby, and Wade Guyton, among others.

3.1 Case Study—Loss

This case study focuses on the conservation of a sculpture by Mr., a contemporary Japanese artist who creates anime/manga-style sculptures, paintings, and videos. When this painted sculpture was fabricated, the paint layers were applied industrially with a spray gun. As a result, the painted fields did not show any brush marks or other application texture, and there was no variation in color or sheen (fig. 6). A small area in the field of blue sustained a loss when some stray wall paint landed on the surface and a nonconservator attempted to remove it (fig.7).

Since the sculpture was painted industrially, a totally flat inpainting layer was needed to reintegrate the damage into the surrounding original. The airbrush was the logical tool of choice. As with most projects that are carried out at the Modern Art Conservation studio, a battery of tests was undertaken before working on the actual artwork. Given the sensitive nature of many of the materials used in modern and contemporary artworks, there is little room for repeated trials on the artwork itself without causing some new form of damage or surface alteration. In case of this painted surface, mockups were prepared to carry out tests for color and sheen as well as effective masking.

To treat this work, the loss was filled with Flügger (an acrylic gesso) and carefully leveled with a scalpel. The sculpture was then protected from overspray with Dartek. A window was cut into the Dartek in the location of the loss. A template made of self-adhesive film was cut out to match the shape of the fill and placed over the Dartek window so as to be adhered mainly to the Dartek and only minimally to the artwork. The area was then inpainted with Schmincke Horadam gouache

Figure 5. A selection of paint-outs, mockups, and spray tests for an airbrush project

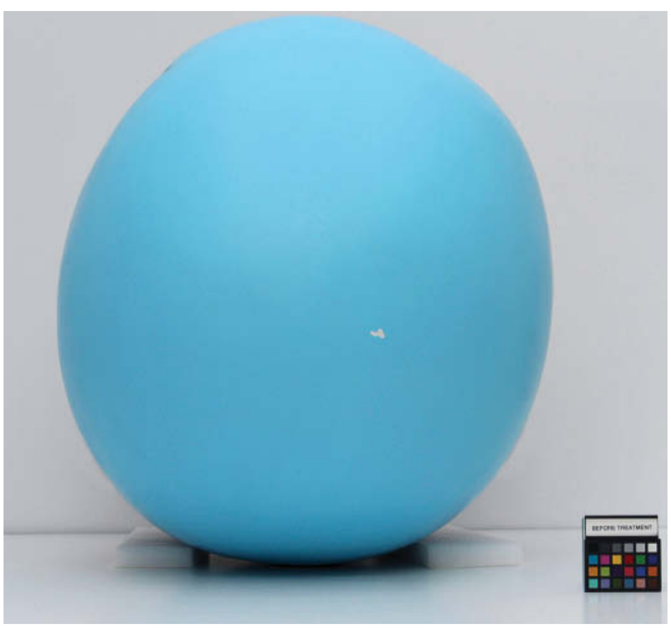

Figure 6. Mr., fiberglass, steel, acrylic resin, iron, and various fabrics, 68 × 22 × 22 in.; detail of sculpture with small paint loss before treatment

Figure 7. Mr., fiberglass, steel, acrylic resin, iron, and various fabrics, 68 × 22 × 22 in.; detail of sculpture with area of loss before treatment

and Lascaux Aquacryl medium using the airbrush. The resulting inpainting was seamlessly integrated into the surrounding original (fig. 8).

3.2 Case Study—Scuff

The following case study describes a Richard Prince work originally painted in acrylic with a traditional brush.

Figure 8. Mr., fiberglass, steel, acrylic resin, iron, and various fabrics, 68 × 22 × 22 in.; detail of sculpture with area of loss after airbrush inpainting

Figure 9. Richard Prince, acrylic on canvas, 75 × 115 in.; detail of scuff before treatment

The resulting surface was a very even, matte and monochromatic paint layer, as is typical for works by Prince. The large painting suffered from a 13-in. long scuff that left the very matte, monochrome original surface burnished and the paint in that area darkened from having been compacted (fig. 9).

After cleaning the painting overall and locally, traditional inpainting by brush was tested in a small area of the burnish. However, it proved impossible to obtain a satisfactory result without leaving an unwanted texture on the surface, particularly when viewed from an angle. The burnished area merely needed toning and matting down; fully covering the area with paint was not necessary.

In this case too, airbrushing was chosen over brush inpainting because of the ability to apply a very thin paint layer that would feather out into the original without adding any noticeable texture. Once again, extensive testing was carried out on mockups, and, in this case, the turnover edge provided an additional area for testing for color and sheen as well as reversibility. After testing, the painting was covered with Dartek and the area surrounding the burnish was masked with Reemay. The Reemay was feathered out with tweezers to create a fine fringe that would further diffuse the edges of the airbrushed inpainting. It was held in place by a Fome-Cor template to decrease the movement of the fringe when spraying. The paint—in this case Schmincke Horadam gouache with the addition of finely ground dry pigments—was airbrushed in very thin layers that feathered out into the original (fig. 10).

3.3 Case Study—Gloss Adjustment

Yet another way to use the airbrush is for sheen adjustment. For unvarnished paintings, airbrushing can be especially useful. The airbrush allows localized gloss adjustment and fading out into the original without creating edges as a brush might. By locally airbrushing, overall varnish application can be avoided and the sheen can be tailored to discrete areas of a painting.

This case study describes the conservation of an oil-on-canvas painting by the Indian artist Maqbool Fida Husain. The painting was damaged by water running down its surface. The water (perhaps with the addition of materials picked up as the water leaked) altered the surface sheen in one specific area. A vertical glossy stripe was found along the right side of the matte and unvarnished painting (fig. 11). Cleaning did not prove successful in reducing the damage.

Figure 10. Richard Prince, acrylic on canvas, 75 × 115 in.; detail of scuffed area after airbrush inpainting

Figure 11. M. F. Husain, oil on pre-primed cotton canvas, 68 × 137 in.; detail of glossy stripe along left side of painting before treatment (image taken at an oblique angle)

Figure 12. M. F. Husain, oil on pre-primed cotton canvas, 68 × 137 in.; detail of water damaged painting after gloss adjustment by airbrush (image taken at an oblique angle)

Again, the airbrush proved to be the best method to restore the damage. Here too, the painting was protected from overspray with a template that was made out of Dartek and Reemay. The glossy area was treated locally with a very thin layer of Lascaux Aquacryl matte medium (fig. 12). The fine mist of medium diffused the gloss in the damaged area and reintegrated it into the rest of the work.

3.4 Case Study—Consolidation

The airbrush can also be used to consolidate underbound paint layers such as those seen in Dan Colen's pigment paintings series. These paintings are made from oil paint and dry pigment powder. Colen (an artist with whom Modern Art Conservation works closely in both the conservation and production of his artworks) intended for the surface of this series of paintings to be extremely matte with the pigment being hardly held to the surface (fig. 13). Once in a gallery setting, both the gallery and the artist realized there were practical concerns with exhibiting and selling a work with so much underbound pigment. It was decided to test options for binding the pigment without altering the artist's aesthetic for future works in the series. The underbound pigment required consolidation without saturation or alteration of the powdery appearance of the surface.

Figure 13. Dan Colen, oil and dry pigment on pre-primed cotton canvas, 105 × 85 in., installation image at Gagosian Gallery, NYC

Figure 14. Mockups for adhesive tests to consolidate underbound pigment

Several mockups were created to test different consolidants and application methods (fig. 14). Among the tested consolidants were various solutions of Funori in water, Sturgeon glue in water, Klucel G in ethanol and Methocel A4C in water. The tested methods were brush application, airbrush application, and the application by a nebulizer.

The advantage of the airbrush over a brush in this case is that it left no edges or halos. Because of its fine mist, the airbrush did not saturate the underbound paint layer as might a brush application; however, the airbrush could not be aimed directly at the paint-pigment surface because of the air pressure involved. To avoid disturbing the loose pigment, the painting was placed flat facing up and the consolidant sprayed in a horizontal direction over the painting. In this way, the airbrush mist gently settled on the paint surface. In comparison to using a nebulizer, the airbrush applies more adhesive and allows for faster treatment.[3]

3.5 Pros and Cons of Airbrushing

Airbrushing cannot and should not be used for all inpainting or varnishing projects, but it can be a viable option for monochromatic and or industrially applied surfaces or when brush inpainting adds too much texture or medium.

Pros:

- A very thin paint layer or paint/varnish mist can be applied.
- The spray layer dries very quickly.
- The spray layer (if applied correctly) adds no texture.
- The spray layer can feather into the original.
- The ability to work very locally and precisely makes intervention minimal.

Cons:

- Training and practice are needed to acquire the skills to airbrush.
- Professional-grade equipment (airbrush, compressor, spray booth, fume extractor) is costly.
- Preparation of test paints, mockups, and paintouts is time-consuming.
- Time and materials are needed to protect the artwork and studio space from overspray.

4. CONCLUSION

The airbrush has proven to be an invaluable addition to the tools available to the conservator. Used perhaps more frequently in other specialties, paintings conservators might find the airbrush more useful than previously thought, particularly for modern and contemporary painted artworks. With control and precision, the conservator can add a very minimal amount of paint or varnish, limit contact with the original surrounding surface, and often obtain more satisfactory results than with even the most fine brush-applied inpainting. It is a tool that should be further explored for its applicability to the myriad of conservation projects and problems conservators regularly face.

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NOTES

1. Autopoles, an adjustable pole system by Manfrotto;http://www.manfrotto.com/alternative-supports-autopoles.
2. Cyclododecane is an organic compound with the chemical formula $(CH_2)12$. It is a waxy white solid that is soluble in nonpolar organic solvents. Cyclododecane is most commonly used as a volatile and therefore temporary binding medium.
3. The testing phase for this project continues. Modern Art Conservation is working with the artist's studio to find a solution not only for the small works of the series but also for the artist's large-scale works that consist of highly underbound pigment.

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ALAN PHENIX and AGATA GRACZYK

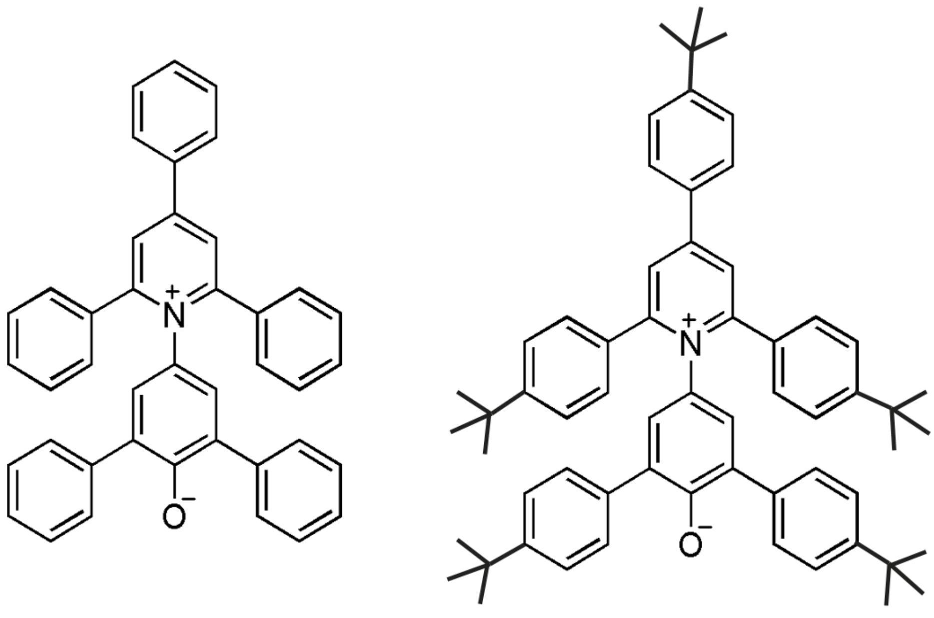
Mapping the Nonideal: Reflections on Graphical Representation of Solubility Parameters as a Tool in Conservation Practice

1. INTRODUCTION

Since their introduction in the 1970s (Toracca 1975; Feller 1976), solubility parameters—especially those approaches that lend themselves to accessible graphic representation of solvent character, such as that of Hansen (Hansen 2000), and the fractional analogues derived therefrom by J.P. Teas (Teas 1968)—have become essential elements of solvent theory within the field of art conservation. Such systems serve as aids to problem-solving in solvent-cleaning treatments (Hedley 1980), as devices to illustrate resin solubility and changes therein (Feller 1976), and as practical guides to selection of carrier for solvent-borne polymers (Horie 2010). Despite the now well-established practical and theoretical shortcomings of the Teas fractional solubility parameter system (Blank and Stavroudis 1989; Michalski 1990; Phenix 1998; Zumbühl 2005), two main factors perhaps underpin its continuing currency in conservation circles: its graphic accessibility by means of a ternary diagram, and the potential to estimate the solvent power of mixtures through fractional additivity of the respective parameters of the component liquids. The limitations of the Hansen/Teas systems have been recognized now for some time, but nothing has yet emerged to replace them that quite matches their functional graphic practicality as a solvent descriptor system for conservation applications.

2. SOLUBILITY DESCRIPTORS: SOME RECENT DEVELOPMENTS

Within solvent science, a number of arguably more rigorous treatments of solvent solubility characteristics have emerged in recent decades, the most prominent of which are all based on the phenomenon of solvatochromism: that is, the shifts in molecular spectroscopic absorptions of chemical probes as a consequence of dissolution in solvents of different kinds. A widely adopted approach to describing solvent character is the single-parameter Reichardt polarity scale $E_T(30)$, which is determined by UV/V is spectroscopy of a pyridinium *N*-phenolate betaine dyestuff (Reichardt & Welton 2011) (fig. 1a). Normalization of $E_T(30)$ values by reference to least- and most-polar solvents leads to the Reichardt E_T^N polarity scale (0.0 = tetramethylsilane; 1.0 = water). Of the many multiparameter solvatochromic approaches to solvent characterization that have been proposed, the α / β / π^* schema of Kamlet and co-workers (Kamlet et al. 1983), and the SA/SB/SPP schema of Catalán and co-workers (Catalán 2001) are among the most widely adopted in solvency science over the past three decades.[1] All of these solvatochromic descriptor systems have now had some modest exposure in art conservation. Within our field, Zumbühl (2014) recently described his own system for parameterization to describe the swelling action of solvents on modern artists' paints, which featured a single numerical descriptor of solvent activity $[h\delta_H + eE_T(30)_{cv}]^N$. Zumbühl's $[h\delta_H + eE_T(30)_{cv}]^N$ descriptor comprises essentially two components: the Hildebrand/total solubility parameter δ and a correlated polarity parameter [akin to Reichardt's empirically determined solvatochromic polarity value $E_T(30)$] calculated from the Catalán parameters, SSP (polarity/polarizability), SA (solvent acidity), and SB (solvent basicity). In the Zumbühl (2014) system, the graphic representation of paint swelling response involves separation of solvents into separate classes—dispersive and polarizable (types I and II), aprotic (types III and IV), and protic (type V)—but even with that and some other visualization devices, it requires a fair amount of effort on the part of the reader to interpret patterns in paint-solvent interactions.



(a) **(b)**

Figure 1. (a) Reichardt's standard solvatochromic pyridinium-*N*-phenolate betaine dye for determination of $E_T(30)$ values; dye compound #44 in Reichardt and Welton (2011, 453) (b) Reichardt's lipophilic penta-*tert*-butyl-pyridinium-*N*-phenolate betaine dye for determination of E_T' values of apolar solvents. Dye compound #45 in Reichardt and Welton (2011, 453).

POLARITY AND POLARIZABILITY

In the same context of describing the activity of solvents on artists' (oil) paints, Phenix (2013) had earlier explored various approaches to graphical representation of paint swelling data in relation to selected solubility descriptors. One of the simplest and most coherent presentations emerging from that study was offered by a two-parameter system involving Reichardt solvatochromic polarity [$E_T(30)$ or E_T^N] and solvent refractive index [n]. Refractive index is known to be an indicator of the polarizability of a substance; that is, its disposition to have polarity induced in its molecules by proximity to an electric field, like a permanent dipole.[2] When presented graphically in a simple *x*–*y* diagram, the combination of these two properties separated organic liquids remarkably well in terms of their solubility character and swelling action.[3] The Reichardt E_T polarity parameters are understood to be independent of polarizability (Laurence et al. 1994, 5815; Machado, Stock, and Reichardt 2014, 10441); thus, E_T^N and refractive index [n] are complementary descriptors of solvent character.[4] An especially useful aspect of this approach is that both polarity value E_T^N and refractive index [n] can be measured relatively easily oneself using not-too-elaborate instrumentation, meaning that data can be obtained on solvents and solvent mixtures that are not covered by the literature. Refractive index alone is a good descriptor of the relative solvent power of aliphatic and aromatic hydrocarbons.

A NEW GRAPHIC SYSTEM FOR REPRESENTATION OF SOLUBILITY: E_T^N vs. n

Our study explored the potential of the 'E_T^N vs. n' approach to describing solvent activity as a tool for conservation practice and research. In addition to extracting data from literature sources, our study involved experimental determination of $E_T(30)$ and E_T^N polarity values from UV/V is spectroscopic measurements of Reichardt's pyridinium *N*-phenolate betaine dye in solution (fig. 2), and measurements of refractive index by refractometry.[5] When represented graphically as *x*–*y* plots, the respective E_T^N and n values distribute the different families of solvents across the space (fig. 3). Unlike the Teas's diagram, in which most solvents are compressed into a relatively confined area of the ternary plot, in the 'E_T^N vs. n' representation solvents of different types are spread widely across the chart. In the same vein as the Teas chart, solubility of organic substances may be depicted as regions within the *x*–*y* plots, as we have demonstrated for the urea-aldehyde resin Laropal® A81 (Phenix and Graczyk 2015).

Particular attention has been given to the behavior in this descriptor system of solvent mixtures. Using data from published sources and from self-generated measurements, the variation in E_T^N and refractive index as a function of proportion (expressed as mole fraction) was demonstrated for a large number of binary solvent mixtures.[6] For most binary solvent mixtures, the 'E_T^N vs. n' representation is a very nonuniform space. Figure 4 shows the

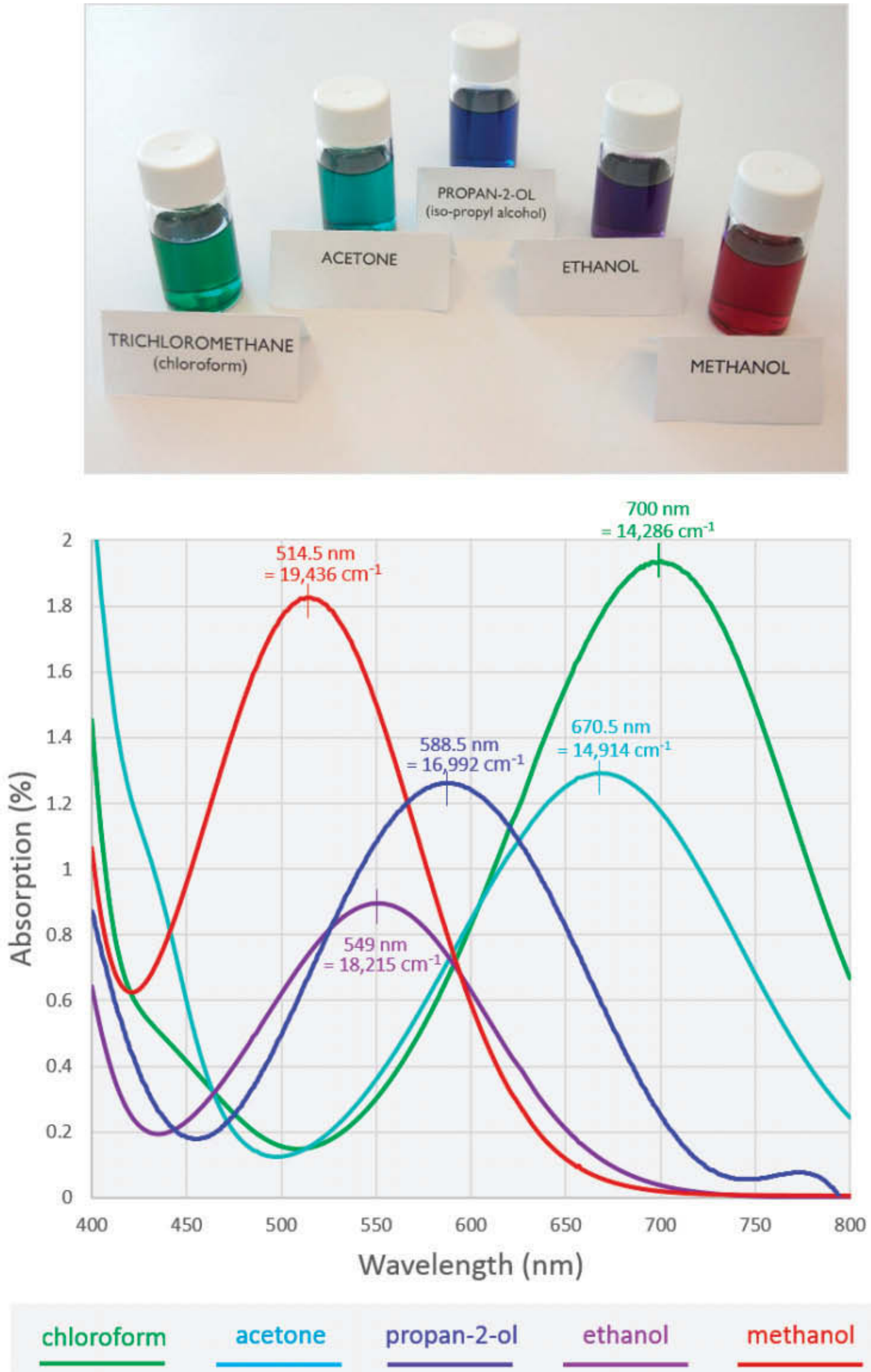
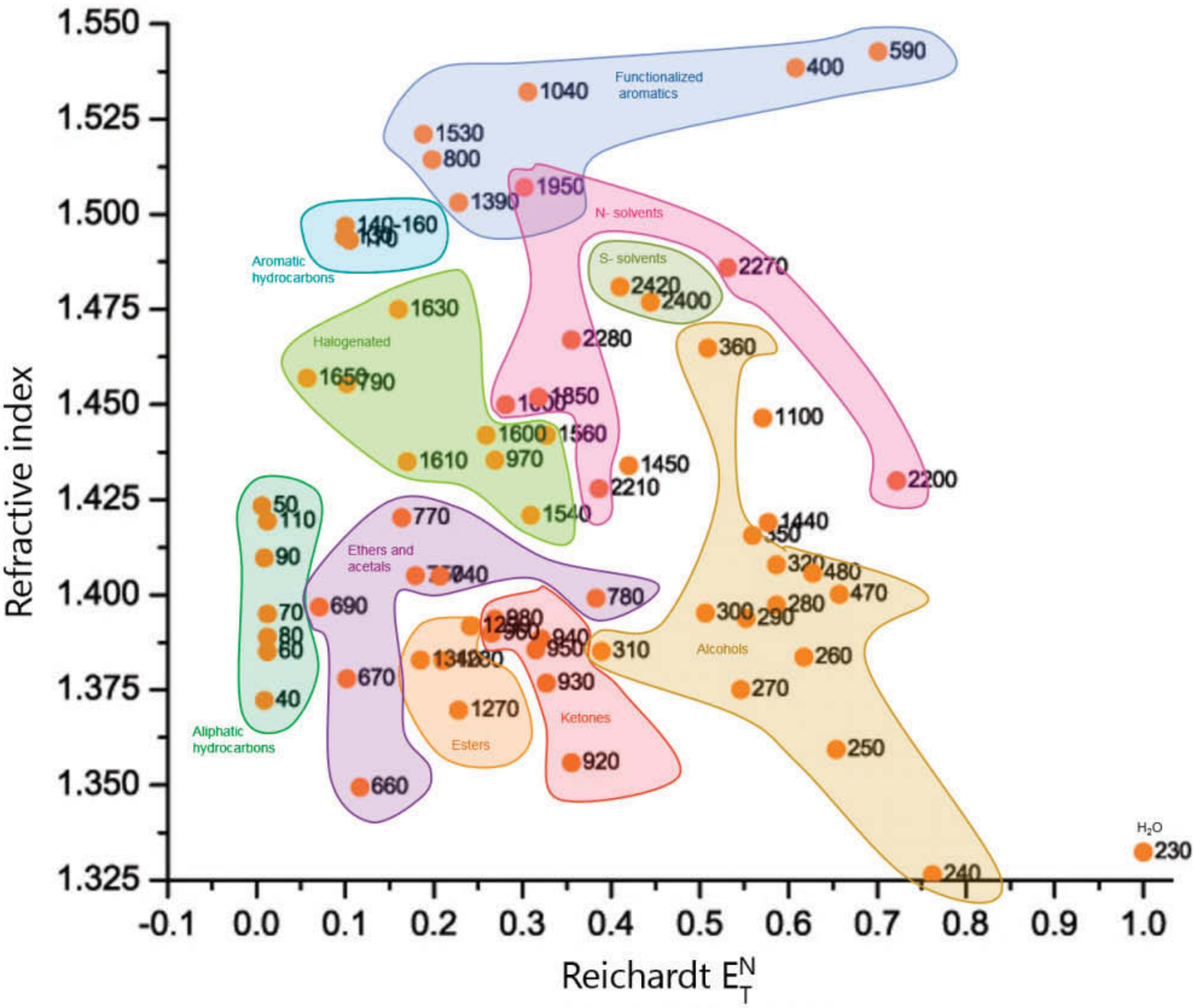


Figure 2. Solvatochromism of Reichardt's pyridinium *N*-phenolate betaine dye. The absorption spectrum of the dye, hence its color, varies according to the polarity of the solvent in which it is dissolved.* The $E_T(30)$ value is derived by calculation from the wavelength maximum expressed as wavenumber (cm^{-1}). $E_T(30)$ values determined from these spectra are chloroform 40.8, acetone 42.6, propan-2-ol 48.6, ethanol 52.1, methanol 55.6. Normalized E_T^N values calculated from the $E_T(30)$ values are chloroform 0.31 (0.259), acetone 0.37 (0.355), propan-2-ol 0.55 (0.546), ethanol 0.66 (0.654), methanol 0.77 (0.762), which compare reasonably well with published values (in parentheses; from Marcus 1998).

**Solvents were tested "as supplied"; no special purification was done prior to the spectroscopic analysis.*



Key to Solvents

Marcus No.	*Solvent*	*Marcus No.*	*Solvent*	*Marcus No.*	*Solvent*	*MArcus No.*	*Solvent*
40	*n*-hexane	300	*sec*-butyl alcohol	800	anisole	1450	γ-butyrolactone
60	*n*-heptane	320	*n*-pentanol	930	butanone	1540	methylene chloride
70	*n*-octane	350	*n*-hexanol	940	pentan-2-one	1560	1,2-dichloroethane
80	*iso*-octane	360	cyclohexanol	950	3-methylbutan-2-one	1600	chloroform
90	*n*-decane	400	benzyl alcohol	960	pentan-3-one	1610	1,1,1-trichloroethane
110	*n*-dodecane	470	methyl cellosolve	970	cyclopentanone	1630	trichloroethylene
130	toluene	480	cellosolve	980	methyl iso-butylketone	1650	tetrachloromethane
140-160	xylene (isomers)	590	phenol	1000	cyclohexanone	1850	morpholine
170	ethylbenzene	660	diethyl ether	1040	acetophenone	1950	pyridine
230	Water	670	di-*n*-propyl ether	1100	acetylacetone	2200	N-methyl formamide
240	methanol	690	di-*n*-butyl ether	1270	ethyl acetate	2210	N,N-dimethyl formamide (DMF)
250	ethanol	740	THF	1280	propyl acetate	2270	2-pyrrolidone (butyrolactam)
260	*n*-propyl alcohol	750	2-methyl THF	1290	*n*-butyl acetate	2280	N-methyl-2-pyrrolidone (NMP)
270	*iso*-propyl alcohol	770	1,4-dioxane	1340	diethylcarbonate	2400	Dimethylsulphoxide (DMSO)
280	*n*-butyl alcohol	780	1,3-dioxolane	1390	ethyl benzoate	2420	sulfolane
290	*iso*-butyl alcohol	790	1,8-cineole	1440	ethyl acetoacetate		

Figure 3. Graphic presentation of solubility descriptors: Reichardt E_T^N vs. refractive index; distributions of different solvent families; data and solvent numbering from Marcus (1998).

behavior of mixtures of different solvents with acetone. In many instances, especially where the components of the mixture were quite different in chemical character, as in the case of polar solvents mixed with relatively apolar ones, significant deviations from linearity were observed in the relationship between E_T^N and refractive index (fig. 5). Furthermore, in most cases linear additivity of response in relation to solvent proportions was not observed. This effect was most evident in binary mixtures containing an alcohol or other hydroxylic solvents: small additions of alcohol to an apolar solvent produced a disproportionally large shift in E_T^N values especially. Almost certainly, this behavior derives from the known preferential solvatochromic response of the pyridinium *N*-phenolate betaine dye in solvents that contain an –OH group. The differing nonlinear responses of series of binary solvent mixtures in relation to relative proportions of the components impacts significantly on the coherence of the graphic representation of solvent mixtures in the 'E_T^N vs. n' system compared with the representation of pure solvents: the representation of the solvent activity of mixtures may not be superimposable on that of pure solvents.

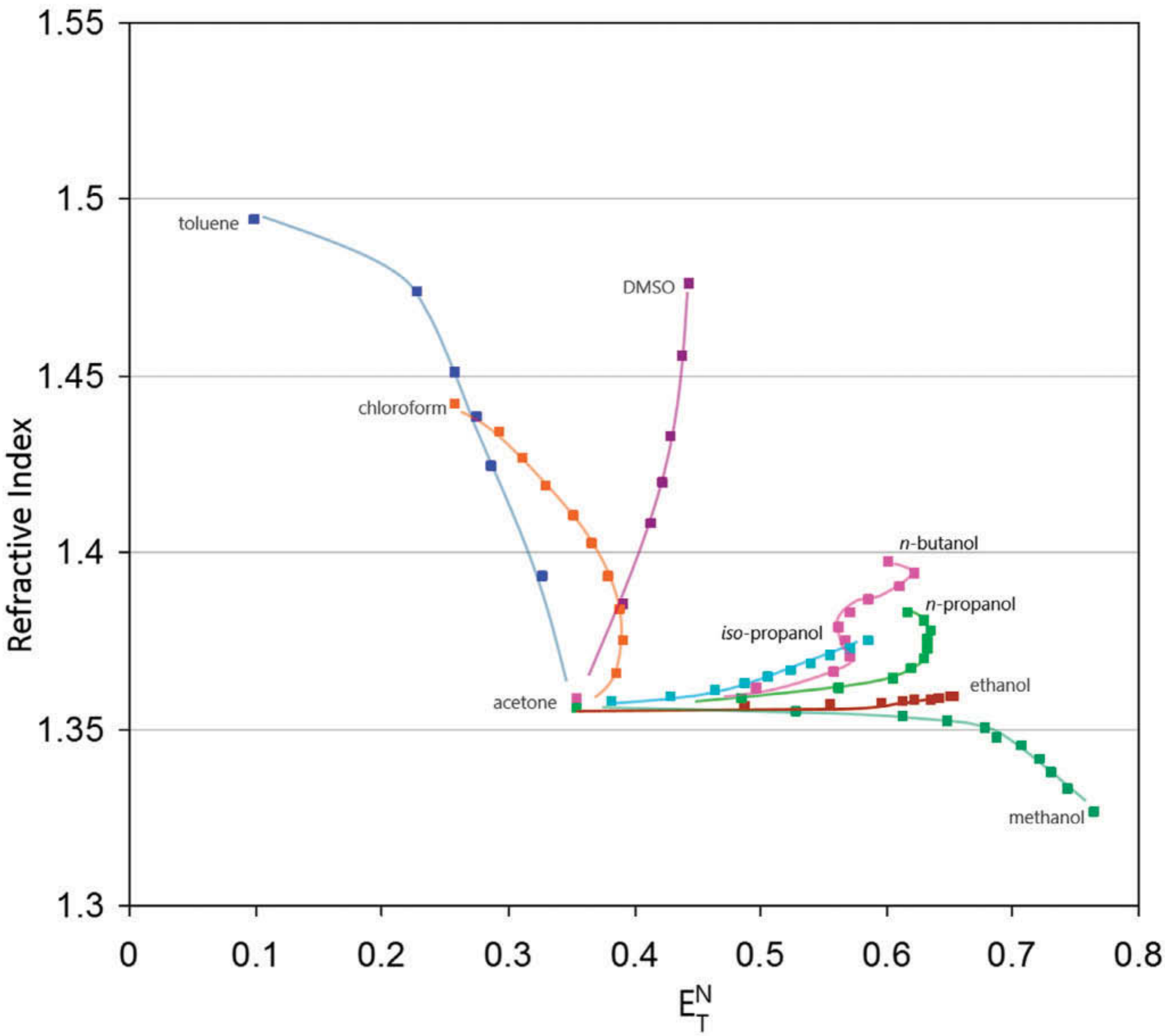


Figure 4. Variation of E_T^N and refractive index as a function of proportion (mole fraction) within different series of solvent mixtures with acetone. Significant deviations from linearity occur for most solvents. E_T^N data from various published sources, primarily Marcus (1994) and Mancini et al. (1995). Refractive indexes measured by authors.

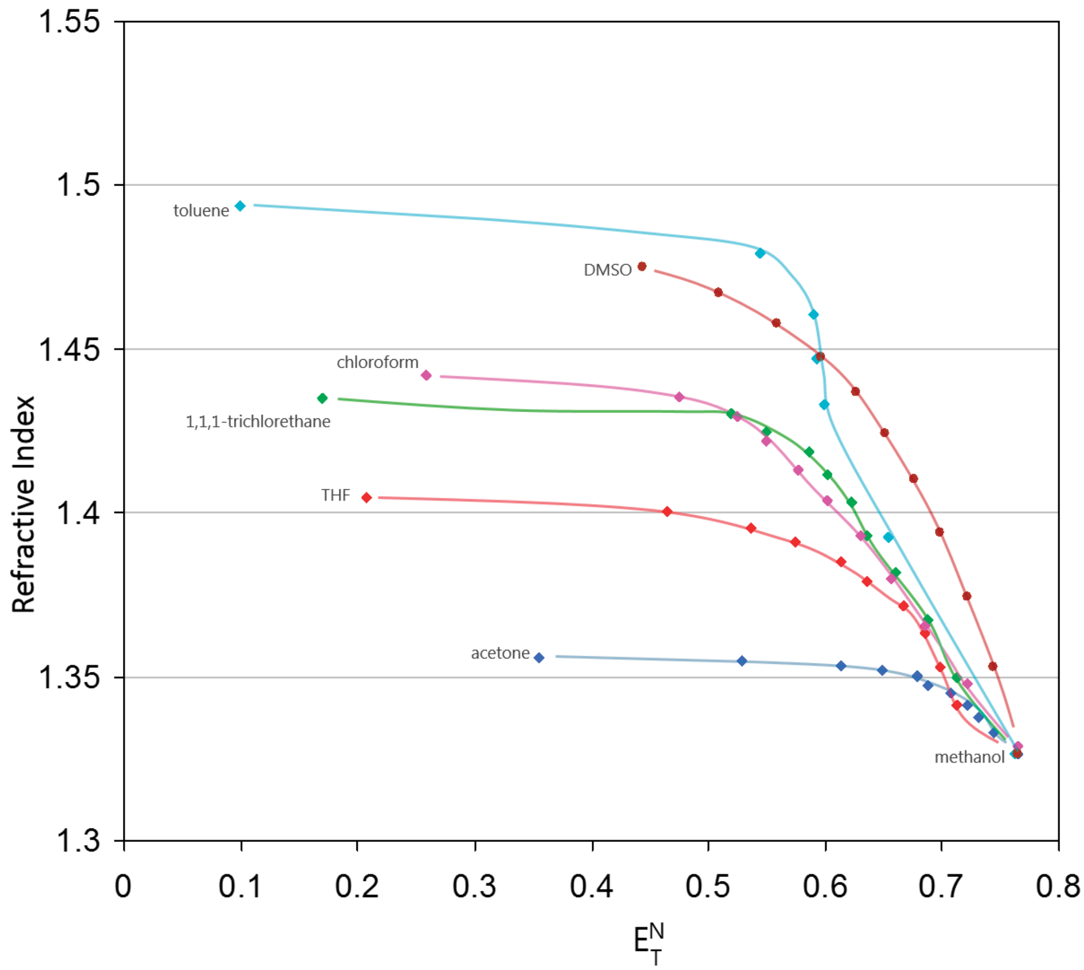


Figure 5. Variation of E_T^N and refractive index as a function of proportion (mole fraction) within different series of solvent mixtures with methanol. Significant deviations from linearity occur for most solvents. E_T^N data from various published sources, primarily Marcus (1994); and Mancini et al. (1995). Refractive indexes measured by authors.

The coherence of the 'E_T^N vs. n' representation of solvent activity for mixtures compared to pure solvents has been tested using published data on the solvent-induced swelling of oils paints. Using datasets from Phenix (2002) and Zumbühl et al. (2013) on the respective swelling powers of pure solvents and of various binary mixtures, it has been demonstrated that in the 'E_T^N vs. n' *x–y* graphic representation regions of particular degrees of swelling do not register coincidentally across the two solvent sets: pure solvents and binary mixtures. On this evidence, it was proposed that, if the 'E_T^N vs. n' system is used as a device for graphic representation of solubility effects, data for pure solvents and binary mixtures should be rendered separately because they are not coherent and superimposable.

In terms of utility for applications and research in art conservation, one particular advantage of the 'E_T^N vs. n' descriptor system is worth highlighting: the possibility for self-determination of parameter values for solvents or solvent mixtures on which no published data exists in the literature. An important technical constraint of Reichardt's pyridinium-*N*-phenolate betaine dye for the determination of $E_T(30)$ and E_T^N polarity values for apolar solvents and mixtures was noted, however—the insolubility of the dye in very apolar liquids. A solution to this technical problem does exist, in principle, in the form of a lipophilic alkyl-substituted version of Reichardt's solvatochromic dye: penta-*tert*-butyl pyridinium-*N*-phenolate betaine (fig. 1b), which is soluble in very nonpolar liquids (Reichardt and Harbusch-Görnert 1983). With some qualifications, the very good linear correlation between E_T values determined, respectively, for the two dyes—$E_T(30)$ for the regular dye and E_T' for the alkyl-substituted dye—allows for determination of $E_T(30)$ and E_T^N polarity values across the full polarity spectrum, even for solvents in which the regular dye is not soluble (Laurence, Nicolet, and Reichardt 1986; Mehranpour and Hashemnia 2006).[7] Studies of the solvatochromism of the lipophilic penta-*tert*-butyl pyridinium-*N*-phenolate betaine dye in apolar binary mixtures are envisaged for future work, spectrophotometer access allowing. We are reminded, though, that the idea of a solvatochromic dye as a convenient indicator of the solvent power of apolar solvents is not new, even in art conservation: Robert Feller, not surprisingly, had that thought nearly 50 years ago (Feller and Page 1967).

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NOTES

1. In the Kamlet-Taft-Abboud approach, the parameter α is an indicator of solvent hydrogen-bonding acidity/donicity, β is an indicator of solvent hydrogen-bonding basicity/receptivity, and π* is an indicator of solvent (di) polarity. In similar fashion, in the approach of Catalán and co-workers (at least up to Catalán 2001) SA is an indicator of solvent hydrogen-bonding acidity, SB is an indicator of solvent hydrogen-bonding basicity, and SPP is a combined indicator of solvent polarity/polarizability.
2. Polarizability is the disposition for the electron cloud of the molecules to be distorted from normal shape by an external electric field. Substances with tightly bound electron clouds, like fluoroalkanes, have low refractive indexes. Solvents with relatively high-refractive index and high polarizability, such as aromatic hydrocarbons, are capable of strong dispersion force interactions. Polarizability and refractive index are related according to the Lorenz–Lorentz equation (Reichardt 2011, 14). A connection between solvent polarizability and refractive index is illustrated in Catalán and Hopf (2004, 4697); table 1.
3. If further discrimination of solvent action is needed, the possibility exists for the addition of a third descriptor so as to form a 3D *xyz* space. Perhaps most useful in that connection would be a parameter related to hydrogen-bonding interactions, either acidity or basicity.
4. Recognition of the significance of polarizability as a solubility descriptor, independent of solvent (di)polarity, underpins a recent elaboration of the three-parameter approach of Javier Catalán. Subsequent to work on the solvatochromism of a compound 'ttbP9' to derive an indicator of solvent polarizability (Catalán and Hopf 2004), in a recent reconsideration of his generalized treatment of solvent effects (Catalán 2009) his original three-parameter system is expanded to four, the combined polarity/polarizability descriptor SPP being now split into two separate, independent parameters: SdP (solvent dipolarity) and SP (solvent polarizability).
5. Refractive indexes of pure solvents and binary mixtures were made using a Mettler-Toldeo RM40 sapphire cell refractometer. $E_T(30)$ and E_T^N polarity values were determined from UV/V is spectroscopy Reichardt's *N*-pyridinium phenolate betaine dye in solution. UV/Vis absorption spectra were obtained on an Agilent G1369A single-beam spectrophotometer, using pure solvent minus dye for the reference spectrum. Raw spectra off the instrument were postprocessed using Microsoft Excel. The empirical solvent polarity parameter $E_T(30)$ is derived from the wavelength maximum of the long-wavelength charge transfer absorption band of the solvatochromic pyridinium *N*-phenolate betaine dyestuff measured at 25°C. With the wavelength maximum expressed in wavenumbers (cm^{-1}), $E_T(30)$ is calculated using the equation:

$$E_T(30) = 2.859 \times 10^{-3} \times \bar{\nu}_{max} \text{ (unit = kcal/mol)}$$

The normalized polarity E_T^N scale covers the range from 0.0 (least polar: tetramethylsilane; $E_T(30) = 30.7$) to 1.0 (most polar: water; $E_T(30) = 63.1$), with the normalized E_T^N parameter of any given solvent being calculated from its $E_T(30)$ value using the equation:

$$\frac{E_T^N = E_T(30)_{solvent} - 30.7}{32.4}$$

6. Within the solvent science literature, binary mixtures of solvents are almost always described in terms of mole fraction or ratio; that is, the relative proportion of each component expressed as a decimal fraction of the total number of moles. See the many examples of different solvent combinations in Marcus (2002). 1 Mole of any given substance contains Avagadro's number of molecules and corresponds to the mass contained in the molecular weight of the substance expressed in grams. For example, 1 Mole of toluene is contained in 92 g of that liquid; 1 Mole of *iso*-propanol is 60 g.

Thus an equimolar mixture (0.5:0.5; equal numbers of each type of molecule) of these two solvents consists of 46 g toluene and 30 g *iso*-propanol.

It can be seen immediately that, because the molecular weights are different, expressing proportion as mole fraction gives quite different quantity ratios compared to weight (mass) fraction. A 0.5:0.5 mixture of toluene and *iso*-propanol by weight actually corresponds to a mole fraction of 0.395:0.605. A further variation occurs if relative proportion is expressed in terms of volume ratios, on account of the different densities of the liquids. Taking again the example of toluene (density 0.867) and *iso*-propanol (density 0.786), 100 mL of a 0.5:0.5 mixture by volume would comprise 43.35 g toluene and 39.3 g *iso*-propanol, the mole ratio then being 0.418:0.582.

These examples of the variation of relative amounts depending on whether one is expressing relative proportions in terms of volume, weight, or moles have a bearing on the reliability of the practice within conservation of estimating solubility parameters of mixtures in the Teas fractional solubility parameter system using proportional linear interpolation from the parameters of each pure solvent. Measuring out and expressing solvent proportions by weight as opposed to volume is probably the safer approach.

7. We use the term E_T' for the solvatochromic polarity parameter derived from Reichardt's lipophilic penta-*tert*-butyl-pyridinium-N-phenolate betaine dye (#45) in compliance with the convention adopted by Laurence, Nicolet, and Reichardt 1986.

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Researching and Presenting Fragments of Late 17th- and 18th-Century Dutch Painted Chambers: "Re-Presenting" Jurriaan Andriessen (1743–1819), a Case Study[1]

ABSTRACT

In the Netherlands in the 17th and 18th centuries many paintings were commissioned for specific locations as part of decorative interior schemes. Large painted wall hangings, overmantels, overdoors, and ceiling paintings, together with architectural elements, sculptures, plasterwork, and wood carvings formed a coherent whole. Only a handful of these "painted chambers" have survived in situ; some have been dismantled and reconstructed as period rooms in museums. For most ensembles, the elements were separated and scattered between institutions and museums as isolated objects

This article deals with the interrelated topics of analyzing, conserving, and exhibiting paintings that originally were part of a painted ensemble. Examples of current museum presentations of dislocated fragments are followed by an in-depth case study of three painted canvasses that once belonged to a painted chamber by Jurriaan Andriessen (1742–1819), an Amsterdam artist who specialized in painted wall hangings. This case study of combined art historical study and conservation research suggests alternatives for the treatment and presentation of these fragments

1. PAINTED WALL HANGINGS

The tradition of painted wall hangings for domestic residences of the wealthy citizens started in the Netherlands in the second quarter of the 17th century and became fashionable in the last quarter of that period. These so-called "painted wall hangings" (*geschilderde behangsels*) were originally referred to as "salon pieces" (*zaalstukken*), "painted chambers" (*geschilderde kamers*) or "chambers in the round" (*kamers in 't rond*) (Van Eikema Hommes 2012, p. 15). In the course of the 18th century, painted wall hangings became so popular that apart from individual *behangsel schilders* (wall hanging painters) like Jurriaan Andriessen (1742–1819), large-scale workshops sprung up in which several painters worked together on painted wall hangings under the supervision of one painter. These workshops were called "painted wall-hanging factories" (*behangselfabrieken*) (Harmanni 2006, p. 154–67).

A limited number of painted chambers have survived in situ (see website Netherlands Institute for Art History, RKD, Inventory Decorative Interior Paintings in the Netherlands 1600–1940).[2] Apart from these remaining painted ensembles, there are several other sources that can give information about how these painted wall hangings were placed and functioning. For example contemporary doll houses, pictures representing interiors, designs and (contemporary) testimonies describing ensembles (fig. 1). Mantlepiece, stucco-ceiling, and painted wall hangings, for example, were designed together as a whole. This site specific art also followed illusionistic conventions, such as, taking the natural direction of the light into account. An example of a painted ensemble that still survives in its original context is the chamber painted in 1771 by Jurriaan Andriessen (1742–1819) for Herengracht 524 Amsterdam (now in the care of the Rijksmuseum inv. nos. SK-A-4854-A/J/4855-A/B, fig. 2). In 1997, one of the canvasses was dismantled from the

[1] This research is part of the project 'From Isolation to Coherence: an Integrated Technical, Visual and Historical Study of 17th and 18th Century Dutch Painting Ensembles' supported by the Netherlands Organization of Scientific Research. This project is based at Delft University of Technology. The Rijksmuseum and the Cultural Heritage Agency of the Netherlands (RCE) are partners in the project. See: www.fromisolationtocoherence.nl
In 2017 the Rijksmuseum will publish this research in a special issue of *The Rijksmuseum Bulletin* dedicated to the *Beuning Kamer*, alongside an exhibition on the history of the room will be organized.

[2] http://english.rkd.nl/Projecten/Decoratieschilderingen

Figure 1. The salon in Petronella Oortman's doll's house (ca. 1686–ca. 1710) with painted wall hangings by Nicolaes Piemont from around 1690 – 1709, Rijksmuseum, inv.no. BK-NM-1010

Figure 2. Jurriaan Andriessen, *Arcadian Landscape* and *Two* Trophies, 1771. Oil on canvas. Wall hangings *in situ* in the garden room of the main floor at 524 Herengracht, various dimensions. Amsterdam, Rijksmuseum, inv. nos. SK-A-4854-A to J and SK-A-4855-A and B; H.L.P. Jonas van 's Heer Arends-kerke-Lefèvre de Montigny Bequest

room and displayed separately in an exhibition on the representation of the landscape in the 18th and 19th century *(Along Fields and Roads)*. The individual display of the fragment—as if it was an easel painting—outside the room where it was specifically designed for, altered its very meaning, understanding, and appreciation. This was illustrated by a newspaper review of the 1981 exhibition. When discussing Andriessen's painting from the series, the journalist stated that these painted wall hangings must have been oppressive to be surrounded within a domestic environment. He concluded that this must have been the reason why the fashion of painted ensembles did not last long. To call a tradition that lasted for over one-and-a-half century merely a short-lived trend, illustrated the limited knowledge of these ensembles (Harmanni 2006, vol. I, p. 15; Loos et al. 1997). Since this exhibition, the general awareness, understanding, and appreciation of painted wall hangings has improved, but the difficulty of exhibiting ensemble paintings outside their original setting in a way that respects their original context while following the given practical situation in the museum galleries, persists.

The Rijksmuseum houses several examples of paintings that once belonged to ensembles. Different types of display have been considered to show these works outside their original context in their new museum setting. For example, the set of five monumental allegorical paintings, painted in grisaille by Gerard de Lairesse (1640–1711) for the vestibule of the house "Messina" of Philips de Flines, Herengracht 164 Amsterdam (ca. 1675–1683, inv. nos. SK-A-4174/4178, fig. 3a-3e) has been displayed in different arrangements. The set was acquired by the museum in 1970. At that time the condition of the pictures was moderate, and two of the five pictures were severely damaged (Snoep 1970, p. 188). The restorations proved to be problematic, and the condition of one of the allegories is such that its display is not possible even today. As such, the series was never installed completely. It was in 1981, two of the five grisaille paintings were restored and exhibited for the first time in the Rijksmuseum as part of the exhibition, *God, Saints, and Heroes*. After the 1981 exhibition, one of the pictures was kept permanently on show. In his 1992 monograph of De Lairesse, Alain Roy stated the difficulty to picture the original effect of the five grisailles in the vestibule of the canal house for which they were specifically designed. He exclaimed this was even more problematic as the Rijksmuseum exhibited only one of the grisailles and, although painted for a vestibule, placed it at the end of a hall way (Roy 1992, p. 79). Between 1998 and 2002, two of the three remaining untreated paintings were successfully restored, and from 2003 up until 2013, four of the five grisailles were presented together in the Philips wing of the Rijksmuseum. In 2010, the order of the pictures in the gallery was adjusted so the painted light and shadow in the paintings coincided with the actual direction of the natural light in the exhibition room (fig. 4a, 4b). De Lairesse always took great care to depict the light in his paintings to correspond with the actual light of the room for which they were made, a necessity he elaborately discussed in his highly influential treatise called *Groot Schilderboeck*, first published in 1707. Since the renovation of the Rijksmuseum, in 2013, two allegories of the ensemble are on display. The paintings were intentionally installed on either side of a cabinet to stress their function as part of a decoration scheme (fig. 5). A label explains their original context.

Another example of the presentation of a painted chamber in the Rijksmuseum is that of an ensemble designed by Andriessen in 1776 for the Nieuwe Doelenstraat 22 Amsterdam (inv. nos. BK-2011-38/43, on loan from the Amsterdam Museum). In 1898, painted wall hangings and wainscotting were sold to the Stedelijk Museum Amsterdam and reinstalled in one of the period rooms of the Suasso wing. Two of the three overdoors of the original ensemble were not included in this new configuration and the current whereabouts of these canvasses is unknown. As the exhibition room had less floor space—was less deep but wider than its initial location—the original arrangement of the canvasses was altered (fig. 6a, 6b, Harmanni 2006, vol. III, pp. 478–9). Toward the end of the 1970s, as the Stedelijk museum shifted its focus to modern art and the period rooms of the Suasso wing were needed for the exhibition of modern art, the painted chamber was dismantled once again and put into storage. The care of this room was transferred to the Amsterdam Museum were it remained in storage until 2011 when it was transferred to the Rijksmuseum in preparation for the 2013 reopening of the museum. Available exhibition space and the condition of the painted wall hangings led to the decision to install three of the painted wall hangings of this series of six paintings in a somewhat narrow gallery. By presenting them together with contemporary furniture and decorative objects such as candelabras and a Parisian-made guilt-bronze mantel clock, the suggestion of a chamber was created (fig. 6b). Despite these thorough considerations in displaying the objects, it illustrates the compromise of these interior paintings presented in a museum setting out of their original context.

2. THE *BEUNING KAMER*

A remarkable case of a painted room displayed in a museum setting is that of the *Beuning kamer*, once the main reception room of the Amsterdam canal house at Keizersgracht 187. The elaborate decorative scheme for this room with a spectacular stucco ceiling and Cuban mahogany paneling was commissioned in 1744–1748 by the rich merchant Matthijs Beuning (1707–1755) and his wife Catharina Oudaen (1704–1764). Of the painted decorations from this period, only the overmantel has survived. *Saint Philip Baptizes the Eunuch*, painted by Jacob de Wit (1695–1754), signed and


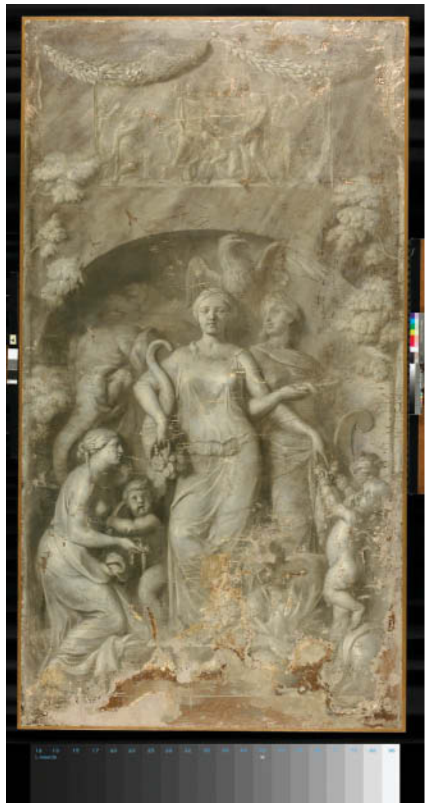


Figure 3a – 3e. Gerard de Lairesse, *Allegory of Riches,* 1675-83. Oil on canvas, painted in grisaille for 'Messina', Philips's house at 164 Herengracht, various dimensions (c. 288 x 153 cm). Amsterdam, Rijksmuseum, inv.nos. SK-A-4174 to 4178; purchased with the support of the Stichting tot bevordering van de Belangen van het Rijksmuseum


Figure 4a, 4b. Display of *Allegory of Riches* (fig. 3), second configuration, after 2010. Philips Wing, Rijksmuseum, Amsterdam. Display of *Allegory of Riches* (fig. 3), current display showing *Sciences* and *Fame*

Figure 5. Current display
SK-A-4177/4178 *Sciences* and *Fame*


Figure 6a, 6b. Jurriaan Andriessen, *Three wall hangings with a Dutch landscape*, originally in Nieuwe Doelstraat 22 Amsterdam, 1776, long term loan Amsterdam Museum, inv.nos. BK-2011-38/43 Display of Andriessens' wall hangings in the Stedelijk Museum 1898-1979 (6a). Photo: Stedelijk Museumandcurrent display in the Rijksmuseum

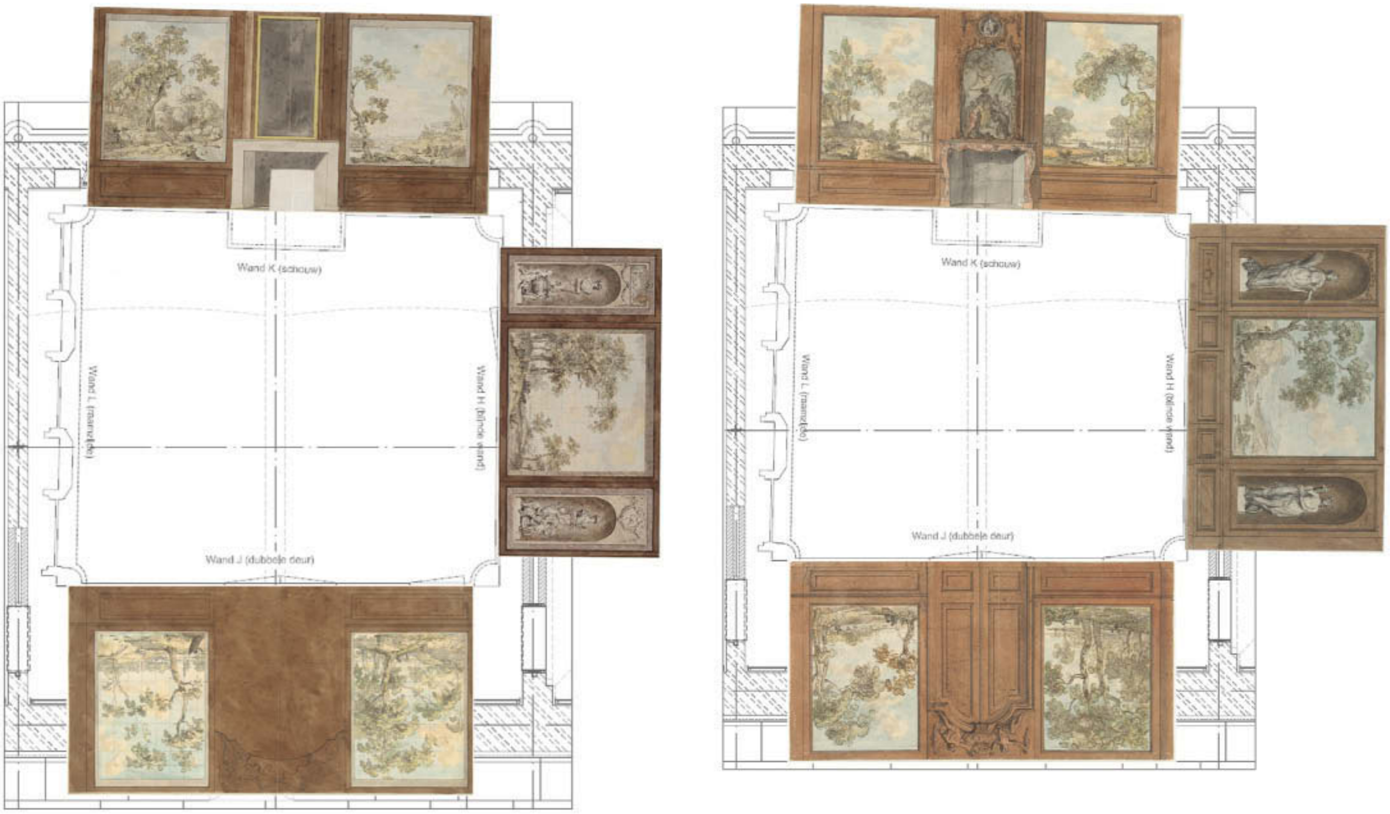

Figure 7a, 7b. Jurriaan Andriessen, design sketches for the *Beuning Kamer* superimposed on the floor-plan, after 1781. Reconstructed by the author with maps by van Hoogevest Architecten. 7a: design I, 7b: design II. Amsterdam, Rijksmuseum, inv. nos. RP-T-00927, RP-T-00-1031 to 2, RP-T-00-1121 and the Amsterdam City Archives, inv. nos. G207-5, G206-4. See also figure 8a, b

dated 1748, is present above the *rouge royal* chimney. The theme of the painting relates to the religious background of the Beuning couple, as prominent members of the Hernhutter community. Nothing is known about the wall covering that would have been applied above the mahogany wainscoting at that time.

The room underwent a drastic transformation at some point after 1781, when the new owner, Jan de Groot (1733–1801), publisher, bookseller, and owner of a lottery office, commissioned Andriessen to paint a series of wall hangings for the room. Two sets of autograph design sketches of Andriessen for to the *Beuning kamer* have survived (fig. 7a, 7b). In his designs, Andriessen has taken into account the painting by De Wit and the mantel piece. Until recently, it was assumed that of Andriessen's painted canvasses, only the decorative overdoor remained (figs. 7–9).

In 1896, the house at Keizersgracht 187 was demolished, and at that time all painted canvasses with the exception of the overdoor by Andriessen and the mantelpiece by De Wit were missing. The ensemble consisting of the stucco ceiling, mahogany paneling, pier mirrors, mantelpiece, and the overdoor and overmantel paintings were reinstalled in the Stedelijk Museum (figs. 10-11). At this time, changes to the paneling were carried out, especially at the window façade, in order to fit the room in the gallery (Brugge-Drieksma 2015). Photographs of installations in the Stedelijk Museum show different types of wall covering; initially, painted imitation tapestries were installed. In the second configuration of the room at the Stedelijk Museum, these were replaced by a modern fabric and the overdoor by Andriessen was removed (fig. 11a, 11b).

At the end of the 1970s, with the shift in the collection focus of the Stedelijk Museum, the *Beuning kamer* was dismantled once again and put into storage. The revival of the chamber began in 2001–02 when the Rijksmuseum presented the most important elements of the room in its *Rococo in the Netherlands: A Riot of Ornament* exhibition, including the overdoor by Andriessen and the overmantel by De Wit. The Rijksmuseum hoped to make this unique example of a Dutch Rococo room part of its permanent exhibition in 2013 (Van Duin, Ter Brugge-Drielsma 2015). The installation proved to be a complex conservation project for which many aspects had to be taken into account (fig. 12, Van Duin 2010). The focus of the museum was to show the exquisite example of a Rococo interior and to emphasize the outstanding woodwork as had been commissioned by the Beuning family around 1745–1748 (permanent loan from the

Figure 8a, b. Jurriaan Andriessen, *design for the Wall with Doors at the Home of Jan de Groot*
a. First version, c. 1786. Pencil, pen and grey ink, grey wash, watercolours, 161 x 307 mm. Amsterdam, Rijksmuseum, inv. no. RP-T-00-1031
b. Second version, 237 x 461 mm. Amsterdam, Rijksmuseum, inv.no. RP-T-00-1121

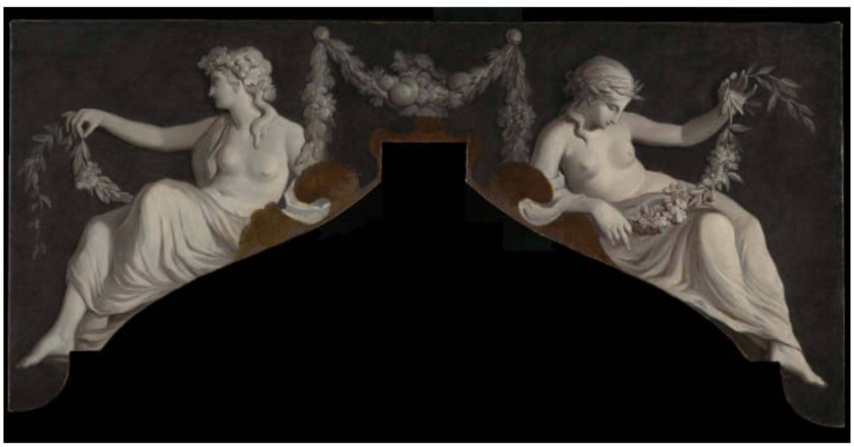

Figure 9. Jurriaan Andriessen, *Overdoor with Representation of Two Reclining Women with Garlands*, 1786. Oil on canvas, 124 x 260 cm. Amsterdam, Rijksmuseum, inv. no. BK-C-2007-1-B; on loan from the Amsterdam Museum

Figure 10a, b. Photographs taken before the dismantling of 187 Keizersgracht in 1896
a. Overmantel by Jacob de Wit, 1748
b. Overdoor by Jurriaan Andriessen, 1786.
Photo's: Koninklijk Oudheidkundig Genootschap

Figure 11a, b. Photographs taken during the installation in the Stedelijk Museum.
a. c. 1908, photograph Amsterdam, Stedelijk Museum
b. c. 1976, photograph Amsterdam, Stedelijk Museum

Figure 12a, b. Photographs taken during installation in the Rijksmuseum, 2013

city of Amsterdam, Amsterdam Museum fig. 13a, 13b). The walls≈were covered with a new, rich green fabric, based on an 18th-century pattern, specifically chosen to make the mahogany color of the woodwork stand out. The overdoor by Andriessen, dating from the 1780s, was restored and reinstalled as well. This means that the room, just as in the Stedelijk Museum, shows elements from different phases in the history of the room: the Beuning period, the Andriessen period, and the current Rijksmuseum configuration. This stresses the ambiguity of reinstalling a period room; it is inevitably subject to multiple meanings.

2.1 Jurriaan Andriessen and the *Beuning Kamer*

Soon after the reopening of the Rijksmuseum in 2013, two paintings—each depicting life-size female figures as *trompe l'oeils* of white marble sculptures situated in a brown/yellow marble niche and surmounted by a frieze—surfaced in Italy. The female figures are personifications and represent a Bacchante and Peace (oil on canvas 277 x 102 cm fig. 14a, 14b, De Fouw 2015). *Peace* is signed and dated *Jn. Andriessen inv. & fec. 1786*. The provenance of the paintings only dates back to 2006 when the paintings were put up for sale at an open air antique market in Montpellier, France. Bought by an Italian art dealer, the canvasses, unlined and stored on a roll, were subsequently restored and stretched in Italy (Romanovici and Malagutti, Milano). Of the numerous design sketches by Andriessen that have survived, only one set shows two comparable life size figures painted in grisaille flanking a landscape. This particular design was drawn for the rear wall opposite the windows of the *Beuning kamer*, as proven by autograph notes on the back of the designs (figs. 7a, 7b, 14a, 14b,–16). These designs together with the painted shadows formed a strong indication that the canvasses with the figures of Bacchante and Peace were specially

Figure 13a, b. Photographs of current display of the 'Beuning Kamer' in the Rijksmuseum.
Main reception room 197 Keizersgracht 187 Amsterdam, 1745–1748. Cuban mahogony, rouge royal marble, plaster, damast, 878 x 770 x 466 cm. Amsterdam, Rijksmuseum, inv. no. BK-C-2007-1; on loan from the Amsterdam Museum

Figure 14a, b. Jurriaan Andriessen, *Painted wall hanging with Bacchante* and *Painted wall hanging with Peace*, 1786. Oil on canvas, 277 x 102 cm. Amsterdam, Rijksmuseum, inv. nos. SK-A-5025, SK-A-5024; purchased with the support of Fonds De Haseth-Möller/Rijksmuseum Fonds. *Peace* is signed and dated at lower right on the pedestal: 'Jn. Andriessen / inv. & fec. / 1786'

Figure 15a, b. Jurriaan Andriessen, *design for the Back Wall at the Home of Jan de Groot*.
a. First version, c. 1786. Pencil, pen and grey ink, grey wash, watercolors, 159 x 264 mm. Amsterdam, Rijksmuseum, inv. no. RP-T-00-927.
b. Second version, c. 1786, 190 x 366 mm. Amsterdam City Archives, inv. no. G207-5

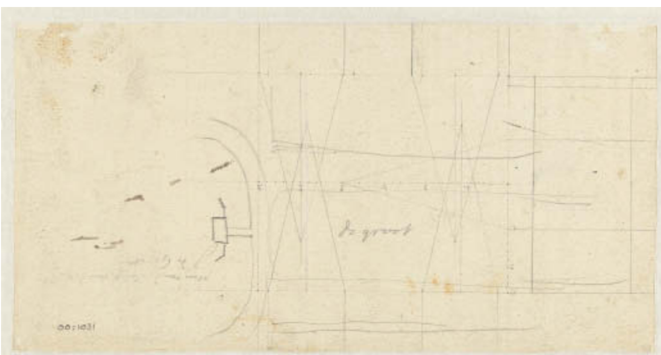

Figure 16. Jurriaan Andriessen, verso of first version Design for the Wall with Doors at the Home of Jan de Groot (see fig. 8a). Inscription: 'plan van de Zaal van den Hr J de Groot; de groot', 161 x 307 mm. Amsterdam, Rijksmuseum, inv.no. RP-T-1031

made for the *Beuning kamer*. In fact, the depicted direction of the light in the paintings corresponds with that of the natural direction of the light at the rear wall of the room. Also their iconography is compatible with that of the two female figures of the overdoor representing summer and autumn. Unfortunately, the whereabouts of the large landscape between the figures in the sketch remain as yet unknown. In 2013, the paintings were acquired by the Rijksmuseum not only because of the strong hypothesis that they belonged to the *Beuning kamer* but also to enrich the collection.

To make the hypothesis more solid that the newly acquired grisailles belonged to the *Beuning kamer*, material research was carried out on the paintings themselves. The pictures were lined in Italy in 2006 with a traditional glue/starch paste, and filling material and retouching were liberally applied to adjust their fit in a private Milanese interior. When comparing the only photograph taken during the 2006 treatment and the paintings' current states, it was obvious that several details were overpainted (figs. 17, 18a, 18b). An infrared reflectogram made this much clearer (fig. 19a, 19b IRR OSIRIS detector: InGaAs, infrared sensitivity: 900–1700 nm, with a 16 x 16 tile system of 512 x 512 focal plane array). Furthermore, the infrared image revealed an elaborate underdrawing. The underdrawing in the two allegorical figures show the same type of preparatory sketch as found using infra-red reflectography in the overdoor and give insight into the carefully calculated proportions and placements of the figures and architectural elements. In fact, the underdrawing shows that Andriessen followed the guidelines of classicism advocated by De Lairesse, whom he highly admired (Harmanni 2006, p. 68). On a vertical line indicating the middle of the niches, markers are placed that perfectly divide the female figures into eight sections in accordance with the classical ideal human proportions.

To confirm the notion concerning the original placement of the wall hangings, it was important to investigate the edges of the canvasses. Paper tape was attached to the edges of the canvasses during the treatment in Italy. This tape and overpaint that covered all tacking edges was removed, revealing original paint remnants of a grayish/pinkish marble imitation in these areas (fig. 20). Cleaning windows were also made on the face of the paintings, along the overpainted borders, revealing a narrow purplish band with marble imitation (fig. 21a-21c). These original details correspond to the aforementioned design series of Andriessen. On this sketch, the brown/yellow marbling next to the niche is framed by a narrow dark band, followed by a broader strip of grayish/pinkish marbling. The uncovered original paint layers correspond directly to this design (figs. 15b, 20–22). Moreover, the grayish/pinkish marble imitation resembles the *rouge royal* marble of the original

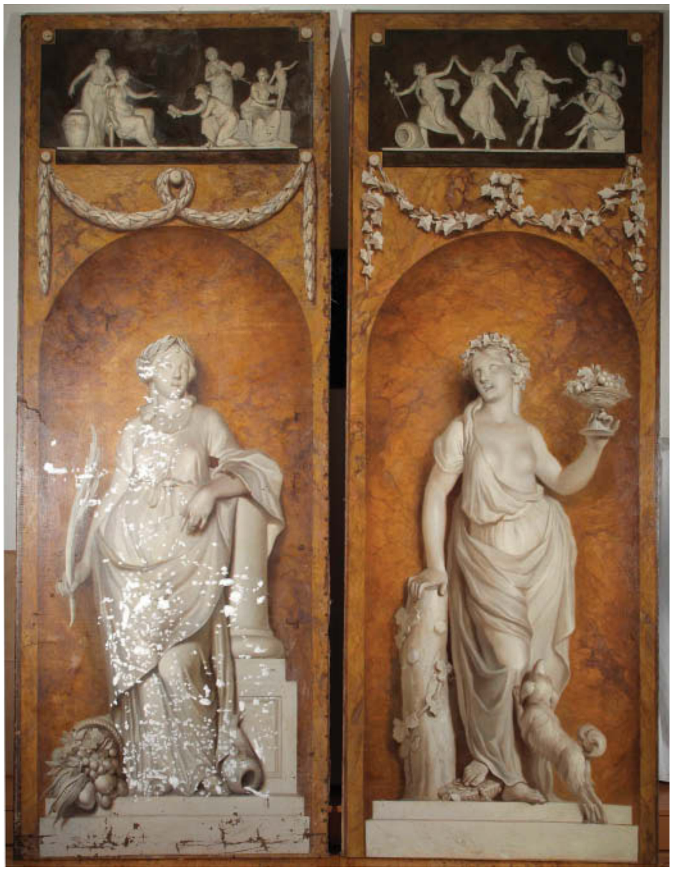

Figure 17. Photograph during treatment, Italy, 2006 (private conservation studio, Romanovici and Malagutti, Milano)

Figure 18a, b. UV-fluorescence, 2014

mantelpiece in the *Beuning kamer*, indicating Andriessen adapted his designs to the designated location (fig. 22). It is now clear that given the paint remnants found along most tacking margins and the correspondence with the border marbling and bands in the sketch, the paintings were originally around 10–15 cm (3.94–5.91 in.) wider. It is clear that Andriessen adapted his designs—format, color and figures—to fit the surroundings, an important aspect for a commission for a painted ensemble.

2.2 Reconstruction of Original Appearance

Using the design sketches as guidance, it was possible to make a digital reconstruction of the original setting of the two allegorical figures in the room (fig. 23a, 23b). The difference in visual effect compared to the present state of the paintings is quite dramatic. The missing borders create more visual depth, adding to the illusion of three dimensionality of the painted sculptures. To determine the exact placement of the paintings on the wall to establish a detailed reconstruction of the

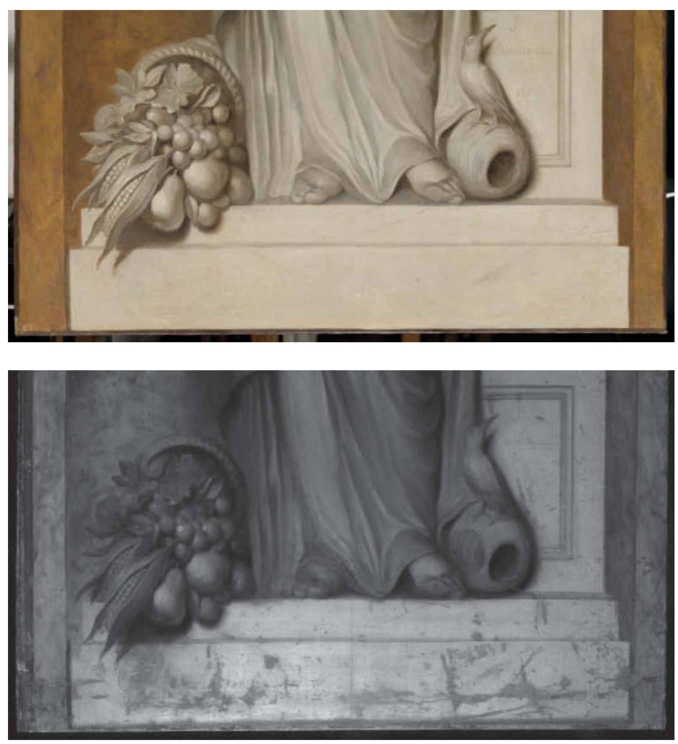

Figure 19a, b. VIS and infrared reflectogram of *Peace*, overpaint and an underlaying band is visible

Figure 20. Detail of turnover edge, marble imitation visible

fragments within the painted ensemble in the *Beuning kamer*, the measurements of the different elements are essential. Andriessen noted several measurements in his first sketch series. These numbers were compared with those of the actual room nowadays. The sketches were also scaled to the wall plan using Photoshop (fig. 24).

The digital reconstruction of the paintings in the room shows that everything fits well, with the exception of the placement of the hidden door in the wall facing the windows. The measurements Andriessen gives for the door vary slightly from its present dimensions. The hidden door has always caused some confusion. For instance, it has a rich ornamentation on the inside, which is curious, considering that the door on the Keizersgracht only provided access to a cabinet and was never intended as a passageway. During the installation of the room in 2013, the conservators established that this cabinet door and most of the paneling of the wainscoting in this section were not original (Van Duin, Hoving, oral communication). This was probably altered during the installation of the room in the Stedelijk Museum at the end of the 19th century, when several changes were made to the room. Since then we know that Andriessen always placed his painted wall hangings carefully, aligned with the wainscoting, as can be seen in his design sketches (Harmanni 2006). The fact that the painted wall hanging on the left would overlap the door approximately 5 cm (1.97 in.) if the wall hangings are placed centrally above the paneling remains problematic. In this setting, the current, enlarged door could not be opened. The digital reconstruction was therefore made with the door closed (figs. 24, 25). The reconstruction shows how the room most likely looked when Commissioner Jan de Groot owned the house. Despite the fact it is a digital manipulation, and the design sketches instead of the paintings are projected onto the walls, it does give an impression of the space and the effect of the presence of the painted wall hangings.

When the paintings in their present condition are digitally depicted onto the green wall, their appearance is a bit

Figure 21a, b, c. Details of cleaning windows showing the band with marble imitation (c. 1 – 1.5 cm)

Figure 22. Detail of the *rouge royal* mantelpiece

Figure 23a, b. Digital reconstructions of missing borders

Figure 24. Digital reconstruction of *Bacchante* and *Peace* and design sketches in the 'Beuning kamer'

Figure 25. The wall hangings in their current condition superimposed on the rear wall of the 'Beuning kamer'

Figure 27. Digital reconstruction of *Bacchante* and *Peace* in the 'Beuning kamer'

Figure 26a, b. Digital reconstructions with strip-lining in neutral toning

disappointing when compared to the overall digital reconstruction (fig. 25). The green wall covering seems to have an overpowering effect and emphasizes the incomplete nature of the wall hangings (with their overpaint, altered sizes, and without the central landscape painting). The following dilemmas arise from such a reconstruction: how can these remnants of a painted wall hanging ensemble be re-presented? What conservation treatment is most desirable? How will these two aspects influence each other? And how can the experience be defined and safeguarded?

The first option is to keep the paintings in their current—fragmented—sizes; however, if all the overpaint is removed, the image will be fragmentary, because of the presence of the narrow purplish band and the surrounding grayish/pinkish marbling which is not equally divided or not present along all edges. This will distract from the intended symmetry of the paintings, and is probably the reason why these details were overpainted in the first place. A second option is to flatten the turned over edges and make all the original paint remnants visible. Again, the result would be fragmented, because the composition has been cut off irregularly (fig. 29). A third option is the addition of a strip-lining, to reconstruct the most probable original size of the two canvasses, as concluded by the research. This implies an addition of 10–15-cm strips of canvas depending on the unequal widths of border remnants at each edge. Such a strip-lining could be toned in a neutral color (fig. 26a, 26b). Another option is not to tone the strip-lining in a neutral way, but to make a physical reconstruction of the marbling on the basis of fragments of original paint. The actual *rouge royal* marble of the mantel can also offer guidance (fig. 23a, 23b). A digital reconstruction in Photoshop of this last option, superimposed onto the current wall covering of the *Beuning kamer* indicates how this would look like (fig. 27). In the actual room, it might also be an option to fill the empty space in the middle and the missing borders of the allegorical figures with a digital reconstruction by means of augmented reality, or a 3D print (fig. 24). The missing wooden framework separating the two female allegories and the landscape wall hanging could also be reconstructed physically or digitally. In short, there is a whole range of possibilities for presentation.

3. ORIGINAL CONTEXT VERSUS RECONSTRUCTION

To experience the impact of the painted wall hanging fragments in the room they were originally designed for *Peace* and *Bacchante* were temporarily installed in the *Beuning kamer*. This exercise proved a highly important step within the decision-making process toward the new presentation and subsequent treatment. Digital reconstructions can give an indication of the visual impact, but they cannot replace the experience of a real-life construction. During the display of the wall hangings, curators, conservators, and external specialists were invited to express their opinions. Because the paintings were positioned on easels in front of the wainscoting, different configurations could be tested as well (figs. 28–31).

The overall response was positive; that is, the Andriessen fragments were generally appreciated in their "home-coming." Despite the green wall covering, the overall consensus was that the wall hangings not only blended nicely into the *Beuning kamer*, they also give the room more allure. The connection with the different elements in the room was astonishing, showing that Jurriaan Andriessen was highly skilled in adapting the design of his painted wall hangings to its surroundings, and making it a coherent whole. The debate on whether to provide a temporary, or more permanent housing for *Bacchante* and *Peace*, is nevertheless ongoing. The treatment, or more specifically, the uncovering of the original details, would significantly contribute to the establishment of a "final" decision. The questions about to how to present and how to reconstruct the missing borders prove to be inseparable.

The Andriessen case study illustrates the importance of the integrated research, not only of the individual objects themselves, but also that of the context when dealing with parts of ensembles. Such a study is necessary to present the female personifications within a museum environment and to help decide on the conservation treatment of the canvasses.

Figure 28. Temporary installation, "try-out" of the wall hangings in the 'Beuning kamer', 2015

Figure 29. Temporary installation, "try-out" of the wall hangings in the 'Beuning kamer', 2015

Figure 30. Temporary installation, "try-out" of the wall hangings in the 'Beuning kamer', 2015

Figure 31. Temporary installation, "try-out" of the wall hangings in the 'Beuning kamer', 2015

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Resurrecting a Giant: The Visible Conservation of Villanova University's Triumph of David

ABSTRACT

Beginning in the fall of 2013, the conservation of a large oil on canvas measuring 12 × 20 ft. began within the walls of Villanova University's Falvey Library in a public space. The 17th-century painting, currently attributed to Pietro da Cortona, was believed to be damaged beyond repair and has remained inaccessible to students, faculty, and the public since the1980s. In early 2013, a team of conservators, scientists, and art historians discovered that much of the original composition was simply buried beneath multiple layers of varnish and overpaint. A variety of analytical tests and imaging techniques have been performed on the canvas, both to guide conservators throughout the treatment, but also to answer remaining questions regarding the provenance of the artwork. Cross-sectional microscopy in conjunction with SEM-EDX and Raman spectroscopy has helped to reveal the original materials used by the artist while IRR and x-ray radiography revealed information relating to the evolution of the composition. Analytical methods that are less frequently used in the field of painting conservation (time-of-flight secondary ion mass spectrometry and desorption electrospray ionization) were also helpful in imaging organic and inorganic species present within cross-sectional samples. The treatment of the painting has been conducted in a public space that also serves as a study hall. Members of the conservation team, including interns and preprogram volunteers, are able to host formal classes (e.g., art history, chemistry, studio art, and material culture) in front of the painting as well as unscheduled tours for local visitors. A time-lapse camera station continues to document the two-year project and a monthly blog post offers updates from various members of the team as well as a live-webcam. Finally, efforts to restore the large oil on canvas has inspired Villanova University to make their paintings collection more accessible; this small but important collection continues to be a focal point in the renovation plan for the library's new wing.

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Conserving Paintings by American Artists of African Descent in the National Museum of African American History and Culture, Smithsonian Institution

ABSTRACT

The conservation and preservation of paintings in the Visual Arts Gallery at the National Museum of African American History and Culture, the newest Smithsonian museum on the National Mall, are on track for the grand opening scheduled for September 24, 2016. The Visual Arts Gallery will be the only permanent art exhibition on the Smithsonian Mall to illustrate the critical role of American artists of African descent in shaping the history of American art. It will raise these artists' profiles from the periphery of the American art canon to its center. Jia-sun Tsang, senior paintings conservator, leads the team of conservators, which includes Inês Madruga from the Smithsonian's Museum Conservation Institute who are charged with the conservation and safe display of paintings at the NMAAHC. This article highlights the team's long-term plans for preventive conservation and the technical studies designed to support their treatment.

1. INTRODUCTION

Some of the paintings in the VAG were purchased, but most have been donated by the artists, the artists' descendants, or private collectors since 2007. The collection includes artists from the 18th (Joshua Johnson), 19th (Robert Scott Duncanson), and 20th centuries (Charles Alston, Aaron Douglas, Lois Mailou Jones, Augusta Savage, and Hughie Lee-Smith), along with some of the most critically acclaimed artists working today (Radcliffe Bailey, David Driskell, Rashid Johnson, Whitfield Lovell, Jefferson Pinder, Joyce Scott, and Renee Stout). The artworks themselves represent a wide range of materials and techniques, including multiple types of paint (oil, oil pastel, acrylic, alkyd, poster paint, gouache, household paint, and mixed media); three-dimensional "found" objects (rhinestones, nails, and feathers) layered into paint; and primary supports ranging from canvas to paper, engineered (composite) wood, metal, and glass. This evolutionary spectrum of properties poses immense challenges and rewards for the professionals charged with the treatment and preventive conservation of these paintings.

Many pieces in the collection had been previously stored in less than ideal condition and thus required substantial treatment. To streamline the process, a system was established to prioritize emergency treatment according to the severity of damage. The first step involved a comprehensive condition survey that included paint and pigment identification, nondestructive instrumental analysis, and image-based condition reporting. The survey[1] also included treatment recommendations and guidelines for preservation, such as environmental conditions in storage and exhibition, and the display and safe handling of artworks. The survey report served as a platform for communication and planning for a team that included a digital imaging archivist, conservators, curators, designers, registrars, collection managers, and art handlers.

Physical and chemical changes are greatest in young contemporary paintings. This fact underscores the need to use scientific principles and techniques to better understand the composition and aging behavior of the immense array of new materials and techniques used by contemporary artists. An essential element of the team's treatment strategy was establishing guidelines for a technical analysis that combined nondestructive instrumental analysis, minimal sampling of paint binders for imaging analysis, FTIR instrumental analysis, and microchemical tests using optical microscopy. This comprehensive analysis of the paints' chemical behavior directly informed the team's treatment options.

The focus of this article is preventive conservation and treatment, categorized by four essential elements of our conservation strategy: iPad Survey, Travel Box, Hanging Devices, and Technical Analyses: Case Studies.

1.1 Condition Survey

The first step in systematically evaluating the need for preventive conservation and treatment of the paintings in the

Table 1. IPad Features and Applications in the NMAAHC Paintings Condition Survey

Touchscreen technology	Use of applications and digital image marking with the touch of a finger or stylus.
Mobile and lightweight	Survey can be done in front of the work of art being examined.
Apps: Notability and ArtStudio	Enable easy data input and organization, report, and photo documentation. Conversion of files to PDF format.
Wi-Fi	Easy electronic data transfer via e-mail, Dropbox, etc.

VAG collection was to conduct a comprehensive condition survey. Because this survey was often conducted in storage or off-site facilities, we chose a portable iPad as the most efficient way to deliver consistently formatted reports. We developed a template for the iPad that combined a traditional condition-ranking system with additional columns for notes, space for a short summary of treatment recommendations, and an image/diagram for visually documenting each painting's condition. This iPad survey was developed as a convenient tool for any museum staff involved in the care of collections, including registrars, collection managers, fabricators, art handlers, curators, and conservators, and is clear enough to be used by a nonspecialist as well. Particular features of the iPad that made it ideal for use in our condition survey are listed in table 1.

The goals of the condition survey were to identify and document the following:

1. The current condition of the front and back of each painting
2. Preventive conservation needs, including proper hanging and mounting
3. Treatment needs, including structure and paint surface
4. Optimal environmental conditions for exhibition
5. Safe handling guidelines

The survey template is attached as an Appendix to this article. See figure 1 for an example of the visual documentation of a painting's condition using the iPad.

1.2 Safe Art Transport

The Smithsonian's Museum Conservation Institute (MCI) facility is located in Suitland, Maryland, about 15 miles from the NMAAHC storage facility in Hyattsville, Maryland. The new NMAAHC on the Smithsonian Mall in Washington, D. C., is located 15 miles from the NMAAHC storage facility in Hyattsville. For the project to run smoothly and efficiently between these three locations, a safe, local van for transporting artworks was essential. Thus, developing guidelines for the packing, transport, exhibition, and care of these modern and contemporary paintings was the second major step in our plan for preventive conservation. After careful research, MCI conservators adapted a small-footprint, reusable, cross functional, modular, and environmentally responsible travel box for shipping NMAAHC paintings between locations.

Standard museum crates are expensive and often overbuilt for local transport of paintings by van. The travel box we developed (fig. 2) for packing and handling paintings on canvas grew out of the need to incorporate sustainable

Figure 1. Diagram used to mark up the condition of the painting *Self Portait* by Earle Wilton Richardson, est. 1930–1935, NMAAHC collection. The Bank of America Art Conservation Project funded the conservation of this painting

Figure 2. The travel box is made of wood. Ethafoam and Volara inserted in the bottom of the box absorb shock and vibration, and Coroplast covers the front and back of the box

practices into preventive conservation. The back of the painting is attached to the travel box. The free space between the edge of the travel box and the face and sides of the painting makes it possible to pack and unpack with very little handling or direct contact. Conservation-grade materials, such as Ethafoam and Volara, are added to the bottom of the box to absorb shock and vibration, and Coroplast covers the front and back of the travel box.

Figure 3 illustrates the construction of the travel box and the clips used to secure the painting to the box. Unscrewing the wing nuts releases the painting from the box. The Oz Clip remains attached to the back of the painting and can be folded out of sight when the painting is on display. Placing the Oz Clip with a D-ring allows it to secure the painting to the travel box while also functioning as the hanging hardware for the painting, streamlining transport and hanging into one step. If necessary, the travel box can be placed inside a crate for air transport, making it a simple, multifunctional device for temporary storage and shipping, and safe handling.

We also designed a travel box that could hold two paintings (fig. 4) to extend the box's housing capacity and reduce the footprint required for two separate boxes. Each painting is secured with an Oz Clip on either side of the travel box. There is ample gap between the two paintings, preventing any surface contact between them and eliminating the need to cover the surface of the paintings. (The fragile matte surface of a painting can often sustain damage from improper wrapping.) A locking system ensures proper closure of the travel box, and sturdy handles enable lifting and handling.

Figure 3. The painting is secured to the travel box by D-rings and Oz Clips

This travel box system was tested and used effectively as a temporary storage and transport system in another SI exhibition. A variety of conservation and exhibition-related functions were conducted while the paintings were in the travel box. Designers conducted photo documentation and color and dimension surveys, and fabricators carried out surface cleaning, in-painting, and dimension and material confirmation. The only time the paintings were taken out of the box was when they were ready to be hung for display. In our view, the travel box is an essential tool for preventive conservation as well as an excellent investment.

Altogether, the travel box we designed reduces costs, minimizes the risks of mishandling, protects painting surfaces, and ensures the safety of the painting during transit. In collaboration with SI collection care staff, use of the travel box has become standard procedure for packing and shipping paintings.

1.3 Safe Display

The third major step in the preventive conservation of the VAG's modern and contemporary paintings was devising a hanging system that would ensure safe, long-term display. As a rule, the dimension and weight of an artwork and the existing strainer, stretcher, and frame determine the appropriate hanging hardware. Other considerations in the hanging and mounting of artworks include the structural makeup of the wall, any special security requirements, indoor environmental conditions, and safety. In general, hanging hardware should support 25%–50% more weight than the maximum weight of the artwork. Determining the weight of a work ensures that the hardware for both the frame type and the wall structure are appropriate. Some artworks, especially contemporary art, are constructed with material that can be challenging to maintain over time. If inadequate construction materials or methods were used initially, additional support structures could be added to strengthen and stabilize the work.

Figure 4. A two-painting travel box. Each painting is secured with Oz Clips attached to each face of the travel box. There is ample gap between the paintings, which ensures that there is no surface contact between them

The existing hanging hardware doesn't necessarily need to be replaced, but if new hardware is added, considerable care must be taken not to drill over the old supports. Whenever possible, hanging hardware should be placed on the frame.

Our goal is to narrow the options for appropriate hanging hardware and to standardize methods of installation wherever possible. For medium- and large-sized paintings on canvas, we use the Oz Clip with D-ring (fig. 5). The clip is made of heavy-gauge brass with a steel pivot pin and ring (stainless steel loop). When placed in the open position (L-shape), the device has the double function of securing the artwork into a transport/storage system as well as hanging for exhibition or storage using the ring. It is designed to be a permanent attachment to the frame or stretcher and eliminates fitting each time the artwork is transported, as the Oz Clips can be pivoted to a closed position during exhibition.

Figure 5. Sample board illustrating various types of hanging hardware. Top row from left to right on the display board are two sizes of Oz-clips with D-ring and one without D ring

For large and heavy paintings not on canvas, we use a cleat system. The cleat is built in at the back of the support panel during treatment, and the hanging hardware is usually installed when conservation is complete. The painting can be secured in a travel box with the Oz Clip in the open position, and can be hung with the Oz Clip in the closed position.

At the beginning of the NMAAHC project, we carried out research to document the various types of hardware currently available for hanging paintings on different types of wall surfaces. We produced a booklet for use in SI facilities that lists all the hanging hardware available in the United States, the United Kingdom, and Japan, as well as specifications, prices, and supplier information. The booklet is divided into five sections: Wall-Mounted Hangers, Artwork-Mounted Hangers, Hanging Systems, Mending Plates, and Security Straps. A resource section has information on where to buy these items. The booklet also includes a mechanical analysis of shear-loading condition, tension, and anchoring systems.

We then created a wooden example board that demonstrates the various types of hanging hardware listed in the booklet. The example board is currently on display at the MCI painting studio, where it serves as a teaching and communication tool for fabricators and exhibition staff. Working with conservators, the example board helps museum staff, and even staff who are not well-versed in paintings conservation, to select the appropriate hanging hardware for each piece of art on display.

1.4 Technical Analyses

There is limited technical information available on conservation of the kinds of modern and contemporary paintings included in the VAG collection. Thus, despite the pressures of a heavy workload and tight deadlines, we set out to establish a database of the materials and techniques employed by the artists in the collection. It is vital that the MCI develop and evaluate new materials and approaches to specific conservation treatments through scientific testing and critical assessment. It is also imperative that we share this scientific and empirical information with other conservators and the wider art community. Our technical studies of the VAG paintings informed our approach to treating these works. By detecting problematic grounds, over-painting, losses, and light-sensitive pigments, we were able to tailor treatment to the unique challenges presented by each painting. Our technical examination of these paintings required the use of portable and macro XRF for pigment characterization, FTIR spectroscopy for binder identification, and imaging techniques including UV-induced visible fluorescence, IR and IR reflectography, and x-ray radiography. Since many pigments, and thus paint colors, can be identified by their inherent elements, we can usually learn something about the quality of the paints, whether the colors used were appropriate to a particular period, and, sometimes, which areas of a painting are original and which have been retouched.

1.5 Reflectance Transformation Imaging: A Case Study

The MCI digital imaging laboratory employs reflectance transformation imaging (RTI), reflected IR and UV imaging, and digital radiography. The painting *Self Portrait* by Earle Wilton Richardson, est. 1930–1935, was stored unstretched and rolled for long time under poor storage conditions, which resulted in severe planar distortions and horizontal folding lines

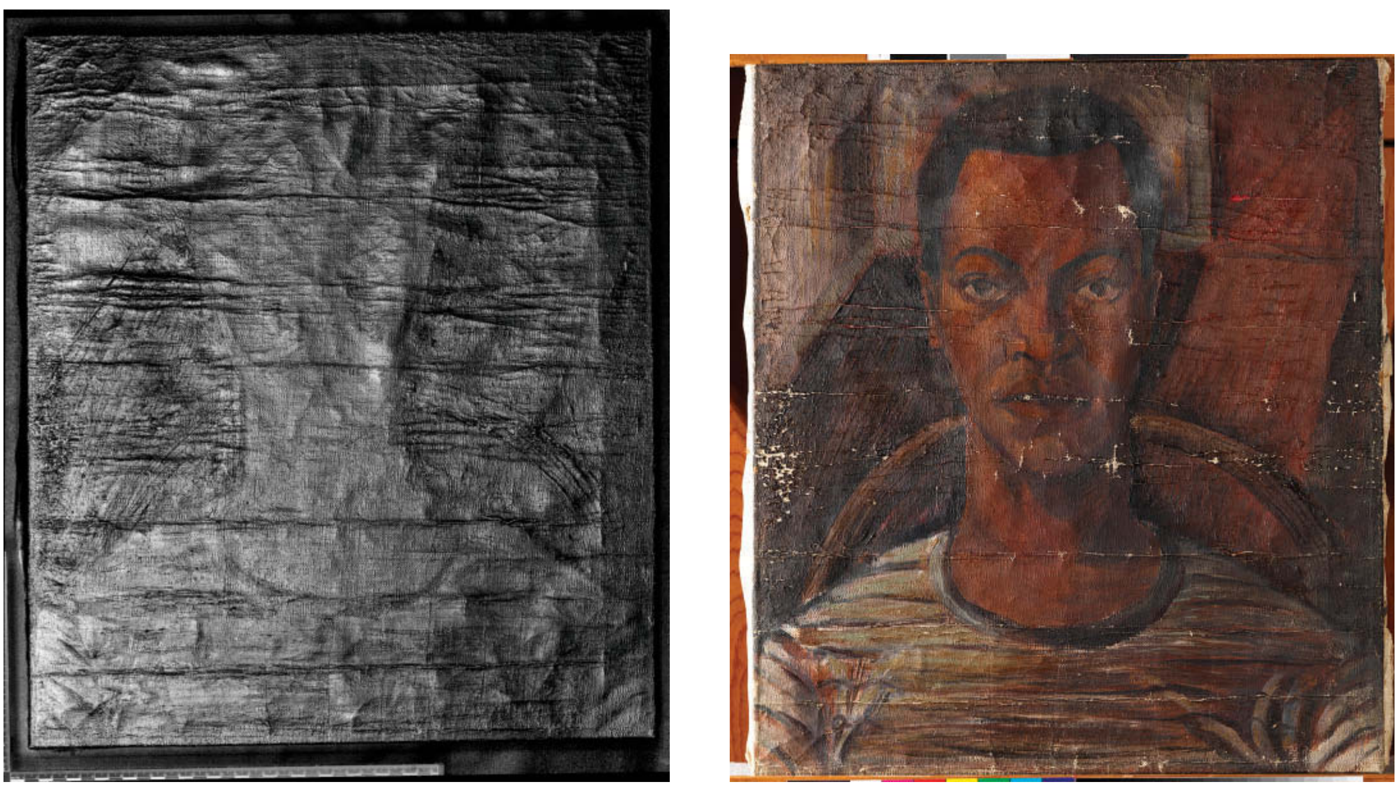

Figure 6. Reflectance transformation imaging (RTI) and raking light of *Self Portrait* by Earle Wilton Richardson, est. 1930-1935, NMAAHC. The Bank of America Art Conservation Project funded the conservation of this painting. RTI image (*left*). Courtesy of Keats Webb, MCI. Raking light image (*right*) Courtesy of Don Hurlbert, NMNH

Figure 7. *Self Portrait* by Earle Wilton Richardson after treatment under normal light. Courtesy of Don Hurlbert, NMNH

(creases), cracking, cupping, and flaking. A surface study is critical to understanding the degree of deformation and is helpful in planning flatting techniques and selecting appropriate lining adhesives and methods. RTI is a computational photographic method that captures a painting's surface shape and color and enables interactive relighting of the subject from any direction.[2] In this case, RTI served as a useful diagnostic tool, providing data about the painting that was not apparent under normal light or a single angle of raking light (fig. 6). Figure 7 shows the conserved painting under normal light (fig. 7).

2. HIROX 7700 3D DIGITAL MICROSCOPE: A CASE STUDY

We used a Hirox 3D digital microscope to examine the small paint sample from Ed Clark's *Big Egg*, 1968, at higher magnification (up to 7000x). We observed and digitally recorded small pigment particles on the surface of the painting to make detailed measurements and profiles. Five cross-sections (A–E) were collected from the painting using a scalpel (see fig. 8a for sampling locations). When capturing images with the HIROX digital microscope, one advantage, when compared to standard microscopy, is that rather than focusing on a single point, the instrument allows you to set a depth of field, or plane of focus.

Figure 8a. A sample location of painting *Big Egg* by Edward Clark, 1968. NMAAHC collection

This means that a larger portion of the sample can be in focus at one time. The user can set those limits to be, by setting the "top" and "bottom" of the sample. Everything between those two set points will be in focus. The instrument achieves this by scanning through a range of depths, and compiling the

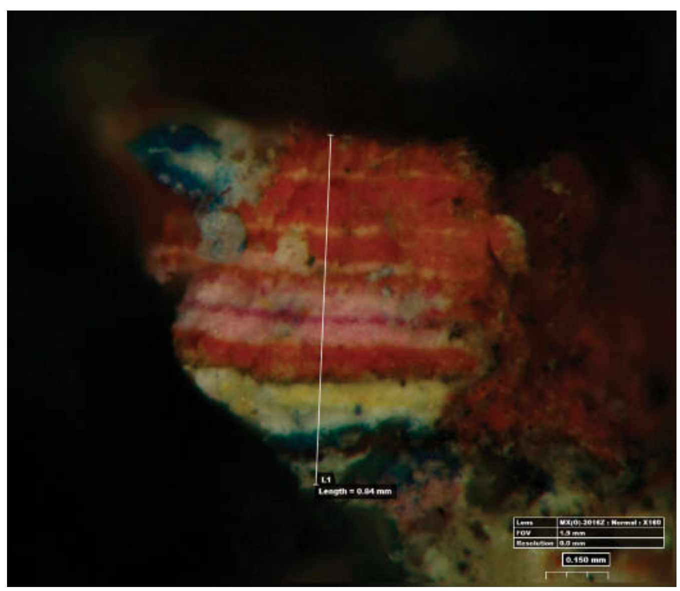

Figure 8b. 3D Hirox microscope image of a cross section of paint from sample D. The sample was not embedded in resin and was examined directly under the Hirox microscope using 3D autofocus features by stacking images to create a 3D image, A drop of water placed on this layer of paint, and paint was breaking apart immediately. This observation was captured via Hirox video features. The Bank of American Art Conservation Project funded the conservation project of *Big Egg*

information into a single image (fig. 8b). Alternatively, this information can be used to create a 3D representation of the surface. This feature eliminates the laborious work of mounting the cross-sections and the samples are not contaminated with embedding resin and can be saved and reused for future chemical analysis. Additional solubility tests with water and isopropanol directly on the cross-section were carried out under Hirox 3D digital microscope and ATR-FTIR analysis was carried out from the top layer sample of the cross-sections. The results indicated that the paint layers are sensitive to water and isopropanol and is most likely acrylic paint.

3. ATTENUATED TOTAL REFLECTANCE (ATR)-FTIR: A CASE STUDY

All fellows and interns working on this project were trained in using the FTIR instrument (located next to the MCI paintings conservation studio) for binder analysis, under the supervision of MCI conservation scientists. The painting *View of Lake Okanagan, British Columbia* by Grafton Tyler Brown, 1882, had a varnish coating that we found was soluble in Stoddard's solvent. We decided to remove a sample for analysis mechanically by ATR-FTIR spectroscopy. On the basis of its FTIR spectrum and solubility, we determined that the varnish was Regalrez 1094, a low molecular-weight hydrocarbon resin that is listed in the MCI FTIR database. Regalrez was developed at the National Gallery of Art around 1990, in large part by Rene de la Rie, for use in conservation. It is soluble in nonpolar solvents, which makes its removal easy with relatively nontoxic solvents such as mineral spirits. Underneath the Regalrez, we discovered a layer of overpaint. Using cotton swabs dipped in solvent, we extracted a sample of the combined residues of Regalrez and overpaint, concentrated the sample via centrifugation and solvent evaporation, and analyzed it by ATR-FTIR. We identified the overpaint as a PVA. C–H stretching registered at 2920 and 2850 in the sample and in the Regalrez, and the C=double bond=O stretch at around 1725. Peaks in the fingerprint region also matched PVA standards (Fig. 9. It is sometimes difficult to identify individual paint binders within mixed media by FTIR analysis. The low-tech analysis developed by Jia-sun Tsang and Maja Rink (2015) was first published in *WAAC Newsletter*, January 2015, can be used to characterize the mixed media paint binders' chemical and thermal behaviors, and results can be used to design proper cleaning and flatting techniques. The low-tech solubility test and melting-points analysis on hot stage (figs. 10 and 11) was routine used in the MCI painting Studio as diagnostic tests.

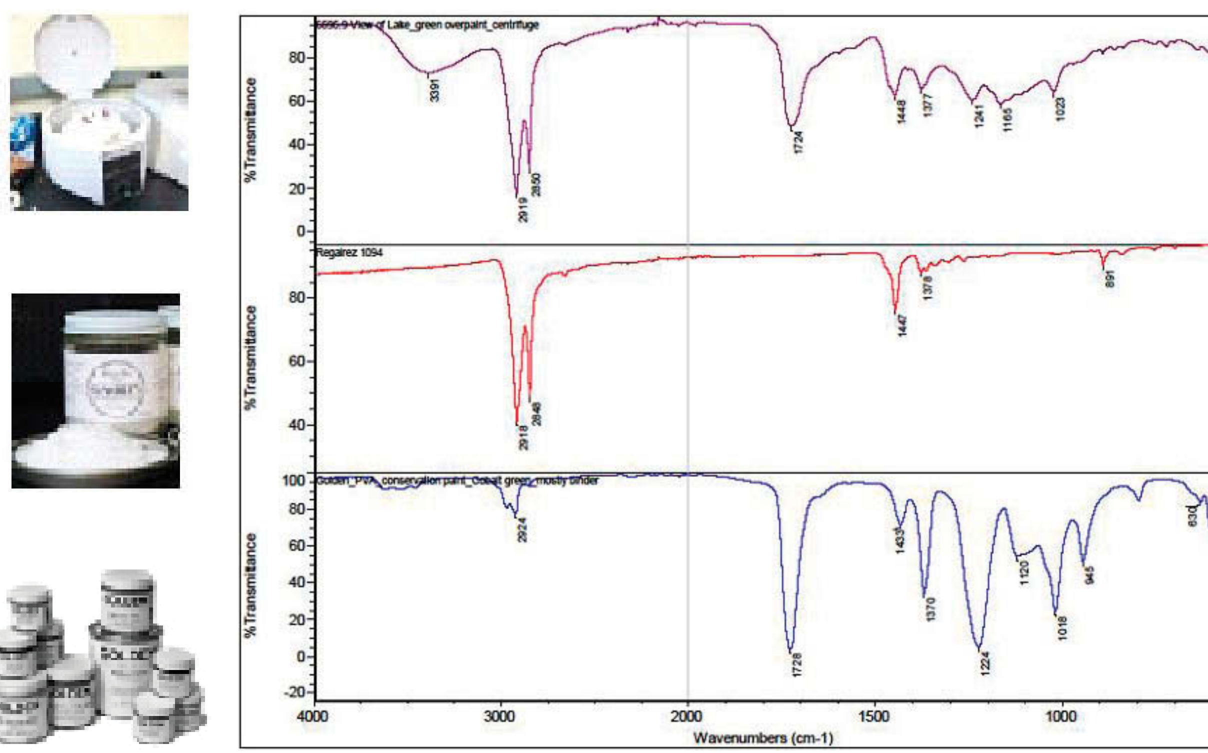

Figure 9. ATR-FTIR analysis of a sample of surface coating recovered from the cotton swab taken during varnish removal from the painting *View of Lake Okanagan, British Columbia* by Grafton Tyler Brown, 1882. A top layer of coating Regalrez and second layer of PVA were found. Courtesy of Christine Romano, 2014 MCI Intern, Buffalo State University Art Conservation Program

	30°C	110°C	130°C	210°C
Acrylic	Soft and elastic	Soft and elastic	Soft and elastic	Soft and elastic
Alkyd	Remains non-elastic	Hardens; does not darken	Hardens; does not darken	Hardens; does not darken
Oil	Remains hard	Softens	Melts, darkens, then hardens	Hardens, darkens, then chars

Figure 10. Melting point analysis of paint binders[1]

	Acetic acid 10%	NaOH 30%	Xylene	Isopropanol
Acrylic	Becomes soft and elastic then swells	No reaction	Becomes soft and elastic, then swells	Becomes soft and elastic, then swells
Alkyd	No reaction	Becomes partially soluble, then completely soluble	Becomes soft, non-elastic	Becomes soft, non-elastic
Oil	Becomes soft, non-elastic	Becomes soluble, darkens	Aged samples, No reaction; Fresh samples: becomes soft, Non-elastic	No reaction

Figure 11. Solubility analysis of paint binders[1]

4. SUMMARY

Since the initial report of our work in conserving paintings from the NMAAHC, presented in May 2015, we have gathered more technical information and our work has intensified. The early preparatory groundwork represented by careful condition survey, development of the safe art transport, and the streamline of safe display have led to positive results, and our initial investment of time, supplies, and research has had significant payoffs.

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THIS ARTICLE HAS NOT UNDERGONE A FORMAL PROCESS OF PEER REVIEW.

NEELA WICKREMESINGHE and GILLIAN RANDELL

Murals of Goldwater Memorial Hospital

ABSTRACT

This paper explores the conservation of the Goldwater Memorial Hospital Murals as both a piece of Works Progress Administration history and as forgotten art, explains the technical process of removing the murals, the technical difficulties encountered along the way, and discusses how the murals will become a permanent link from the now ephemeral hospital complex to the future Cornell Tech campus in terms of institutional memory and historic site interpretation within new architecture. The murals conserved were originally designed and painted by artists Joseph Rugalo and Albert Swinden.

1. BACKGROUND

Coler-Goldwater Memorial Hospital was built on Roosevelt Island in 1939 as the Welfare Hospital for Chronic Disease. The construction of the city-owned hospital was carried out as part of a nation-wide construction campaign under Franklin Delano Roosevelt's Works Progress Administration. Included in the design of the hospital campus were a selection of eight original murals that were installed within circular day rooms. When in these day rooms, patients and hospital staff found themselves located between contemporary, abstract American art and a wall of windows that looked out onto the East River; a highly curated view deliberately orchestrated by the hospital's architect Isadore Rosenfield. The hospital exemplified progressive medical architecture with its interconnected campus setting, emphasis on interior and exterior circulation, and rounded building forms. Over the years, the murals were painted over and completely obscured from public view, remaining only in memory.

In 2010, the City of New York announced plans to demolish Goldwater Hospital to make way for a new technology campus to be built by Cornell University. EverGreene Architectural Arts, led by chief conservator Gillian Randell, was commissioned by Cornell to attempt to locate the obscured murals and assess their conditions. The exposure process included chemical and mechanical overpaint removal in 19 day rooms throughout the hospital complex. As the hospital was still occupied at the time of the investigation, the work had to be done at night and in conjunction with the hospital staff to ensure that the rooms were empty at the time of the investigation.

Two extant murals were found during these investigations, measuring roughly 50 × 7 ft. each. Plans to remove the overpainted murals were set and the removal process began in April 2014, just as buildings within the now-closed Goldwater Hospital were being demolished. Over the next five weeks, the murals were removed and taken off site for conservation.

2. SUMMARY OF WORK

2.1 Mural Removal

Removal of the Rugolo and Swinden murals from Goldwater Hospital was carried out in April 2014. The hospital had just closed to the public, and asbestos abatement and preliminary demolition had begun on site. EverGreene technicians constructed a lead-safe containment area around both day rooms where the murals were located because of the presence of lead within the adhesive used to affix the canvas to the plaster wall (see figure 1).

Onsite de-installation of the Goldwater murals was carried out over five weeks. Each mural was completely obscured by multiple layers of overpaint, so the exact condition of the original paint layer and canvas were unknown at the time of removal. To areas of the canvas where preliminary exposure windows were executed, facing paper was adhered with conservation-grade, water-soluble rabbit-skin glue (see figure 7).

Canvases were slowly removed from the walls using 1 inch wood chisels, tack hammers, thin spatulas, and knives that were 6–12 inch long (see figure 2). Murals were attached to rolling

Figure 1. Mural on Sonotube being removed from wall

Figure 2. Cake knife used for removal

12 foot sonotubes with a 2 ft. diameter during the removal process. Daily removal progress ranged from inches to feet depending on the conditions of the mural. The entire conservation team wore protective Tyvek suits and respirators to ensure that working conditions were lead-safe throughout the removal process (see figures 3-5). After the murals were successfully removed from the fourth and third floor, all rolls and smaller mural pieces were taken offsite to a lead containment chamber within EverGreene's Manhattan studios (see figures 8-9).

Each of the two murals were comprised three sections. In total, four sonotubes were used to transport all mural sections, with smaller canvas pieces packaged in protective foam and bubble wrap. Because of the presence of lead on the murals, each tube and canvas package was sealed in two layers of thick polyurethane sheeting during transport.

The lead-containment area was constructed within the EverGreene Studios specifically for the Goldwater murals (see figure 10). The containment room was constructed from double-walled 6-mm fireproof polyurethane sheeting. The room also included a full three-chamber decontamination corridor for workers to enter and exit the space safely, without contaminating the surrounding work areas. Air-monitoring systems measured the presence of lead particulates within containment to ensure worker exposure levels did not exceed safe amounts. All technicians and conservators participated in blood tests that monitored their internal lead levels to ensure all precautions were effective in preventing lead exposure.

2.2 Lead Adhesive and Plaster Removal

Before work could begin on the front of the murals, removal of remaining plaster and mitigation of the original lead adhesive had to be completed. Once in the studio, the murals were unrolled on to a flat horizontal work surface where the lead adhesive was carefully removed inch by inch, using hand tools and oscillating multi-tools (see figures 11-13).

Removing the adhesive and exposing the back of canvas was required for the next steps: evaluating the condition of the

Figure 3. Mural removal and conservators in lead containment

Figure 4. Mural removal in lead containment

Figure 5. Mural removal in containment

Figure 6. Final pieces of mural being removed in containment

Figure 7. Mural removed from wall, facing paper adhered to damaged canvas

Figure 8. Mural prepped for transport

Figure 9. Murals prepped for transport

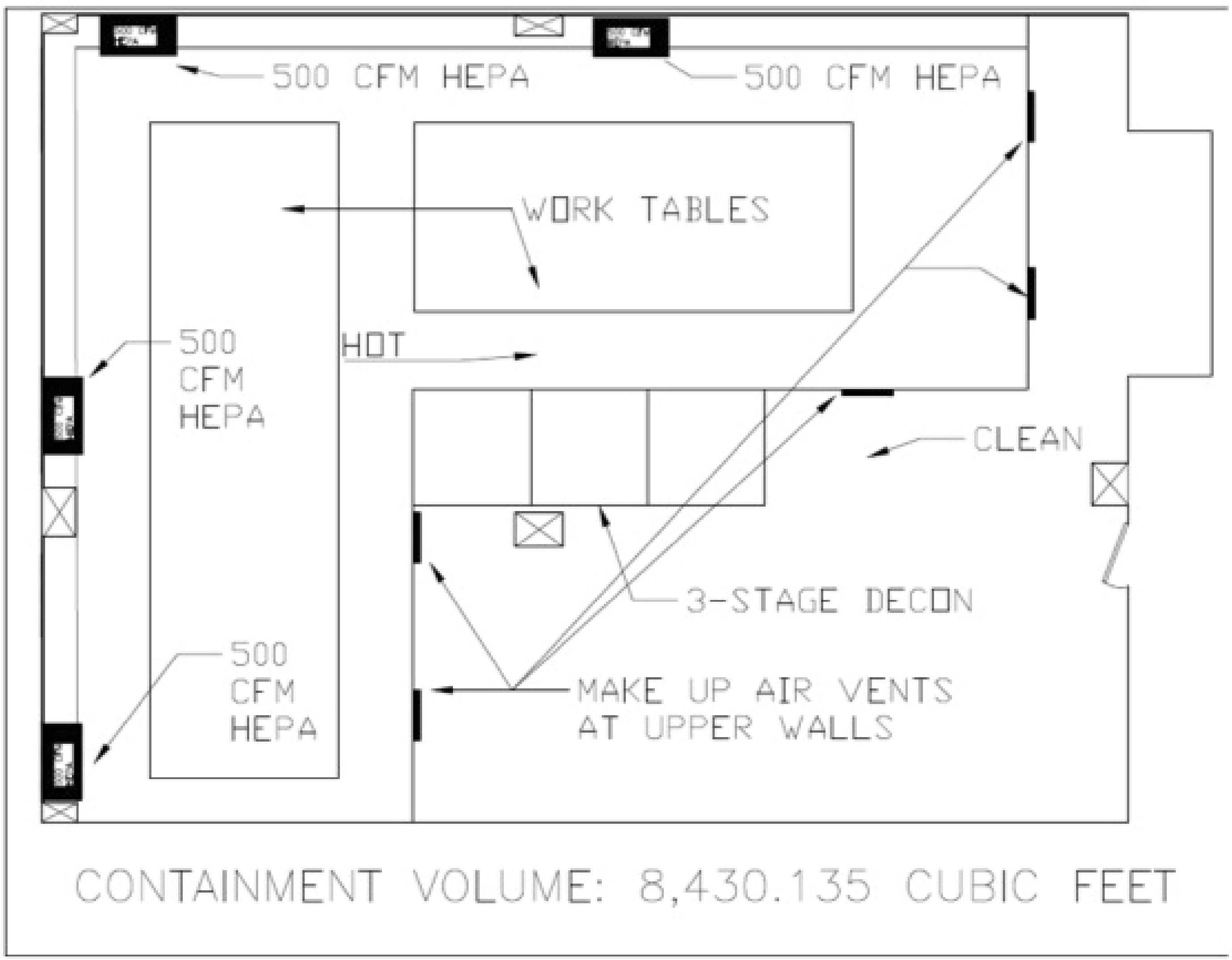

Figure 10. Plan for in-studio lead containment

Figure 11. Lead adhesive removal with oscillating tool

Figure 12. Lead adhesive removal with oscillating tool

Figure 13. Lead adhesive removal with oscillating tool

Figure 14. Manual overpaint removal

canvas and identifying necessary repairs, successfully patching holes, and flattening the mural in preparation for lining and reinstallation.

2.3 Canvas Condition Assessment

The overall condition of the canvases was fair; however, tears and losses were found throughout all mural sections. Overall between 100 and 150 holes were found on the murals, ranging in size from 1–10 inches, with the majority falling between 1 and 3 inches (see figure 19).

2.4 Overpaint Removal

After the back was cleaned, the mural was turned over, and the temporary protective facing paper was removed from the front. Water and mineral spirits dissolved the adhesives that attached the paper to the mural; rabbit-skin glue. Once all of the facing paper was lifted, the murals were ready for overpaint removal and any remaining facing paper fibers carefully removed manually with scalpels (see figure 14). When the murals were still on site, chemical and mechanical paint removal methods were tested. Chemical removal methods did not prove successful. Mechanical removal with scalpels was the only method that worked during this testing phase; however, it was far too time consuming to be used wholescale on each canvas piece. Once in the studio, heat guns were tested on the overpaint layers to great success (see figures 17-18). The heat guns were used in conjunction with scalpels to remove all overpaint found on the murals. After overpaint removal was complete, the surface of the Goldwater murals was unobscured for the first time in over 50 years.

2.5 Paint Condition Assessment and Surface Cleaning

The original paint layer—a palette of oil paints—was in fair condition with the colors holding fast during the cleaning process. Areas of paint loss were found at and surrounding canvas losses and tears and where the canvas was stuck to the substrate. These areas of damage were addressed during the filling and inpainting phase.

Figure 15. Surface cleaning with ammonium hydroxide at a pH of 8.5

Figure 16. BEVA application

Figure 17. Overpaint removal

Figure 18. Overpaint removal

Figure 19. Canvas repair

The murals were cleaned with diluted ammonium hydroxide at a pH of 8.5. This solution removed surface grime still present on the face of the mural after overpaint removal was complete (see figure 15).

2.6 Lead Encapsulation and Varnish

The reverse of the murals were treated with BEVA-371 (diluted in xylene) to strengthen the canvases and encapsulate any traces of lead. Multiple coats were applied for maximum stability, and to create a strong surface for the lining fabric to adhere to (see figure 16).

The front of the murals were treated with conservation grade BEVA UVS varnish (2:1 matte to finishing). This varnish has multiple functions. It acts as a paint consolidant, stabilizing any loose areas of original paint. It creates a reversible isolating layer between the original finish and any repairs, which allows all modern additions to be removed if necessary. Additionally, it creates truer and more stable colors on the mural surface; the varnish saturates the original paint layer for better color representation, and provides a UV-stable surface.

2.7 Ironing

In order for the murals to properly accept their new lining and canvas inserts, the original canvases had to be completely flat. Damage to the canvas and the stress of removal left some sections severely wrinkled and out of plane. Each section of the canvas was painstakingly ironed by hand. Compression poles, sandbag weights, and small tacking irons were also used to flatten the canvases. The murals were ironed again before any inpainting was completed.

2.8 Canvas Inserts

Because of canvas deterioration and loss, patching was necessary. Canvas inserts were cut from canvas that matched the thread count, weave, and thickness of the original. After proper stretching and preparation, the canvas patches were carefully inserted into the mural with hot tacking irons and conservation grade melding powder. Care was take to size and attach the patches so minimal or no seams were visible. Holes and losses smaller than .5 inch were not patched with canvas. Instead, they were filled with Modostuc after the lining was in place. After continuous dialogue with the Public Design Commission, it was decided that the Goldwater murals were not to be restored back to their original appearance. The tears and evidence of damage within the murals illustrate a part of their history that the design and conservation team did not want to erase. In stabilizing the paint layer and structural stability of the canvas and carrying out selective inpainting, the overall composition of the paintings would be preserved while also clearly showing that they had endured quite the conservation history.

2.9 Beva Tear Repairs

Behind canvas tears, Hollytex film impregnated with BEVA-371 Conservation-grade lining adhesive was ironed on to the canvas to ensure structural stability without adding planar distortion or weight to the original canvas.

2.10 Lining

Because of the degraded nature of the Goldwater canvases, a secondary backing, or lining fabric, was required. Polyester sailcloth was selected as the lining material for its strength, stability, light weight, and texture for bonding. It was adhered to the canvas with BEVA-371 conservation adhesive, activated with heated irons from the back. Silicone-coated polyester film was used as a protective heat barrier between the iron and the lining, and between the paint layer and the work surface. The lining was also able to accept all the separate pieces of each mural, creating two large canvases with all pieces present.

2.11 Infill and Inpainting

All losses were inpainted with Gamblin conservation paints blended with the surrounding original finishes. Gamblin paints were using colors that As described previously, an isolating coat of BEVA UVS varnish was applied to the surface of the painting prior to infilling, and another prior to inpainting. These serve as a barrier demarking original and post-historic intervention. The second also sealed the infilling emulsion and provided a receptive surface for the loss compensation (see figures 20–21).

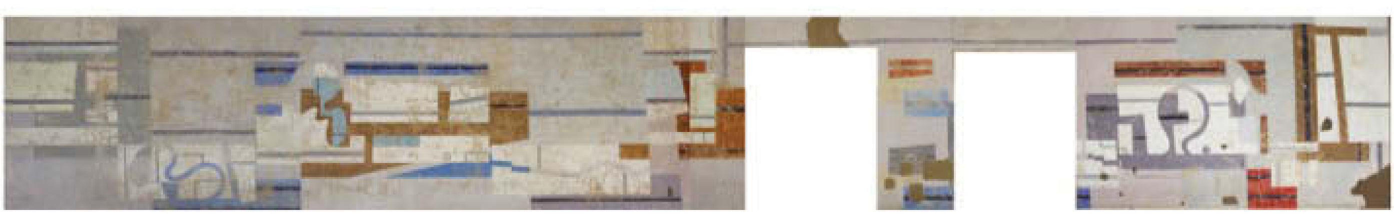

Figure 20. Swinden mural after conservation

Figure 21. Rugalo mural after conservation

2.12 Varnishing

Another BEVA UVS varnish coat was applied over the entire mural surface after inpainting was complete. This created a uniform sheen between the original and inpainted surfaces. It also acts as a protective, non-yellowing, UV-stable, reversible clear coat.

2.13 Re-Crating and Storage

After all conservation procedures were completed, the murals were rolled facing out onto 2-ft. Sonotubes including a protective interleaf layer of silicone release paper on the painted surface. The packed tubes were wrapped in bubble wrap with a final outer layer of 6-mil plastic and packed with appropriate padding and internal blocking for shipment to Transcon International, a GRASP and ArtProtect-accredited facility located in the Bronx. After they were successfully accepted by the facility, the EverGreene conservation team unrolled the murals and packed them into custom flat crates. The crates were constructed of appropriate materials to maintain a level and stable structure, and of adequate length to fully unroll the longest panels. Each mural will be stored in its own crate; three panels stacked with silicone release paper interleaves (see figure 22).

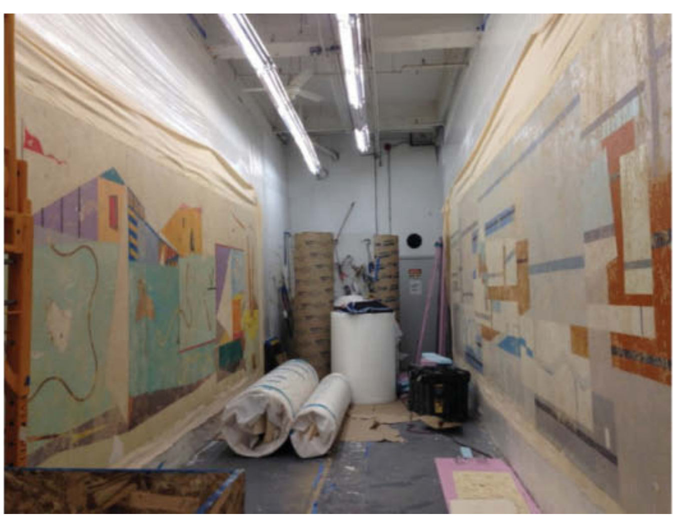

Figure 22. Completed mural awaiting transport to holding facility

2.14 Project Team

The site work and mural removal was overseen by chief conservator Gillian Randell, conservation foreman Neela Wickremesinghe, and project manager Sarah Kloze. All safety procedures concerning lead-containment issues was overseen by Safety Director Forrest Filler.

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Overview of the CCI Lining Project: Do Linings Prevent Cracking and Cupping in Paintings?

ABSTRACT

This project studied the balance in tension between an oil painting and its lining, and the ability of the lining to reduce cupping and cracking. Samples included a model oil painting, its constituent layers, and its linings onto linen, multifilament polyester, and sailcloth, using BEVA-371 or wax-resin. Data from five temperatures were combined to build master curves of stress relaxation from milliseconds (for shock and vibration) to decades. Only sailcloth provided consistently significant support, especially over the long term relevant to cupping. At low RH, sailcloth contributes proportionally less support and RH control by enclosure is recommended.

1. INTRODUCTION

The Lining Project at the Canadian Conservation Institute (CCI) was initiated by D. Daly Hartin and S. Michalski 30 years ago and has been very much a team project. It was started at a time when our profession was learning a lot about the mechanical properties of paintings through the work of Marion Mecklenburg and also when pioneers in our field such as Gerry Hedley, Vishwa Mehra, Bent Hacke, and Gustav Berger were introducing new techniques, new fabrics, and new adhesives to address the problems and disadvantages of previous structural treatments. In this environment, the authors found themselves asking the question: Are these new materials going to do what we think they are going to do?

2. HISTORY AND EVOLVING GOALS OF THE PROJECT

The initial goal was to assess the effectiveness of a lining to support the stress in a painting and ultimately, minimize defects such as cracking and cupping over time. As the project evolved, it also addressed issues arising in risk management studies, such as understanding the behavior of paintings, lined or unlined, in transit or on display, and in response to different climates.

2.1. Project Phases

There were three major phases to the project and much of the information has been presented and published through ICOM-CC.

1. Testing of model paintings (Daly and Michalski 1987)
2. Peel testing (Daly Hartin, Michalski, Pacquet 1993)
3. Testing of lined-model paintings (Michalski and Daly Hartin 1995; Michalski and Daly Hartin 1996; Daly Hartin et al. 2011a; Daly Hartin et al. 2011b; Michalski et al. 2014)

This article refers briefly to the first phase—the testing of model paintings; but concentrates on the tension results of the third and final phase, the testing of lined-model painting samples. The results are summarized from a conservator's point of view, focusing on the implications for treatment and preventive conservation practices.

2.2. Changes to the Mechanical Testing Apparatus Over the Years

Over the 30 years the project moved through three generations of tension-testing equipment. The first equipment, used for the testing-of-model-paintings phase and shown in Figure 1, was totally manual and not computerized (Daly and Michalski, 1987). For testing of lined model paintings, a semi-automated apparatus was built (fig. 2) that allowed a small strain to be applied to 10 samples at once, with the tension logged by computer.

For 15 years, the project went on hold because of other priorities. It was restarted in 2010, shortly after the hiring of E. Hagan who had just completed his mechanical engineering PhD on the mechanical properties of artists' acrylic paints. Hagan completely

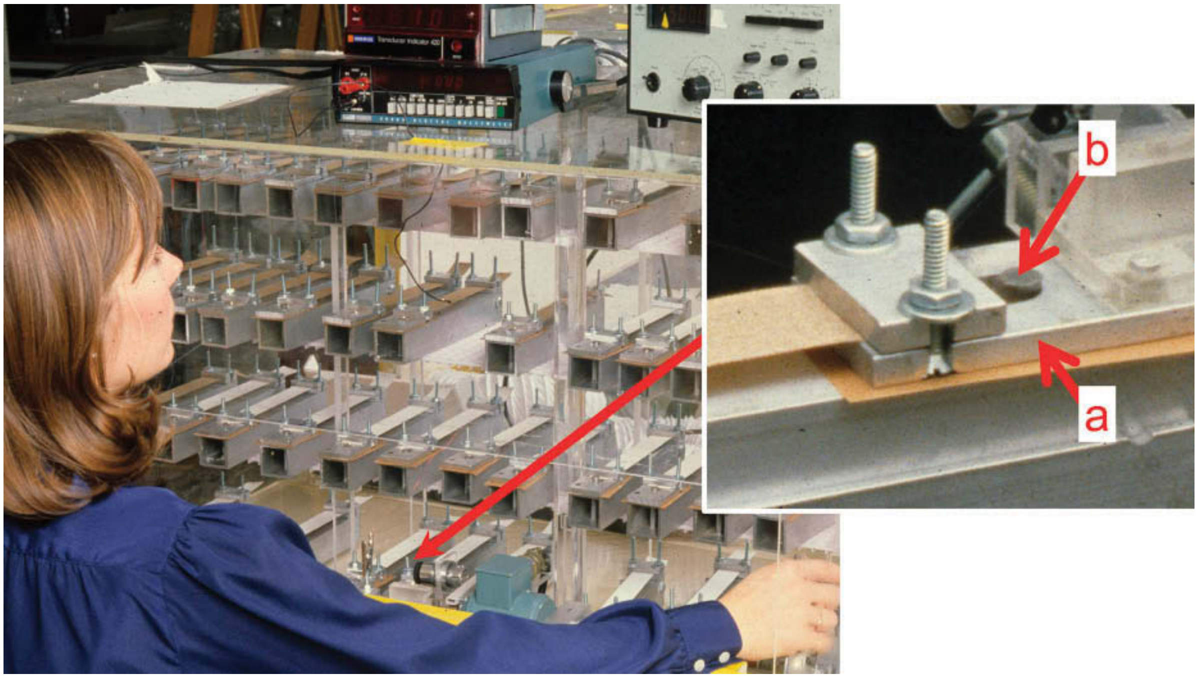

Figure 1. 1993–1996. Manual tension testing apparatus inside an RH controlled cabinet (glove seal removed for clarity). The operator (Daly-Hartin) turns a wheel with the right hand which applies tension to the clamp (a) holding the sample, via a load cell. An electrical resistance meter reads the contact between the clamp and the holding pin (b). When the resistance starts to climb, the load cell is in balance with the sample tension, and a reading taken. © Government of Canada, Canadian Conservation Institute, CCI 86055-0311

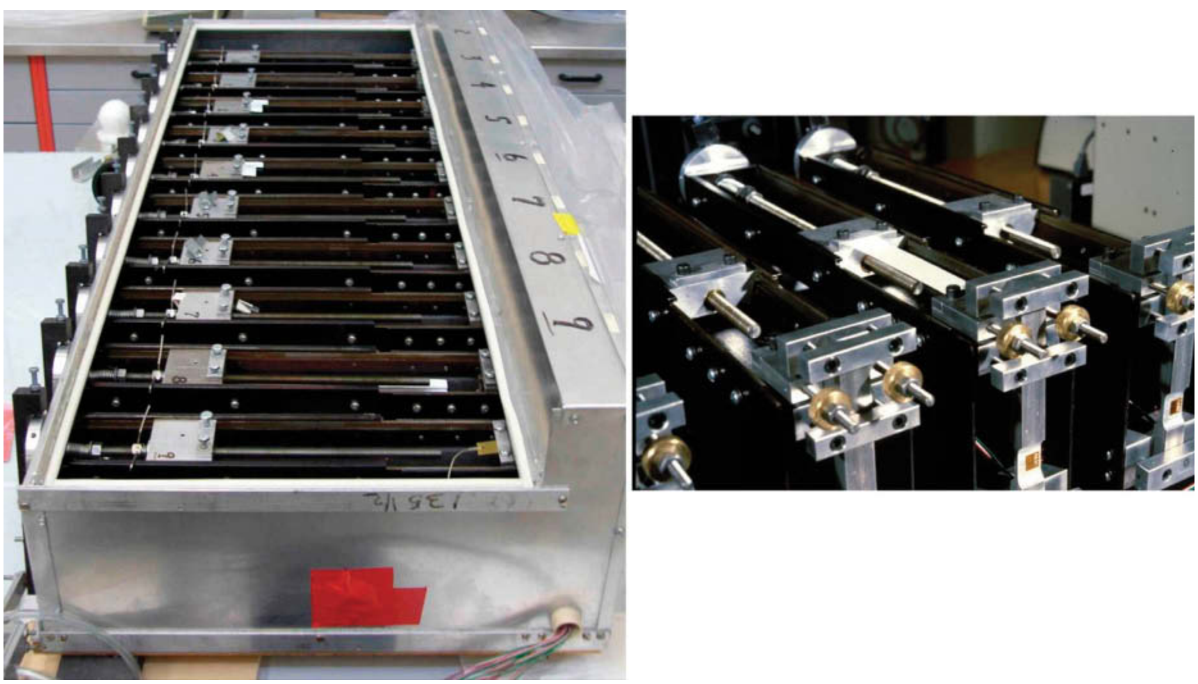

Figure 2. 1996–2009. Semi-automated tension apparatus. Left: Ten jigs in their RH controlled enclosure. Temperature control relied on the room. Right: Detail of the counterbalanced clamps connecting to fabricated load cells. © Government of Canada, Canadian Conservation Institute, CCI 86055-0319

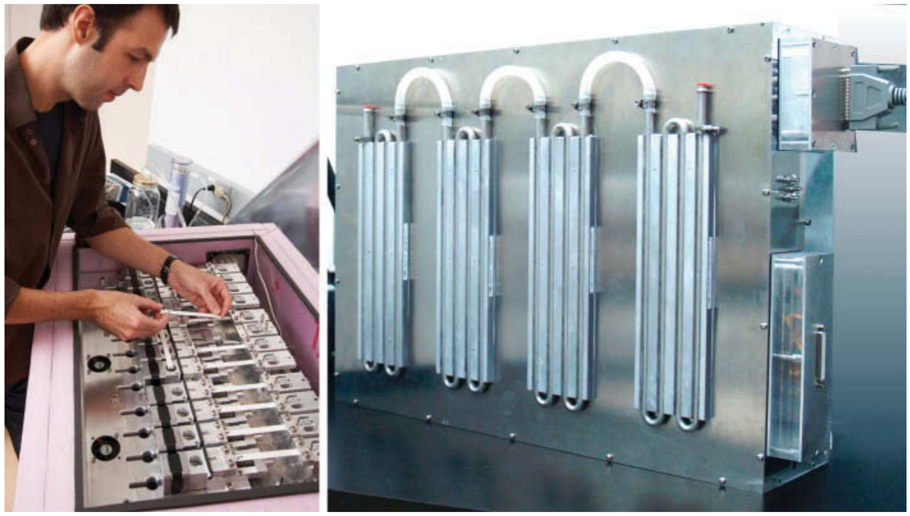

Figure 3. 2010–Present. Tension testing apparatus with RH and temperature control. Left: Lid removed, sample installation (E. Hagan). Right: Bottom view of cooling/heating coils attached to the chassis. Internal mixing fans, extensive insulation, and massive aluminum chassis ensure uniform climate. © Government of Canada, Canadian Conservation Institute, CCI 121601-0004; CCI 86055-0320

redesigned the testing apparatus. He custom built many parts and added equipment that was more reasonably priced than 20 years earlier. This included new load cells and new motors capable of applying faster strains closer to the time scale of shock. The smaller size of the whole apparatus (holding 12 jigs) as well as the computer control of the humidity system and thermal bath made humidity and temperature control simpler and more precise. Strain could be applied precisely with Labview™ software controlling individual stepping motors for each jig (fig. 3).

3. PHASE 1: TESTING OF MODEL PAINTINGS

In the first phase of the project, we looked at the influence of each individual layer of the painting on the behavior of the painting as a whole. Samples with successive layers of a painting were prepared, e.g., canvas, canvas + size, canvas + size + ground, canvas + size + ground + paint. Samples were also prepared with three additional grounds; an emulsion (half-chalk) ground, a glue/chalk ground, and an acrylic ground. Tests included change in tension, weight, and length at different relative humidity (RH).

Two observations from these tests influenced the lab's conservation practice at the time: the fast response of the samples to change in RH, and the potential for the canvas to start to shrink at moderately high RH.

3.1. Fast Response of the Linen + Size Sample to RH

Whether it was change in weight, change in dimension, or change in tension, the samples of linen and size responded within a few minutes (fig. 4), and the total change occurred within an hour or two. This speed of response of the back layers of a canvas painting emphasized the benefit of sealed backing boards or fully enclosed frames in preventing stress development due to RH cycles on the scale of minutes to hours.

3.2. Tension in the Painting as the RH Varies

Phase 1 tests in the 1980s also influenced the use of the Willard multipurpose table in the CCI laboratory, for relaxation and flattening treatments. Graphs of the tension in these samples, shown in Figure 5, were similar to those of Mecklenburg (1982) which illustrated that it is the size, ground, and paint layers that support the stress in a painting, not the linen fabric, at least not until shrinkage of some linens at high RH. Measurements of change in length of linen + size sample (fig. 4) after a change from 47 percent to 71 percent RH showed the onset of linen shrinkage within a period of only an hour or two. It occurred at lower RH than expected from the by-then classic tension plots of Figure 5, where nothing much seemed to happen before approximately 85 percent RH.

This had implications for humidification treatments on tables such as the Willard multipurpose table if heat, even at low levels, is used. When using such tables, even when set at moderate humidity levels, it is easy to achieve higher than desired levels of humidity under the painting because of a temperature gradient between the ductwork and the cooler surface of the table. To reduce this risk, a piece of equipment shown in Figure 6 was developed that allows monitoring of the RH under a surrogate test painting placed to one side of

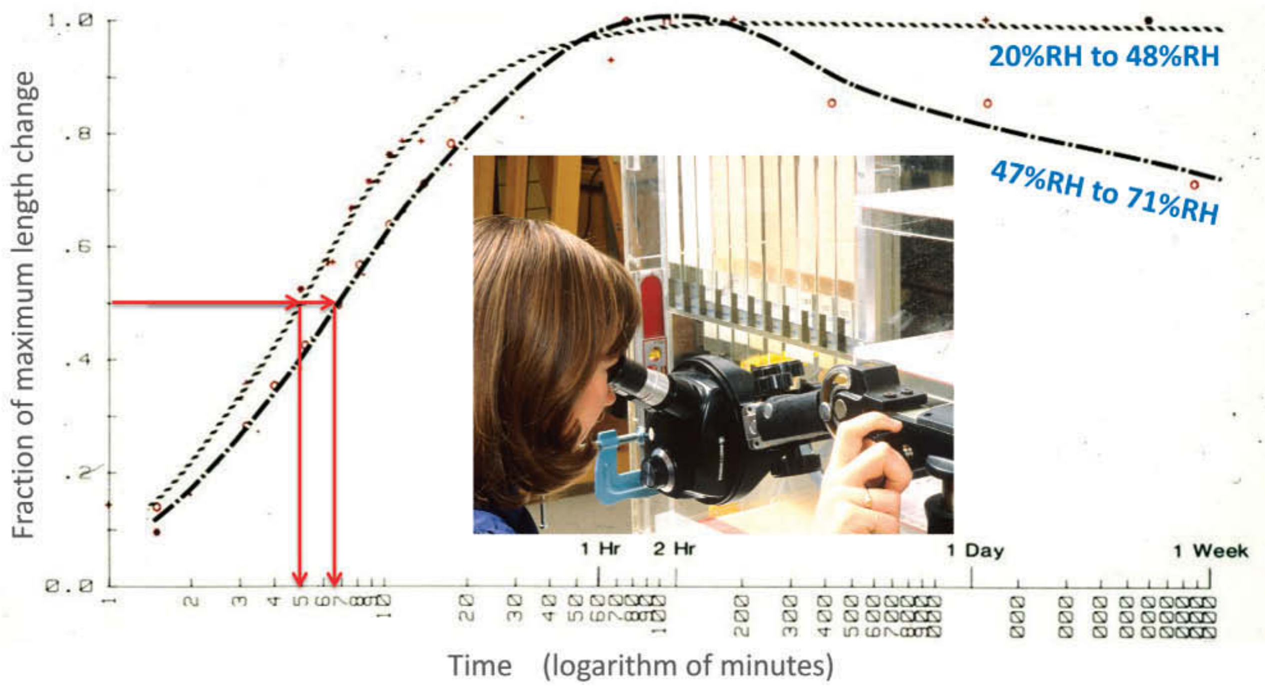

Figure 4. Increase in length of a free-hanging (linen + size) sample in response to a rise in RH. Red arrows show the half-time of response: 5–7 minutes. Inset image: Cemented to the end of each hanging sample was a microscopic scale made with photographic film. (Daly and Michalski, 1987) © Government of Canada, Canadian Conservation Institute, CCI 86055-0321

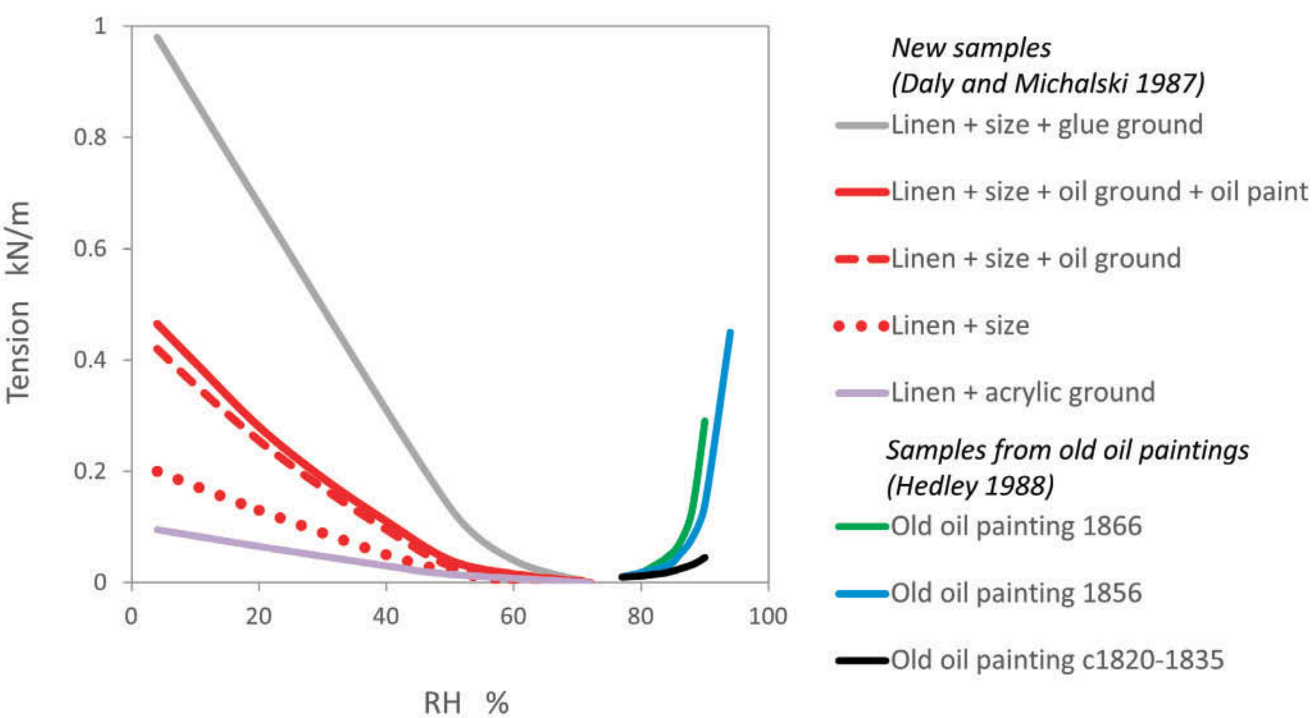

Figure 5. Tension in layers of a painting as RH varies. Results from early tension testing at CCI by Daly and Michalski (1987, plots 1–5, RH below 70 percent) and by Hedley (1988, plots 6–8, showing 19th-century canvas shrinkage response at high RH). The solid red line is for the same model oil painting used later for all the lining studies. © Government of Canada, Canadian Conservation Institute, CCI 86055-0322

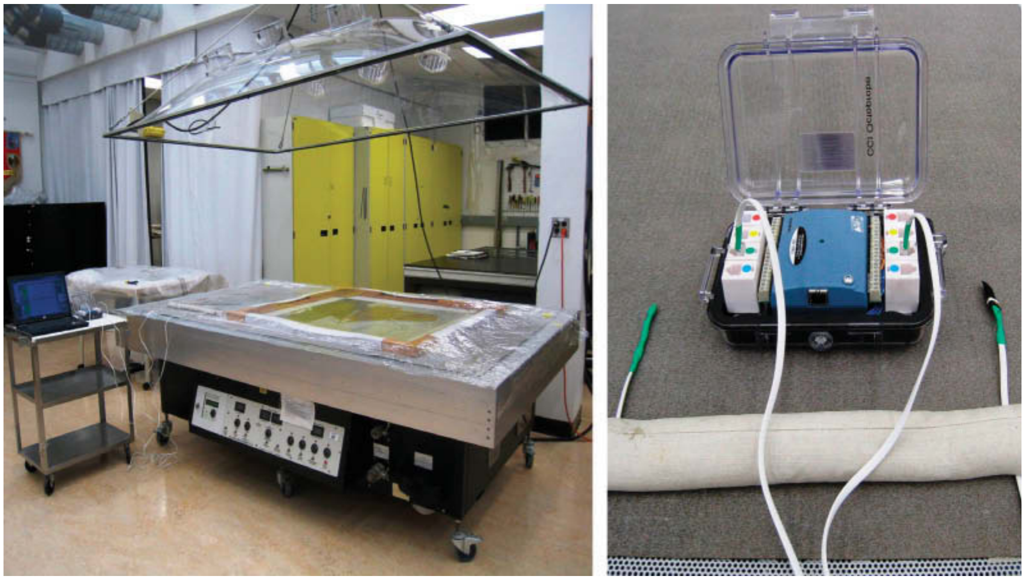

Figure 6. Left: Use of an RH and T surface monitoring device, the CCI "Octoprobe," during humidification treatments on the Willard Multipurpose Table. Right: Detail of the compact electronics package, only one of four temperature probes (left) and one of four RH probes (right) shown for clarity. © Government of Canada, Canadian Conservation Institute, CCI 86055-0323; 86055-0324

the painting being treated. (Daly Hartin, 2011a) With a glance at a computer monitor displaying real-time humidity values under the painting, the conservator can adjust the table's humidity settings to maintain safe levels of humidification. Humidification treatments on CCI's Willard multipurpose table are undertaken starting around 76 percent RH, but not above 79 percent RH. The whole procedure (humidification, flattening and drying to ambient conditions) is repeated as necessary, if it is found safe to do so.

4. PHASE 3: TESTING OF LINED-MODEL PAINTINGS

When interpreting the results of the tests on the lined-model paintings, the following questions emerged: will these materials minimize defects in a painting, and will the lining be stiffer than the painting during stretching, during shock and vibration, and during fluctuations in relative humidity (RH) and temperature?

Our primary samples consisted of a model oil painting,[1] which was 10 years old at the start of the phase-3 tests. Samples of the model painting were lined onto three different supports: a linen, a woven multifilament polyester fabric introduced by Mehra, or a heat-set polyester sailcloth introduced by Hedley. Linings were prepared with two different adhesives: a flocked Beva 371 used as a nap-bond (applied to the lining fabric only), and a wax-resin adhesive[2] (used only with the linen support) that would demonstrate the effect of an impregnating adhesive. A model oil painting was also prepared with a woven polyester fabric lining using flocked BEVA 371, then marouflaged onto an aluminum sheet with flocked BEVA. Two other sample types were included: linen sized with 10 percent Acryloid (Paraloid) B-72/toluene, and linen with a brush coat of 7 percent rabbit skin glue (RSG) size plus two brush coats of chalk ground (equal parts by volume of zinc white, calcium carbonate, and 7 percent RSG). The lining materials were chosen because they represented different options available at the time.[3]

4.1. Does the Lining Dominate Stiffness?

Mechanical testing was undertaken to investigate whether the lining dominates the stiffness of the laminate. In other words, will the lining actually support the painting when the laminate is stretched or exposed to low RH, and can it maintain this support over many years? Interpretation of the results considered:

> How does the tension in the painting and in the lining change over time and at various climate conditions?
>
> What is the ratio of these two tensions; that is, does the lining dominate (support) or not?

Figure 7 shows tension over time, plotted on log scales, using data from the second-generation, semi-automated testing equipment. The initial climb in tension represents the slow application of a small stretch over the course of 4 minutes.

Then we see a continual relaxation of the stress, with points marked at 8 hours, 15 days, 2 years, and—because the samples remained in the jigs during the project hiatus—a data point at 16 years. Figure 7 shows the model painting (red line) as well as four BEVA linings: two on linen (black lines) and two on the woven polyester (green lines). For all, the overall trend is a steady fall in tension over time, with little difference in tension between the lined and unlined model painting. This means that these fabric linings are not adding any significant support to the laminate. Unfortunately, it was suspected that the apparent increase in lined sample tension at 16 years was not reliable data because the equipment had been moved around during a four-year building renovation project at CCI. One of the purposes of the new equipment was to obtain better long time data (right side of fig. 7. The other was to obtain better data at short times representative of shock (far left side of fig. 7).

4.2. Building Master Curves

To obtain data equivalent to long times and very short times without waiting another 16 years or building equipment capable of administering shock, "master curves" were constructed using a well-established method from polymer mechanics called the "time-temperature superposition" principle (Nielson and Landel 1994, 73). This requires a tester that can operate at a wide range of temperatures above and below room temperature. It is analogous to the use of temperature to speed up or slow down chemical processes.

Figure 8 shows the stress relaxation after an initial small strain for the model painting at four temperatures: –10°C (14°F), 5°C (41°F), 21°C (70°F), and 35°C (95°F). Each experiment covered a time range from approximately 10 ms up to a week or two. As long as such graphs can be shifted horizontally to overlap and form a single smooth curve, they can be used to create a "master curve" as in Figure 9. The horizontal shift for each temperature relative to the selected reference temperature (such as 21°C) is not arbitrary, one must show that the shifts themselves are related to temperature following a well-established relation (Nielson and Landel 1994, 76) and are not outside the published values for related polymers. Although the method applies accurately only to one polymer at a time, the model painting data allowed a reasonable fit to a master curve. The time-temperature shift that best fit data of Figure 8 to generate Figure 9 was approximately 3.7°C for each decade of time, consistent with the value of approximately 4°C for most amorphous polymers tested within 20°C of their glass transition (Nielson and Landel 1994, 78).

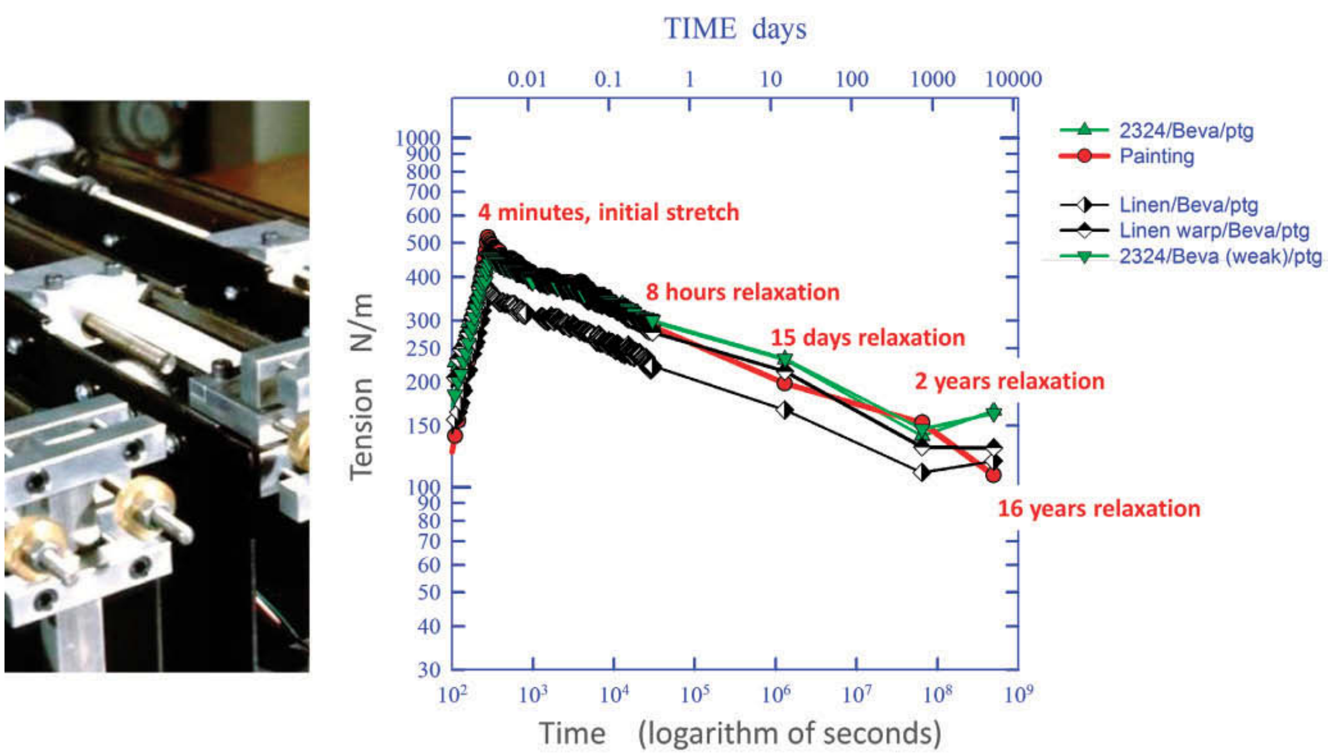

Figure 7. Tension in the model painting (red) and model painting with various linings over time, plotted on log scales, collected from the second-generation, semi-automated testing equipment (detail at left). Only one sample per plot. © Government of Canada, Canadian Conservation Institute, CCI 86055-0325

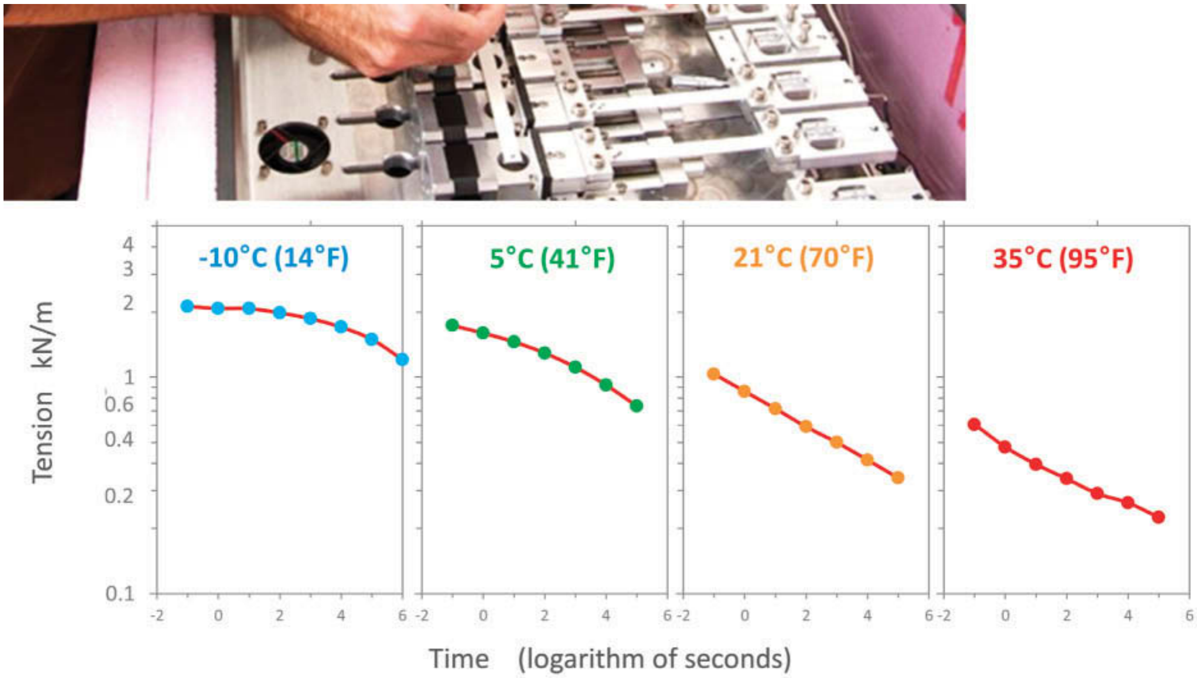

Figure 8. Stress relaxation data for the model painting at 50 percent RH and various temperatures, from the current apparatus. The initial small strain is applied within ~0.1 s (climb not shown). Data points are the mean of three samples.

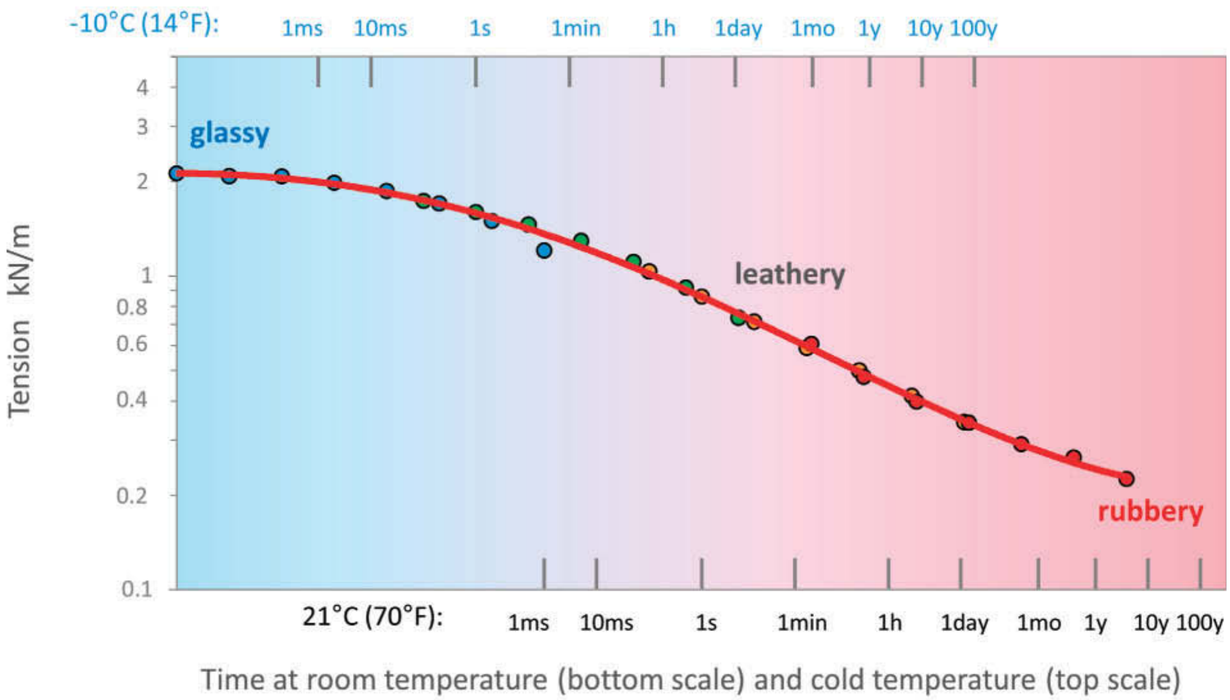

Figure 9. Master stress relaxation curve for the model painting at 50 percent RH. The master curve is assembled from data obtained at four temperatures shown in fig. 8: blue dots –10°C, green dots 5°C, orange dots 21°C, and red dots 35°C. To read the time for cold transit situations (–10°C) use the top scale. To read the time for room conditions (21°C), use the lower scale. When printed out, the colours of the orange dots are difficult to distinguish. Is this a concern? Possibly not when it is really the assembly and shape of the curve that is important.

In Figure 9, two time scales are shown: a time scale for 21°C (71°F) at the bottom and a time scale for –10°C (14°F) at the top. The blue to pink gradient represents the fact that the left side of the graph is for cold or fast events, and the right is for warm events (like the hot table) or for long slow events at room temperatures. Within the framework of viscoelastic polymer mechanics (Nielson and Landel 1994, 44) the left side of the curve is called the glassy region—stiffness reaches a maximum and very little elongation can occur before fracture. The rubbery region is where stiffness reaches a minimum plateau, and large recoverable elongations are possible before fracture. The transition region is referred to as leathery. The model painting master curve (fig. 9) has not fully entered its rubbery plateau, temperature tests above 35°C (95°F)—hot table lining temperatures—would confirm its location. These master curves help us understand which layer is "carrying" the other layers in terms of tension. *Assuming similar thickness, a polymer lining supports a painting in a given event if it is stiffer, or more glassy, than the stiffest layer of the painting, for the temperature and duration of that event.*

Figure 10 shows the master curves for the different lined samples compared to that of the unlined model painting (red line). The curves for the BEVA linings onto woven polyester are almost identical to the painting alone (green lines). The curves for the BEVA linings onto linen (orange lines, one linen lining in the warp direction, the other in the weft) are slightly below the model painting.4 Thus, neither the linen nor the loosely woven (in other words not heat-set) polyester fabrics adds any tension or support to the laminate. In comparison, the sailcloth lining (black line) has significantly higher tension and maintains this higher tension for many years. The wax-resin-impregnated linen lining (brown line, top curve) initially contributes even more support than the sailcloth; however, this support relaxes quickly, falling below sailcloth after one day and approaching the model painting within a few years.

4.3 What is the Contribution of the Lining Support to this Laminate?

Figure 11 shows the contribution of the different lining supports to the total tension of the painting plus lining laminate. The lining contribution has been calculated by subtracting the painting tension from the lined painting tension and is presented as a percentage of the lined painting tension. This can be thought of as showing how the balance in tension between the painting and its lining changes over time.

4.3.1. Linings that Contribute Zero Support

The loose weave linen and polyester fabrics (partially hidden data points near the bottom of fig. 11) scatter around zero percent of total tension; therefore, they offer zero support.

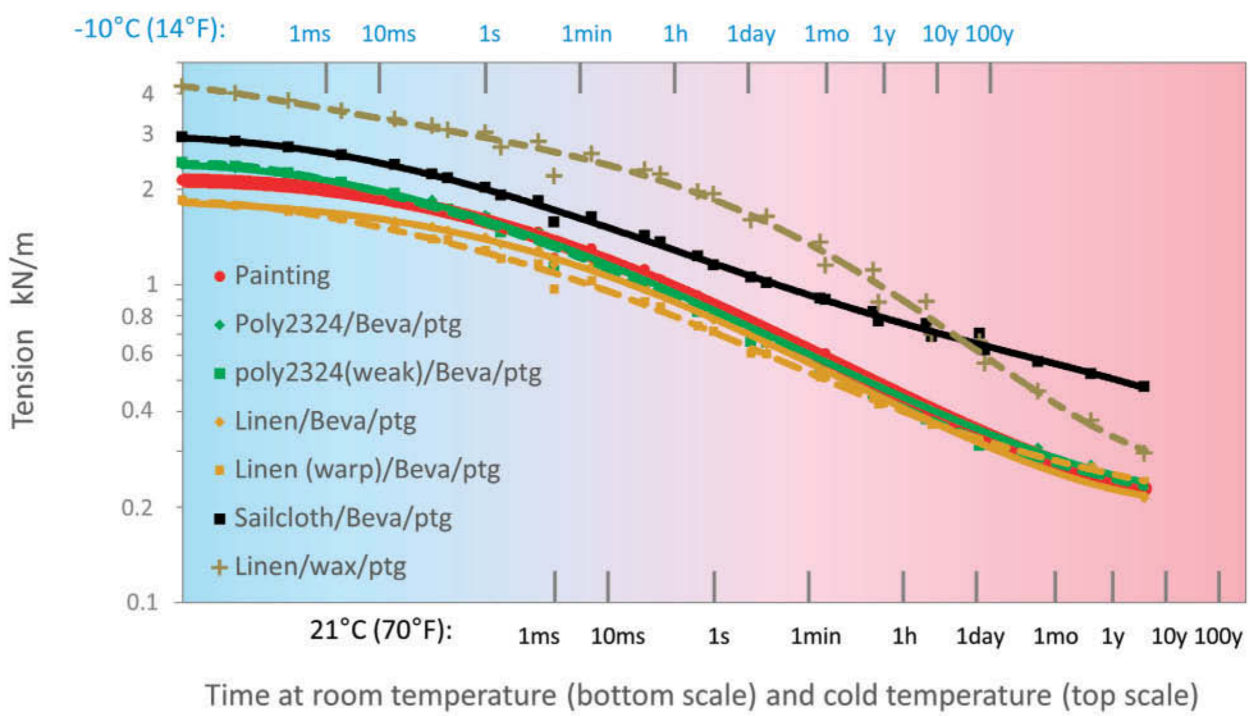

Figure 10. Master stress relaxation curves for the model painting (red line) and various linings, at 50 percent RH. Only sailcloth (black line) and linen/wax (top line) show significant contributions to total tension. © Government of Canada, Canadian Conservation Institute, CCI 86055-0312

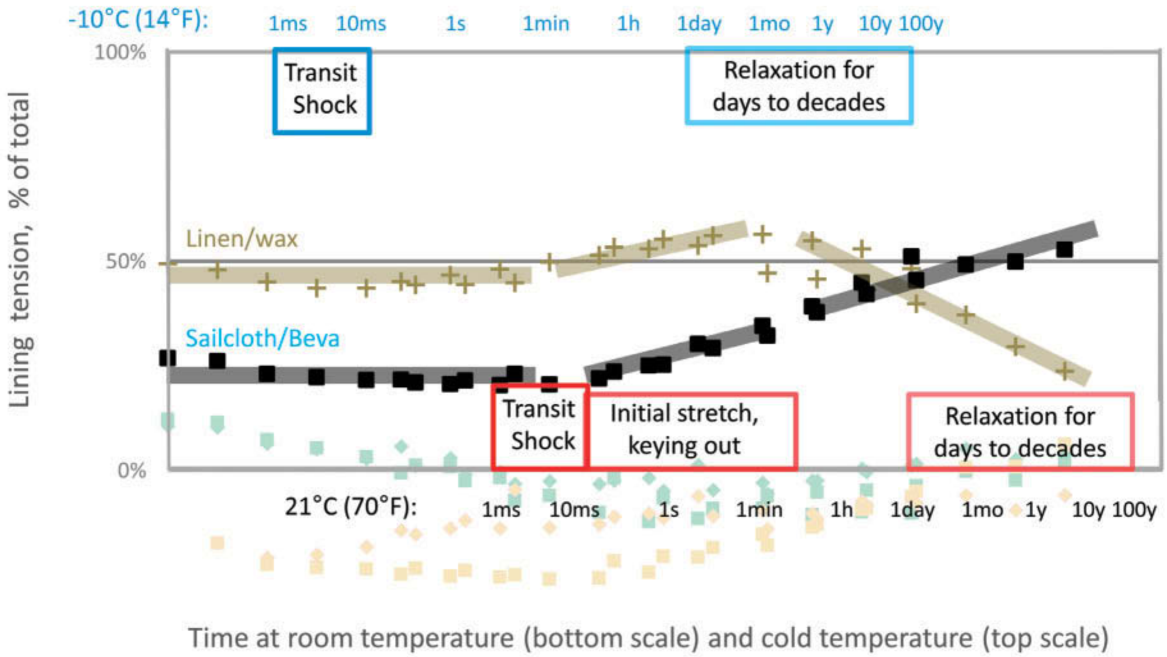

Figure 11. Contribution of the different lining supports to the total tension of the painting/lining laminate. Each point the average of three samples. The linings other than linen/wax and sailcloth are scattered above and below the 0 percent contribution line, and are partly hidden for clarity. © Government of Canada, Canadian Conservation Institute, CCI 86055-0313

4.3.2. Linings that Contribute Some Support

In Figure 11 the two significant linings are the wax-resin-impregnated linen (brown line) and the sailcloth (black line). For both supports, the first phase of each plot is horizontal because both lining and painting are in their glassy or near glassy regimes and are relaxing in harmony (and slowly). The wax-resin-impregnated linen provides approximately 50 percent of the total laminate tension and the sailcloth provides approximately 25 percent of the total laminate tension. The middle phase of the plots shows the relative contribution of both linings increasing, because the painting has entered its leathery phase and is relaxing faster than either lining. The third and last phase of the plots shows the two linings behaving in opposite directions. The sailcloth continues to increase its relative contribution because it maintains its glassy phase while the painting is still relaxing. The wax-resin-impregnated linen drops rapidly in its relative contribution because its leathery drop is much greater and steeper (as seen in fig. 10) than that of the pigmented and crosslinked oil ground and paint.

Figure 11 also provides insight into whether the lining fabric will provide support to the painting during common events such as shock, keying out, and the passage of time. In this discussion, support is considered to be the ability to carry *most* of the tension, i.e., over 50 percent. In the region of interest for transit shock and vibration (about 1 ms to 10 ms) the contributions of the linings are the same whether at room condition, 21ºC (70ºF), or in extreme cold, −10ºC (14ºF). Neither dominates tension (the wax-resin-impregnated linen comes close) but they do carry significant support. They may not eliminate fractures but they could reduce them. For the time periods associated with initial stretching and keying out under room conditions, 21ºC (70ºF), these linings provide more support than for shock, and the wax-resin-impregnated linen even dominates. Finally, when we consider the simple passage of time—days to decades at room conditions—the sailcloth comes into its own and begins to dominate, that is, provide significant support.

4.4. What is the Influence of Linings on the Cupping at a Tear?

In 1993, biaxial samples were prepared in which a "tear" was cut in the center of the painting (5 years old at the time) prior to lining (fig. 12). No mechanical testing was undertaken on these samples, their purpose was to illustrate how each lining influenced the development of cupping over time. Figure 13 was taken 18 years later, using the shadow of a horizontal pin to illustrate the cupping. The pronounced cupping of the painting lined onto woven polyester is evident; in comparison, the tear in the model painting marouflaged onto an aluminum sheet is completely flat. The marouflage sample demonstrates that the BEVA bond was sufficient to counteract curl forces at the painting tear. The back of the woven polyester lining is cupped identically to the front of the painting; that is, the

Figure 12. Biaxial samples prepared with a "tear-cut" in the center of the model painting prior to lining. The center sample is marouflaged onto aluminum; the other lined samples were left free floating. © Government of Canada, Canadian Conservation Institute, CCI 86055-0343

BEVA bond did not fail, it pulled the woven polyester out of plane. The sailcloth lining does not prevent cupping along the tear as well as the rigid aluminum plate, but it does perform much better than the loosely woven linen and polyester fabrics. Since none of these biaxial samples were held in stretchers, Figure 13 demonstrates that the sailcloth was stiff enough to reduce cupping simply in terms of its "plate" behavior, without tension from a stretcher. This is consistent with sailcloth's good performance over days and years in Figure 11, because cupping takes years to develop.

4.5. Do Linings Provide Support During RH Fluctuations?

The linings were also tested for their behavior during extreme RH fluctuations. The uniaxial samples were installed in the testing jigs at 50 percent RH, given an identical initial stretch representative of gentle keying out, then left for 13 days. By then, most of the initial tension had relaxed. The samples were then exposed to various half-day and full-day cycles of RH between 20 percent RH and 70 percent RH, as shown by the top blue line of Figure 14.

Figure 14 shows the resulting tension as RH fluctuated: red line for the unlined painting, black line for the sailcloth lined painting. The black arrows indicate the amount of tension contributed by the sailcloth to the lined painting laminate, the red arrows show the tension in the painting alone. The black arrows are all the same size, that is, the sailcloth is not affected by the changes in relative humidity. The tension in the painting however, is greatly affected by RH (as expected). In this particular sample, at 13 days at 50 percent RH the sailcloth contributes 67 percent of the laminate tension. At 70 percent RH (fig. 11) there is no discernible painting contribution at all; the sailcloth truly supports the painting. At 20 percent RH, however, the painting dominates at 66 percent of the total tension, only 34 percent provided by the sailcloth.

Figure 15 shows the wax-resin lining undergoing the same RH fluctuations as that in Figure 14. The wax-resin slows the response of the whole laminate, including the painting, to RH change. The wax-resin lining not only shows little response to the fluctuations of 12 and 24 hours, it also blocks the response

Figure 13. Photographs of "paintings with a tear" on various linings, after 18 years at room conditions. A straight pin is illuminated from overhead, its shadow (the solid dark line) reveals the cupping. © Government of Canada, Canadian Conservation Institute, CCI 86055-0315

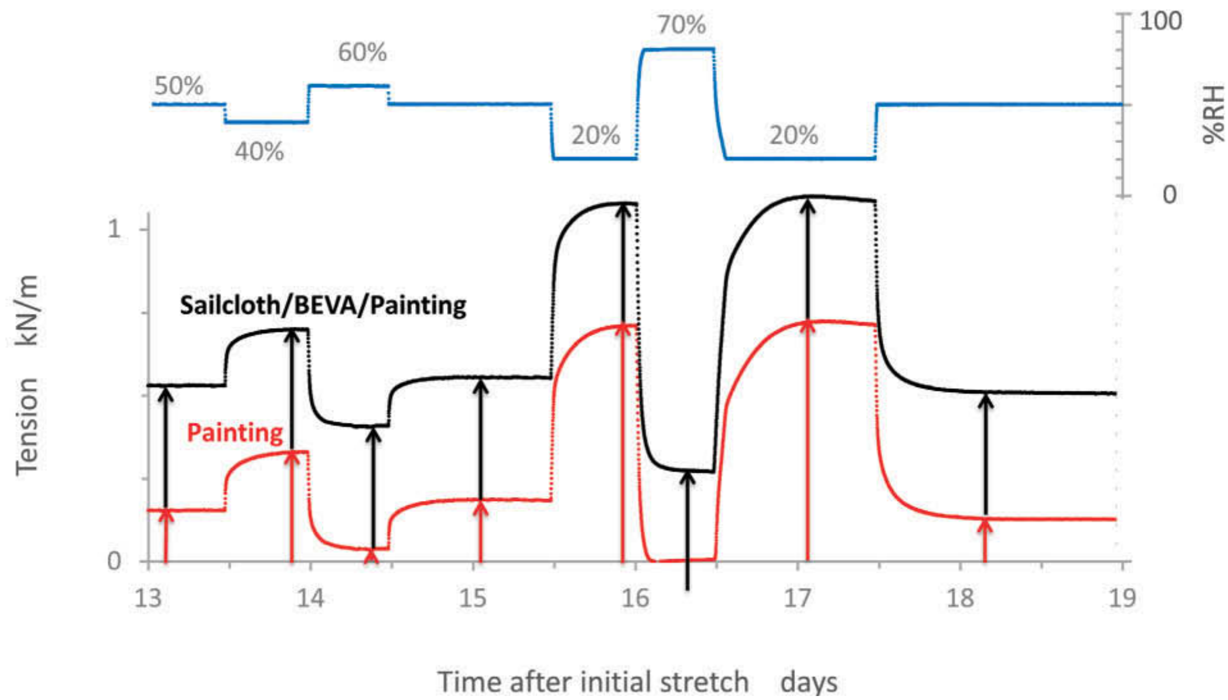

Figure 14. Tension in a sailcloth lined painting compared to the painting when RH fluctuates. Initial stretching took place two weeks earlier. The black arrows are all of equal length. The red arrows show the fluctuating (as well as slowly relaxing) contribution of the painting. © Government of Canada, Canadian Conservation Institute, CCI 86055-0316

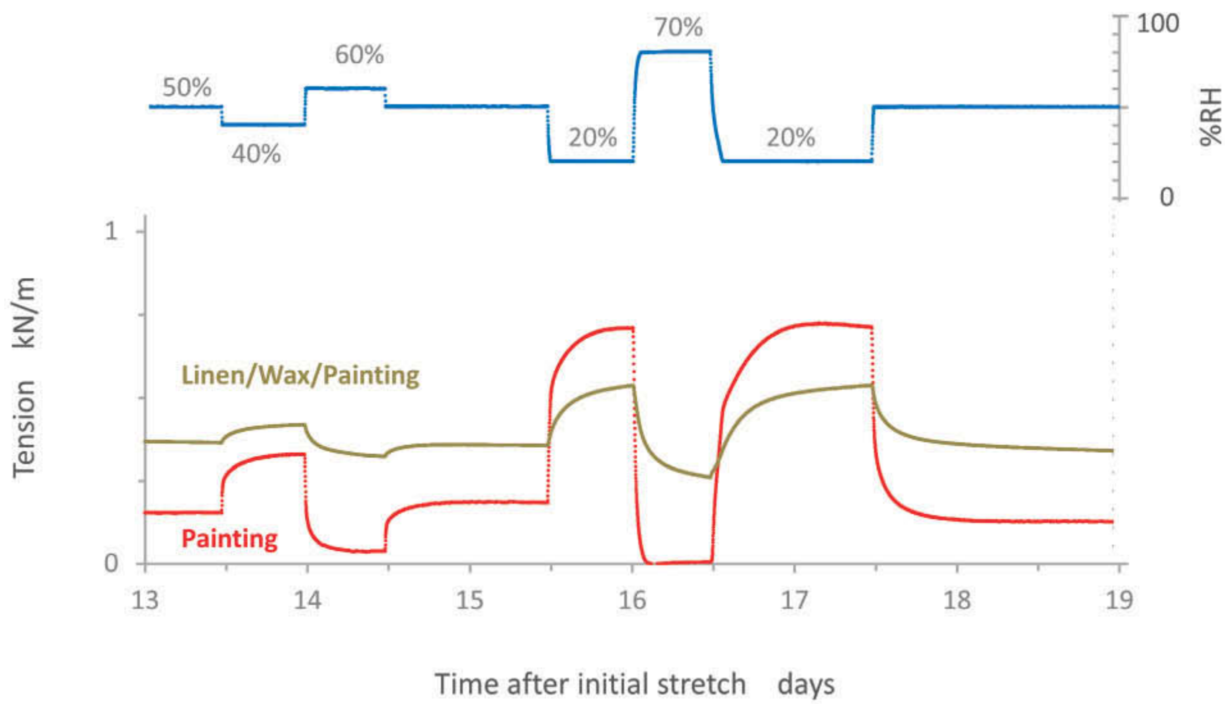

Figure 15. The change in tension of the wax-resin lined sample and the model painting in response to change in relative humidity. The changes to high and low RH are each half-day duration, except the last exposure to 20 percent RH for a full day. © Government of Canada, Canadian Conservation Institute, CCI 86055-0317

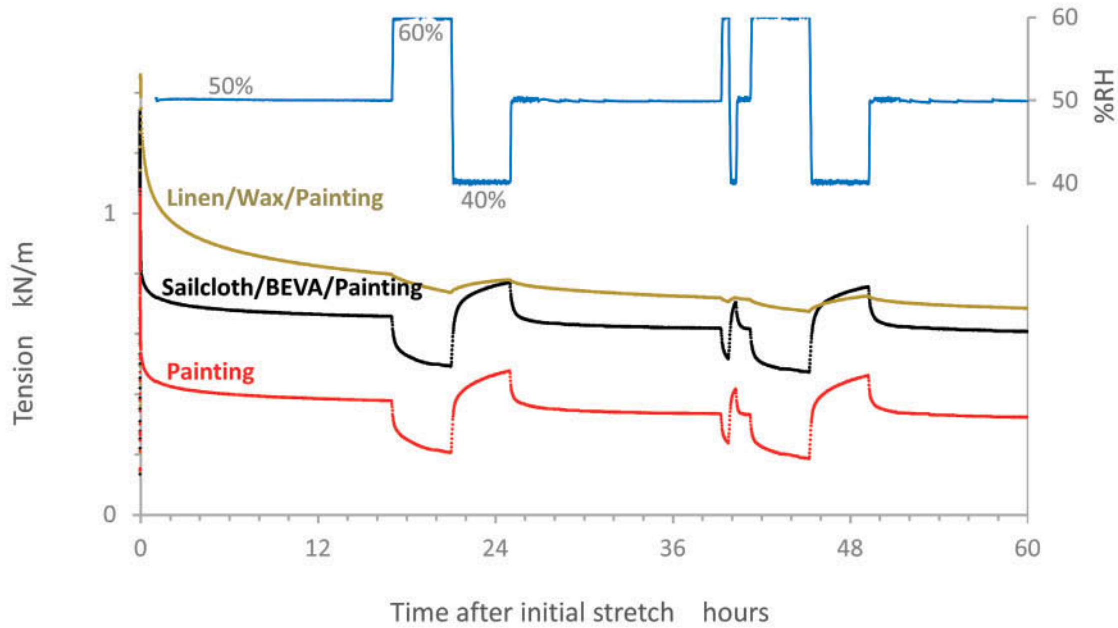

Figure 16. The change in tension of the wax-resin lined sample, the sailcloth lined sample, and the model painting in response to 4 hour and 1 hour changes in relative humidity. © Government of Canada, Canadian Conservation Institute, CCI 86055-0318

of the painting itself. Note that there seems to be two stages to the response of the wax-resin lined sample—a quick phase lasting about ¼ day (~6 hours) followed by a slow drift towards equilibrium that appears would take about one week.

Figure 16 follows both a sailcloth lining (black line) and a wax-resin-impregnated linen lining (brown line) during shorter RH fluctuations—four hours and one hour—just hours after initial stretching. The response of the wax-resin-impregnated linen lining is dramatically slowed by the wax-resin impregnation. One hour fluctuations cause barely a ripple in tension. Sailcloth, on the other hand, doesn't slow the response of the painting at all—as a barrier, it is completely porous. (Figure 16 also shows the rapid decay of tension in the first hour after the initial stretch when using a linear time scale. Time "zero" is actually the approximately 10 ms of the initial stretch. The earlier master curves of stress relaxation used logarithm of time to "spread out" these time regions.)

5. CONCLUSIONS

A summary of the conclusions, in terms of the implications for lining, are presented in table 1. These conclusions are considered generic. They are not intended as specific recommendations of particular materials, but rather as a comparison of the mechanical benefits of different types of composites represented by the linings tested. The following notes consider the columns of Table 1 from left to right:

1. A major purpose of many linings is to bridge tears. All the linings we tested can do this.
2. Over long periods of time (weeks to decades) a heat-set polyester such as sailcloth will dominate tension, that is, provide support, which wax-resin-impregnated linen linings (and woven polyesters without heat set) cannot. This will influence cupping at existing cracks or tears. But, sailcloth is still sharing a significant proportion of the tension with the stiff layers of the painting so it cannot eliminate cupping. It simply comes closer than any other single fabric to matching the stiffness of an oil ground painting during weeks to decades.
3. During initial stretching and keying-out, wax-resin-impregnated linen linings dominate tension, sailcloth does not, but it still contributes enough to reduce the formation or growth of cracks during this process.
4. During shock events, whether in ambient or cold conditions, neither sailcloth nor wax-resin-impregnated linen linings dominate tension; however, the wax-resin comes close and the sailcloth contributes enough to reduce the formation or growth of cracks during such events.
5. During low RH events, wax-resin-impregnated linings slow the response to hourly and daily fluctuations simply by reducing moisture diffusion into the painting. The sailcloth is unable to do so. Although sailcloth will maintain more tension than the wax-resin lining during a sustained 20 percent RH such as a seasonal swing, its contribution will be much less than its dominant

	Able to reduce...							New Risks side effects
	Tears in original fabric	Cupping over the years (long term)	Cracks in ground and paint from...					
			Initial stretch, keying out	Shock, vibration	Cold	Low RH, 1h to 1 day	Low RH, weather, seasonal	
Woven fabrics (linen, polyester)	✓							
Impregnated fabric (Wax-resin)	✓		✓✓	✓✓	✓✓	✓✓		✗
Heat-set fabric (sailcloth (sc), 1 layer)	✓✓	✓✓	✓	✓	✓			
Heat-set fabric (sc) Tight backing board	✓✓	✓✓	✓	✓	✓	✓		
Heat-set fabric (sc) Tight enclosure	✓✓	✓✓	✓	✓	✓	✓✓	✓✓	

Table 1. Summary of the Benefits of Different Types of Linings and Combinations of RH Control Measures in Providing Mechanical Support for a Painting.

contribution at 50 percent RH (and above). This means that reducing low RH exposure by means such as backing boards is still very important for such linings. A sailcloth lining plus an effective backing board could perform as well as, if not better, than a wax-resin-impregnated linen lining against daily RH fluctuations. And of course, if one adds a full enclosure such as a tight-glazed frame, the heat-set fabric (sailcloth) can provide support against low RH from sustained weather change and seasonal change.

6. In terms of new risks, wax-resin impregnation causes a well-known set of undesirable side-effects.

In summary, Table 1 shows that sailcloth—a heat-set fabric of a high-stiffness polymer—can perform well across all needs when combined with measures to prevent exposure to low RH events.

Linings in the lab have certainly decreased since this project started. Effective, less interventive options are available. But there are times when linings are necessary. This research has shown the authors the mechanical benefits and limitations of linings—what a lining can and can't do to support the painting. To use a sport analogy, even though the impregnating lining looks like a "star" for providing support during short-term events, the heat-set polyester is more the "all-round" player.

NOTES

1. The model painting consisted of unwashed linen, 7 percent rabbit skin glue size (1 brush coat) Fredrix lead white ground (2 brush coats), and Grumbacher lead white oil paint (1 brush coat).
2. The wax-resin formula used was Refined Beeswax/ Multiwax W445/ Laropal K 80 (8/1/2)
3. Suppliers are listed in Michalski and Daly Hartin 1996.
4. For some reason still not clear, the BEVA linings onto linen are lower in tension than the painting alone. This is thought to be because of a small difference in the thickness of the model painting that requires correction by doing thickness measurements, or differences in laminate behavior near the sample grips.

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Nielson, L. E., and R.F. Landel. 1994. *Mechanical Properties of Polymers and Composites*. Marcel Dekker: New York.

SOURCES OF MATERIALS

Lining Fabrics:

Linen #9803
Ulster Weaving Co. Ltd,
148 Madison Ave.,
New York, NY 10016,
USA.

Polyester-multifilament woven fabric, #2324
B. Henr. Lampe. B.V.,
Julianstraat-Sophiastraat,
Postbus 202,
8600 AE Sneek,
Holland

Polyester Sailcloth: Picture Restoration Fabric, #00169/Z
Richard Hayward & Co.,
Tiverton,
Devon EX16 5LL,
England, UK.

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THIS ARTICLE HAS NOT UNDRGONE A FORMAL PROCESS OF PEER REVIEW.

FRIEDERIKE STECKLING

STUDIO TIP: The Benefit of Testing Conservation Materials and Sharing Results with Manufacturer

During the treatment of a Henri Rousseau painting belonging to the Fondation Beyeler collection, a dry cleaning method had to be found to remove blanching and dirt from the water and solvent sensitive surface. The use of akapad sponges (vulcanized latex) which are available in yellow and white form and in various degrees of hardness, was considered (fig. 1). The yellow sponges (formerly known as *wishab*) have been used for over 20 years, especially on wallpaintings with good consistent results. The newer white sponges are advertised to be suitable especially for particularly sensitive and paper surfaces and are recommended as unproblematic after analyses by the Netherlands Cultural Heritage Agency (RCE, formerly ICN).

Prior to working on the paintings itself, all sponges were tested, mainly in an attempt to find the most suitable grade of hardness to work with. However, the testing on white and black paper (fig. 2) and white and black acrylic paint (fig. 3) unexpectedly showed that the white sponges consistently left strong residues (apparent mostly under UV and in some cases with the naked eye), while the yellow sponges did not leave the slightest residues even under high magnification.

Analysis of the test samples verified that indeed the white sponges were leaving heavy residues in comparison to the yellow sponges. Digital microscope and REM-BSE images also clearly illustrate this (fig. 4).

Puzzled by these explicit findings, the outcome of the tests were shared with the seller and manufacturer. Surprisingly, both responded and acted immediately. The manufacturer (D.O.G, Hamburg) replicated the samples and tests (and even acquired a UV lamp!) and invested much time and resources to optimize the recipe of the white sponges. Not even half a year later, the pilot production of a improved white sponge already took place. The objective of the new sponge (*akapad weiss pur*) is to eliminate ingredients which can cause residues, while keeping good cleaning action. Tests by the manufacturer show no residues on sample materials. Analyses are planned to scientifically demonstrate the new properties of the material. The sponge has yet to be tested by the author.

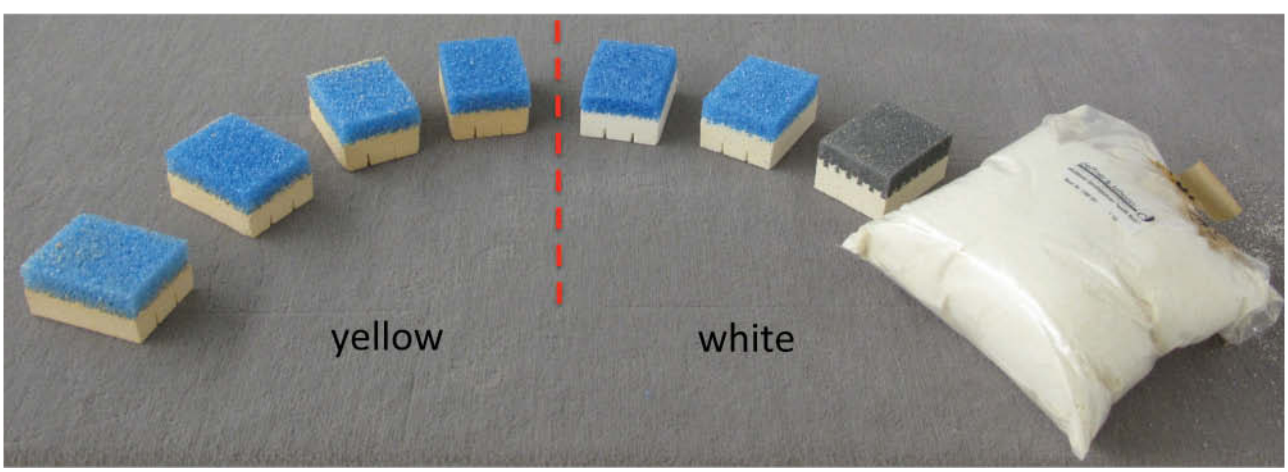

Figure 1. Range of available akapad sponges

This venture demonstrates how important it is to test even already established conservation materials before use and how beneficial it can be to share such input directly with the manufacturer. In this case the enthusiasm and concern of D.O.G. resulted in a new product specifically designed to the needs of the conservator.

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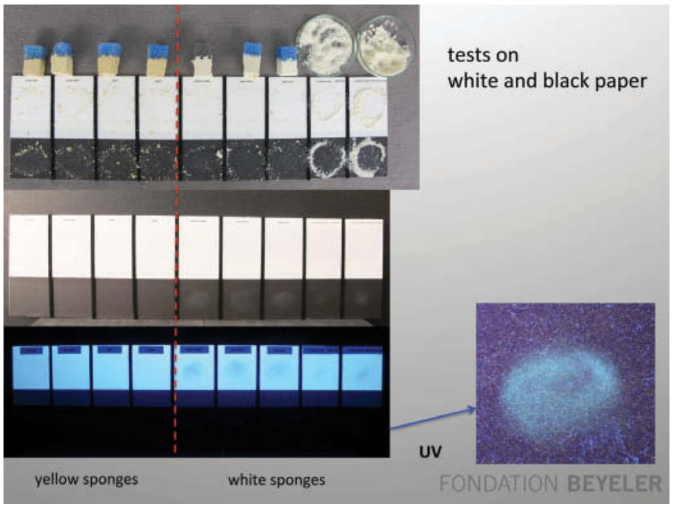

Figure 2. Tests on black and white paper; detail of strong residue under UV

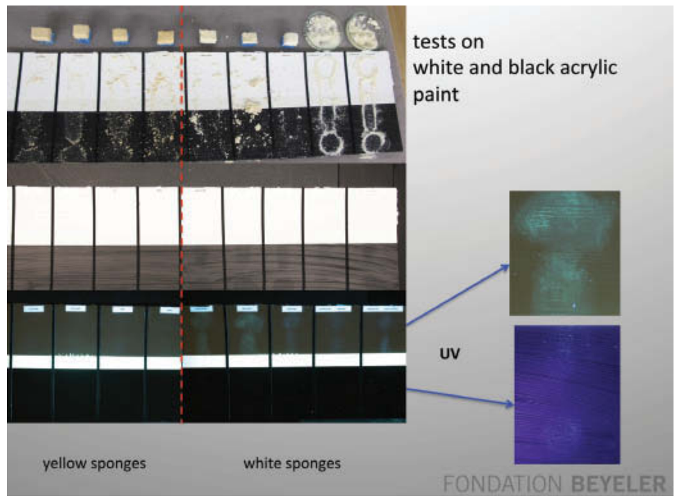

Figure 3. Tests on black and white acrylic paint; detail of strong residue under UV

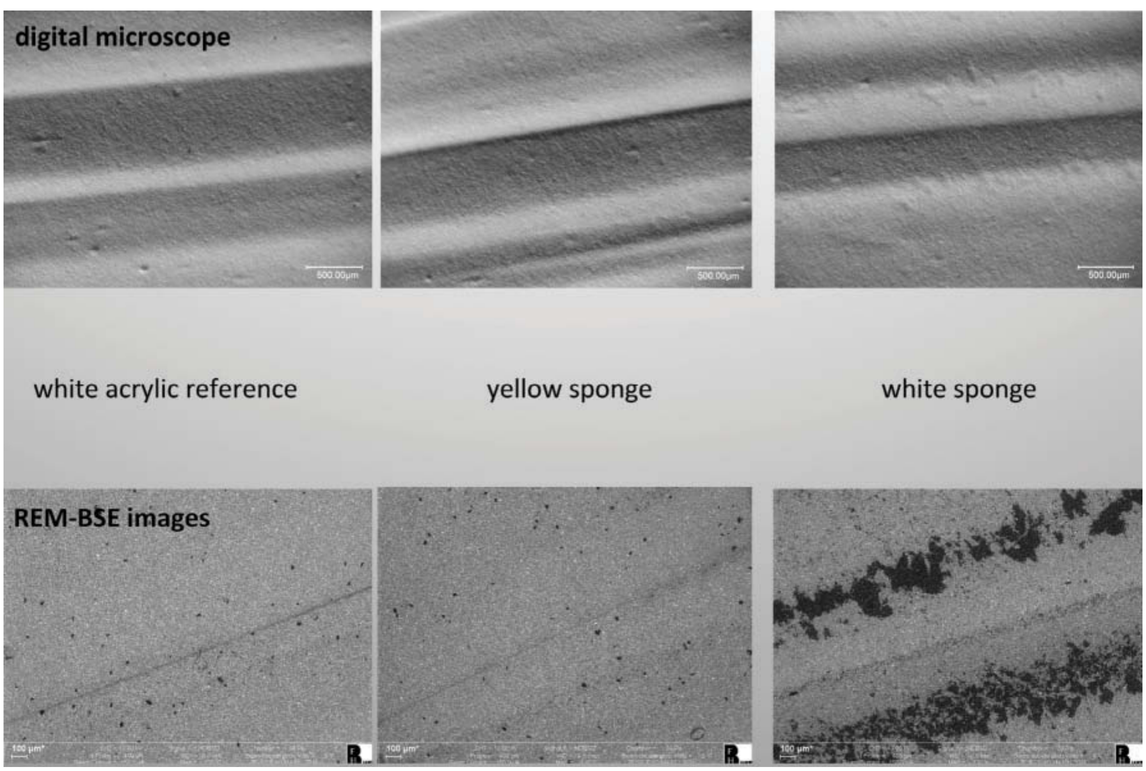

Figure 4. Digital microscope and REM-BSE images of reference sample uncleaned, cleaned with yellow sponge and cleaned with white sponge

PHILIP KLAUSMEYER*, RITA ALBERTSON and MAJA RINCK

STUDIO TIP: A Velcro-based Approach for Securing Polyester Batting Material to Backing Boards for Paintings

This tip offers a Velcro–based method for attaching polyester batting to backing boards, along with two convenient methods for placing the polyester batting on the Velcro tape. The method formerly was developed in 2002 by Philip Klausmeyer, paintings conservator and conservation scientist at the Worcester Art Museum.

One starts by cutting an acid-free blue board backing to a proper size for attachment to the stretcher support. Following, the inner dimensions of the stretcher pockets are measured and the corresponding placement is outlined in pencil on the inside face of the backing board (fig. 1). The polyester batting is then cut to fit within the stretcher pockets, using a dry-wall T-square (fig. 2). To avoid overlaps, the pieces are cut about 1/2 inch smaller in dimension than the stretcher pockets, leaving a 1/4 inch gap between the edge of the batting and the inside edge of the stretcher bars all the way around. If present, space is cut away for keys. In the next step, multiple strips of 100% nylon Velcro hook tape backed with pressure-sensitive acrylic adhesive are cut to a length slightly shorter than the vertical dimensions of the stretcher pockets and these strips are adhered to the backing board within the outlined shape of the stretcher pockets (fig. 3). Placement of strips at the far edge of each vertical side is recommended to help achieve optimal contact with the batting.

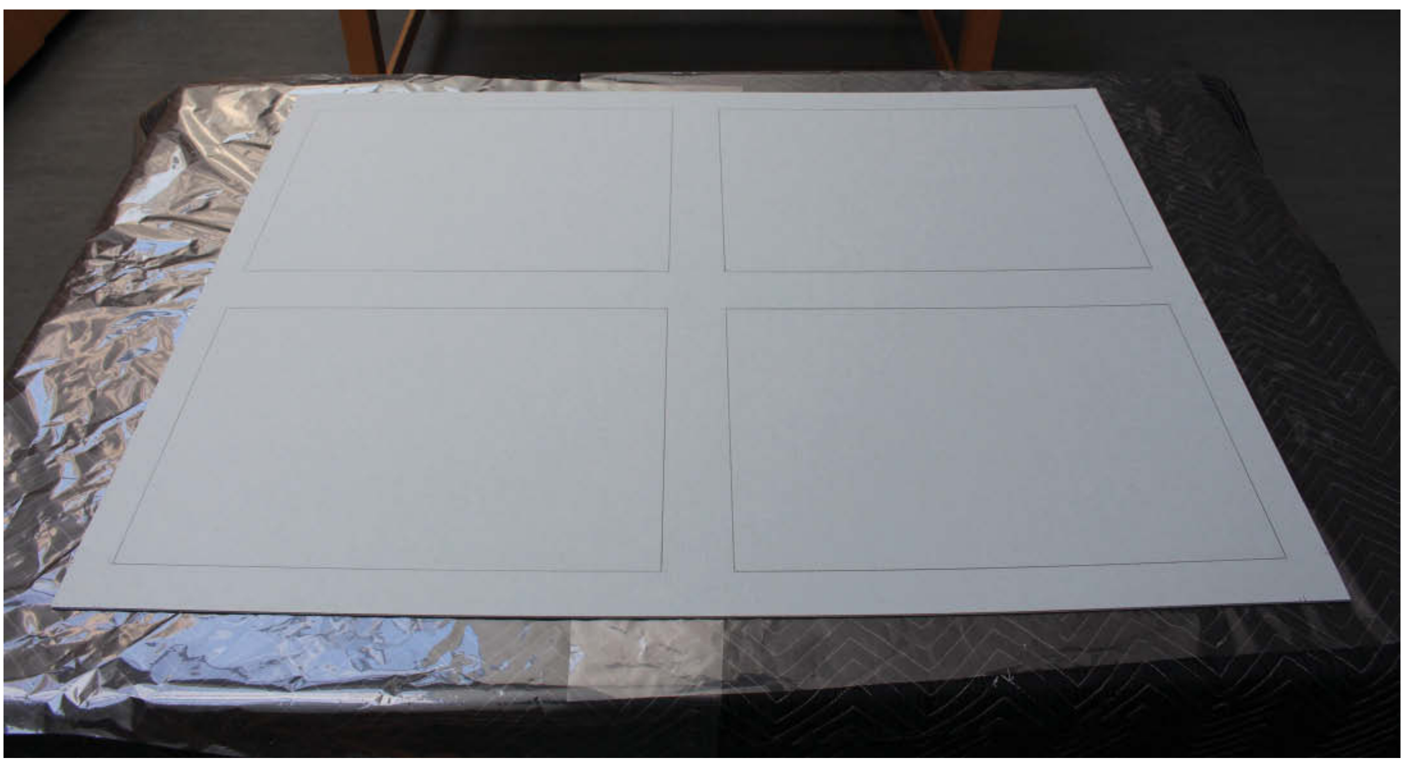

Figure 1. Cutting of acid-free blue board and outlining of stretcher pockets

* Deceased August 25, 2016

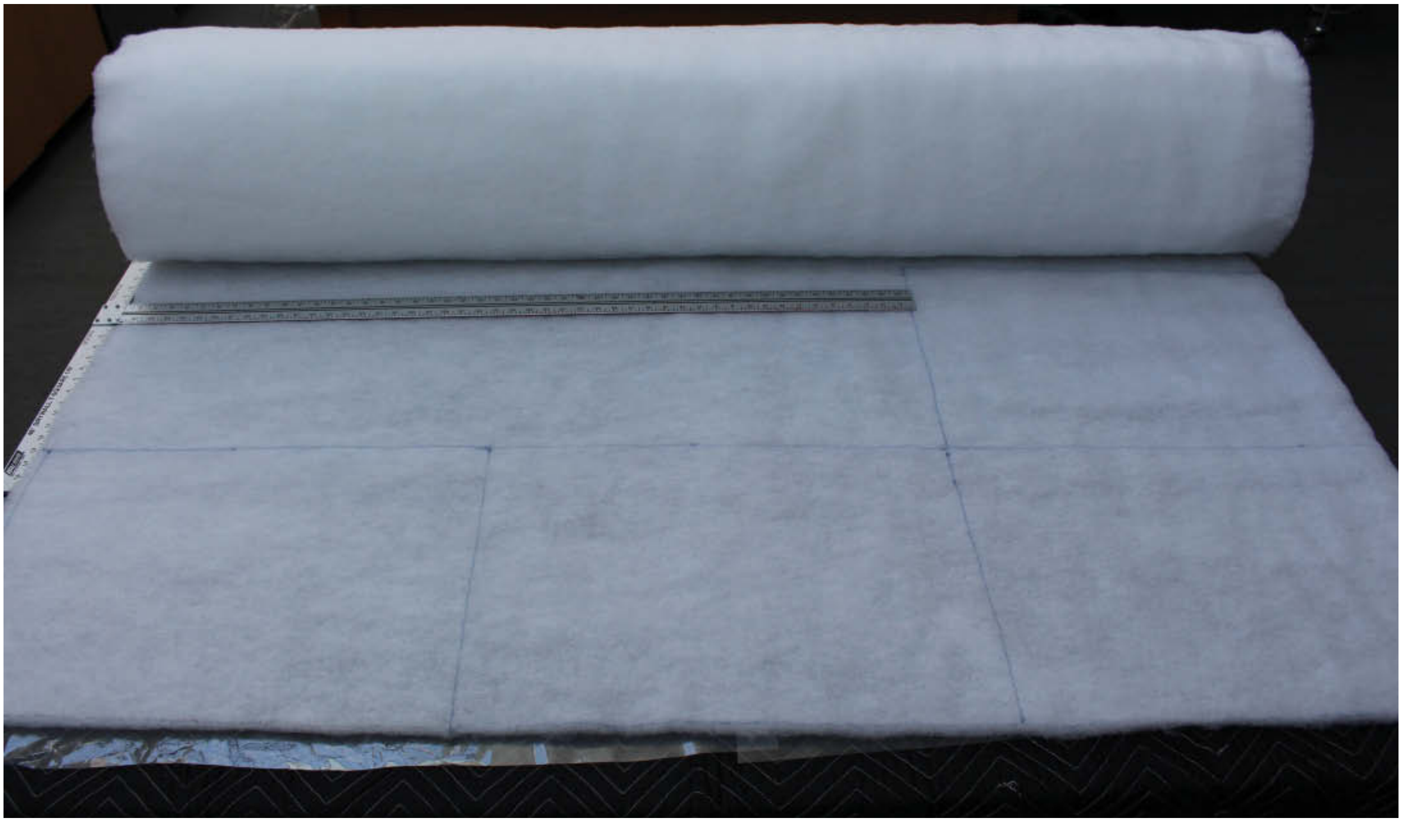

Figure 2. Cutting polyester batting to fit within stretcher pockets

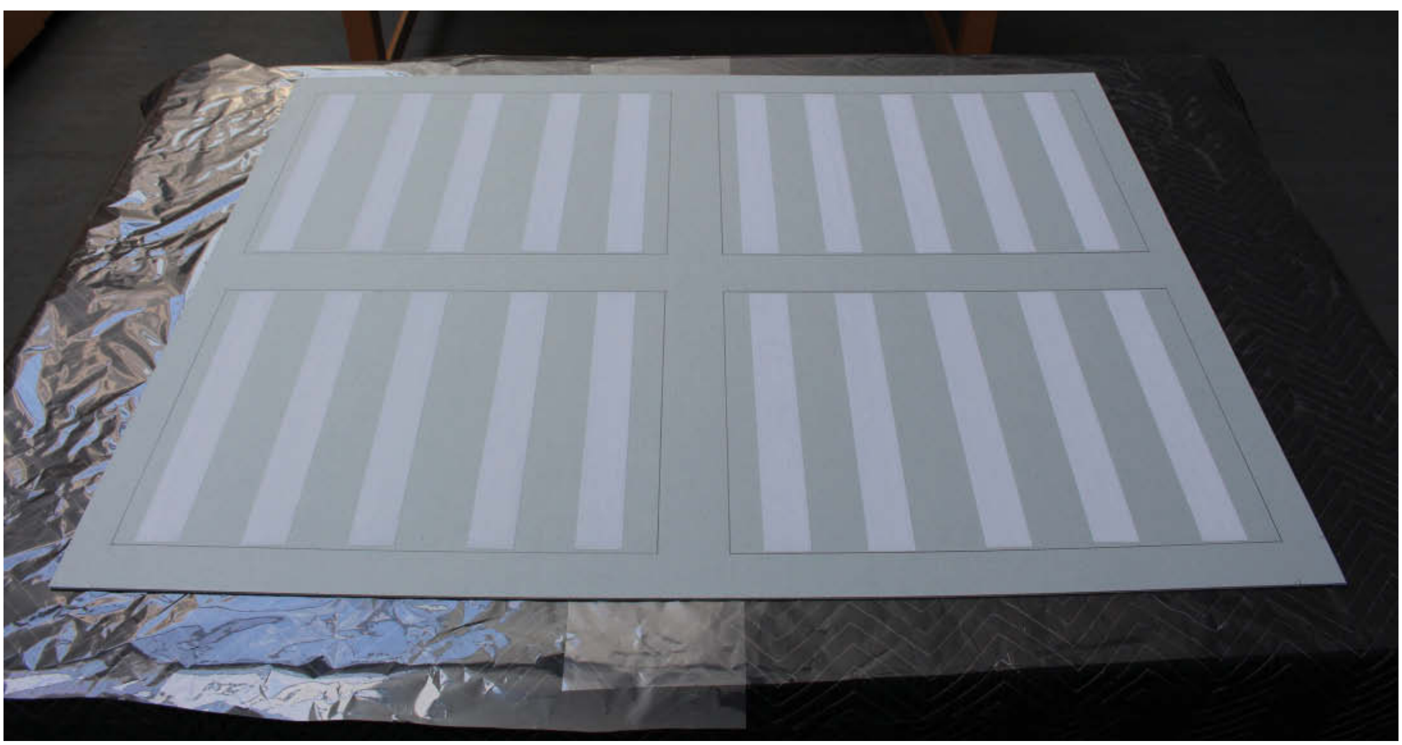

Figure 3. Cutting of Velcro tape strips and attaching to backing board

There are two options now for securing the polyester batting to the backing board: Option 1 requires the painting to be face down. The cut-to-size polyester batting pieces are placed within the stretcher pockets and the backing board with the attached Velcro strips is carefully lowered onto the reverse of the stretcher (fig. 4). Registration marks made beforehand will guide the placement of the backing board. Once the backing board is lowered in place, slight hand pressure on the surface ensures that the Velcro tape makes contact with the polyester batting (figs. 5, 6). At this point we also recommend inserting a screw for attaching the backing board on at least two sides. These can later be used to re-establish proper placement of the board. After the placement of the board is determined and initial contact with the batting is made, the backing board is carefully lifted up and the polyester batting should come away with it (fig. 7).

Figure 4. Option 1 for securing polyester batting to the backing board: Cut polyester batting is placed within stretcher pockets

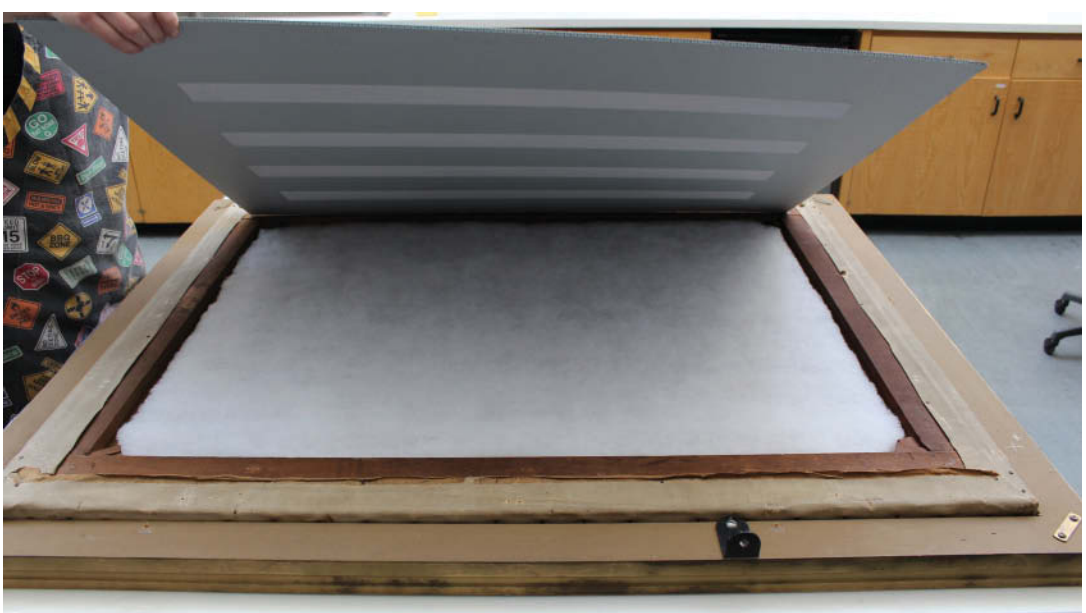

Figure 5. Option 1 for securing polyester batting to the backing board: backing board with attached Velcro strips is lowered onto reverse of the painting

Figure 6. Option 1 for securing polyester batting to the backing board: light hand pressure on the surface

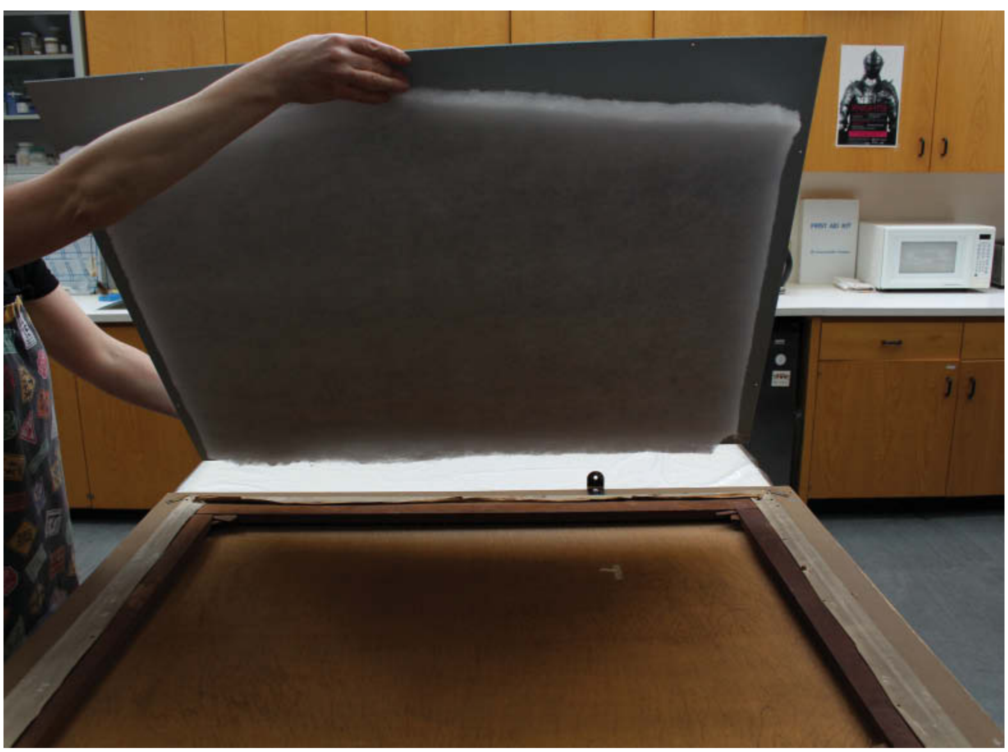

Figure 7. Option 1 for securing polyester batting to the backing board: backing board is lifted up and polyester batting comes away with it

In Option 2, the backing board is placed with the Velcro strips face up on a table and a sheet of Dartek is placed on top to cover the Velcro strips (fig. 8). The cut pieces of polyester batting can then be positioned within the pencil outlines without attaching to the Velcro strips. While holding the polyester batting in place, the Dartek sheet is carefully pulled out so that the polyester batting comes in contact with the Velcro strips without losing its positioning (fig. 9).

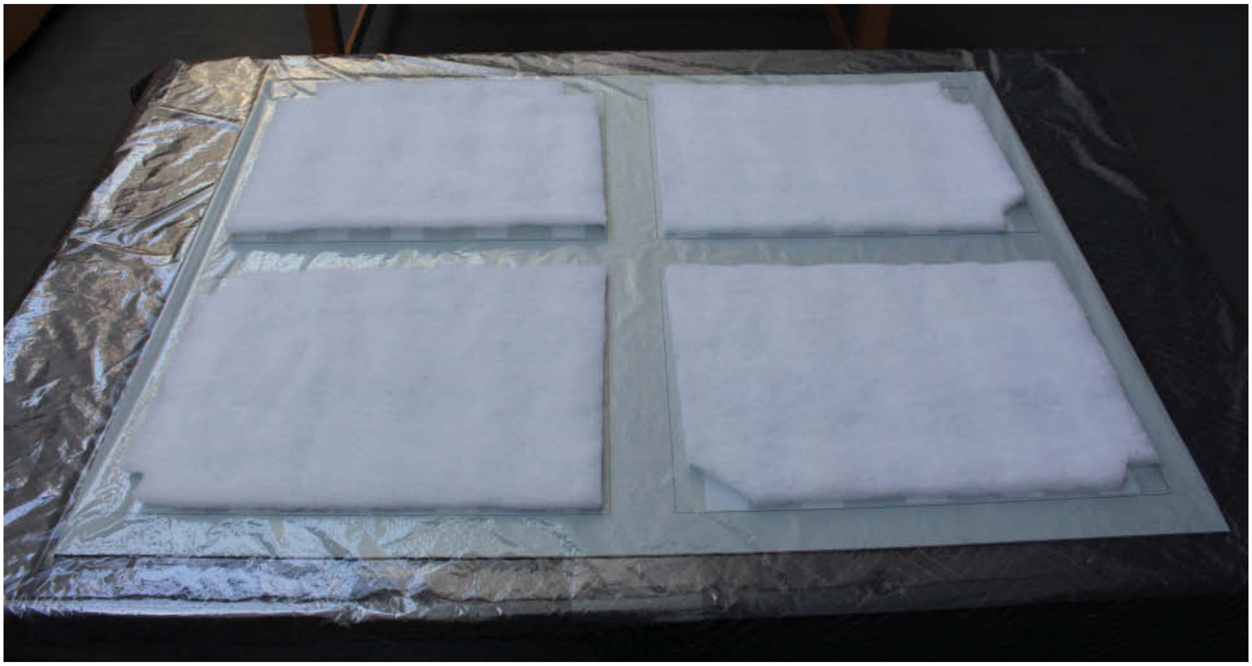

Figure 8. Option 2 for securing polyester batting to the backing board: cut polyester batting is placed over a Dartek sheet that covers the Velcro strips

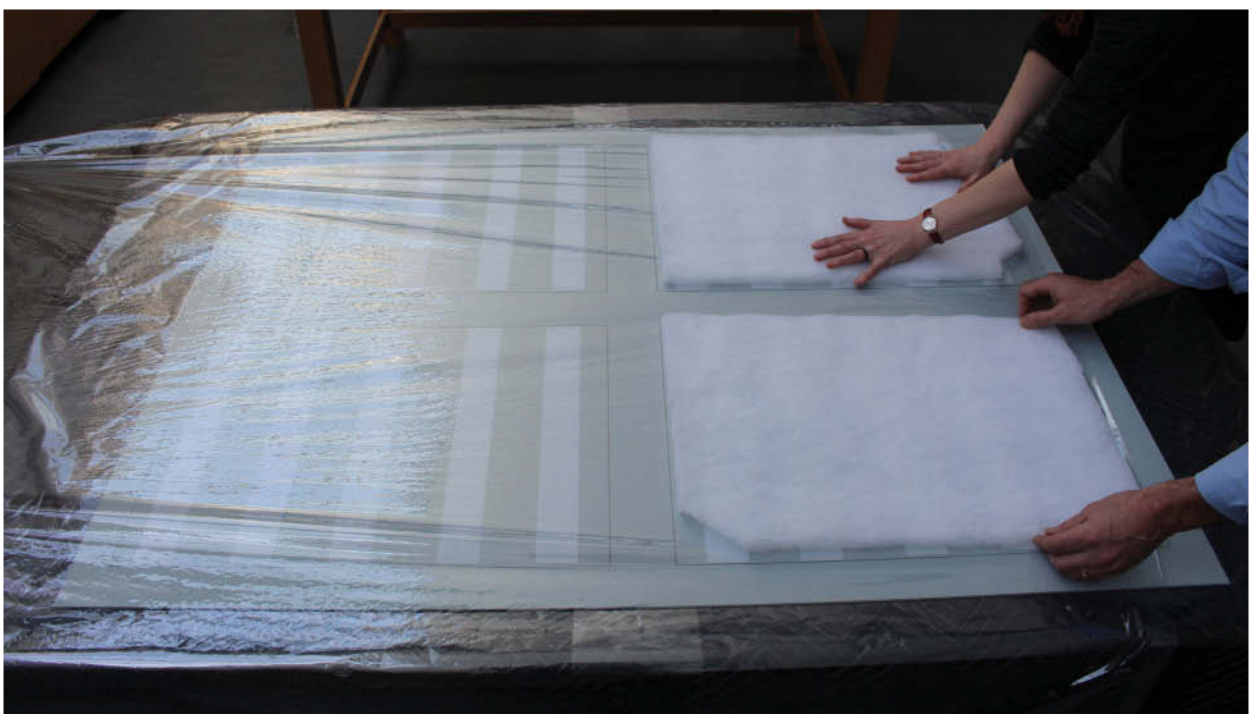

Figure 9. Option 2 for securing polyester batting to the backing board: the Dartek sheet is carefully pulled out while the polyester batting is held in place

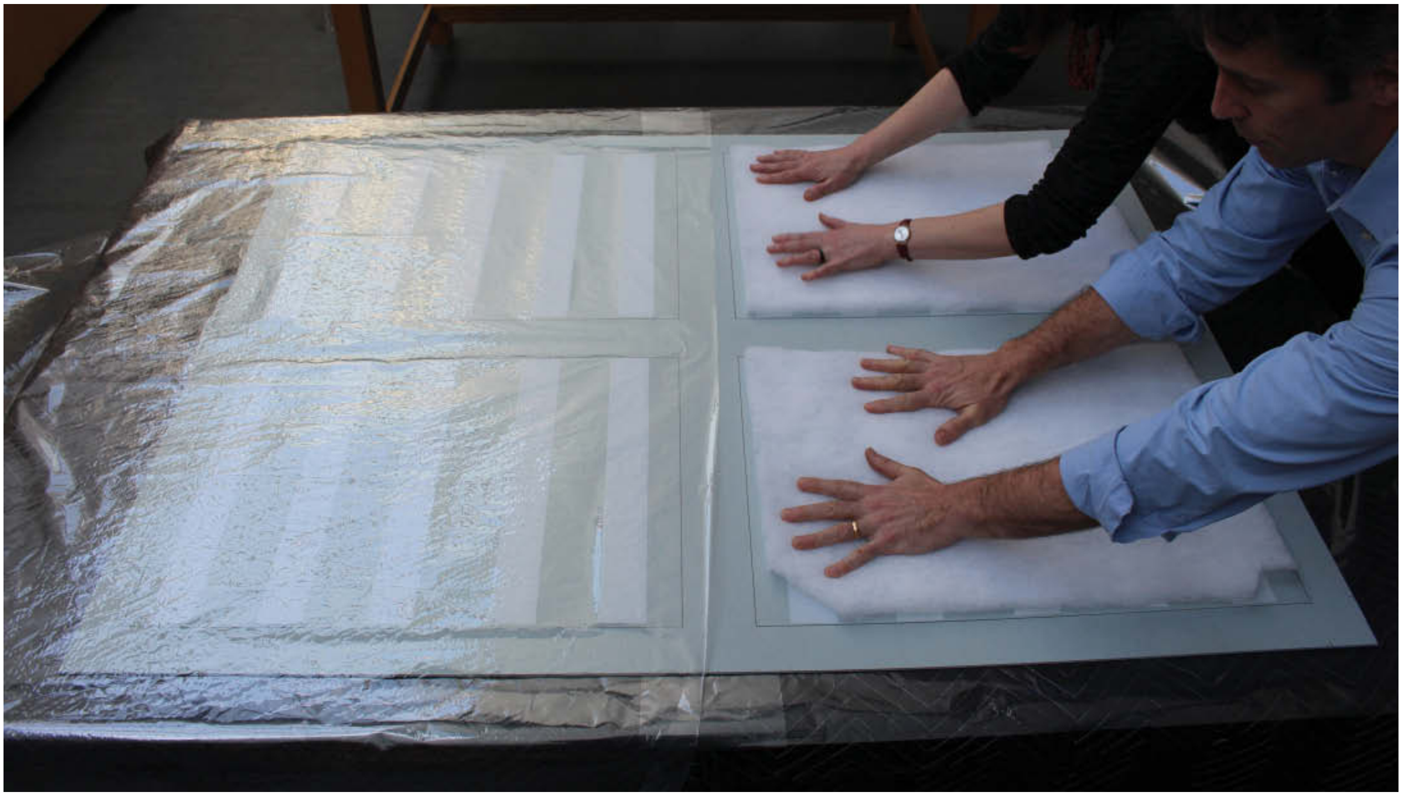

Figure 10. Pressure on the batting

For both options we recommend to lightly press the overall surface of the batting with the palms of your hands to firmly secure the polyester batting to the Velcro tape (fig. 10). Take special care to use batting that is thinner than as the depth of the stretcher pocket. This ensures that nothing comes in contact with the canvas, avoiding any possibility for bulging on the face of the painting.

For the final step, the backing board is placed on the reverse of the stretcher, using the screw holes made previously as placement guides, and is then secured to the stretcher with appropriate hardware (figs. 11, 12).

Keep in mind that the Velcro tape we use in this method has an acrylic adhesive and not a rubber-based adhesive, which we suspect may be at the root of some reports of adhesive failure. Also, it is critical to use acid-free blue board with the acrylic-adhesive Velcro tape rather than Coroplast, as this type of tape is not recommended for use with polypropylene. Future research on the possibility of adhesive failure and slumping of the batting would be desirable. Since 2002, this method has been used at the Worcester Art Museum with only positive results.

SOURCES OF MATERIALS

Acid-free blue board
Acid-free Buffered Perma/Dur B-Flute
Corrugated Board 48x 90
www.universityproducts.com

Velcro tape
VELCRO® brand Adhesive 72, hook 88, 2″ white
http://www.velcro.com/business/products/adhesive-options

Polyester batting
Musetex Polyester Batting,
M0001-491, 72″ × 21′ roll, 1″ thick/M0001-494, 72″ × 21′ roll, 0.5″ thick
www.gaylord.com

Figure 11. Placing the backing board on the reverse of the stretcher

Figure 12. Secure backing board to the stretcher with hardware

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ROBERT PROCTOR

STUDIO TIP: Shopping at the Pet Store

The reptile section of many pet stores can offer surprisingly valuable tools at very low prices, here are three. An infrared thermometer is useful for reading the surface temperatures of paintings or tools like irons and hot tables. A digital hygro/thermometer is good for monitoring conditions in humidity chambers. A reptile low temperature heat mat has been found to be useful for treating planar deformations in canvas paintings, adding a little warmth to a humidity chamber, and for keeping gesso warm.

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Figure 1. Infrared thermometer, a digital hygro/thermometer, and a reptile heat mat

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STUDIO TIP: A Scraping Tool

A box cutting blade can be inserted into a small slot cut into a wood handle to make a scraper for removing brown paper glued to the back of stretchers. The scraper can be taped to the end of a vacuum, which will allow the paper to be sucked away during removal.

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Figure 1. Scraper for removing brown paper tape from the back of frames

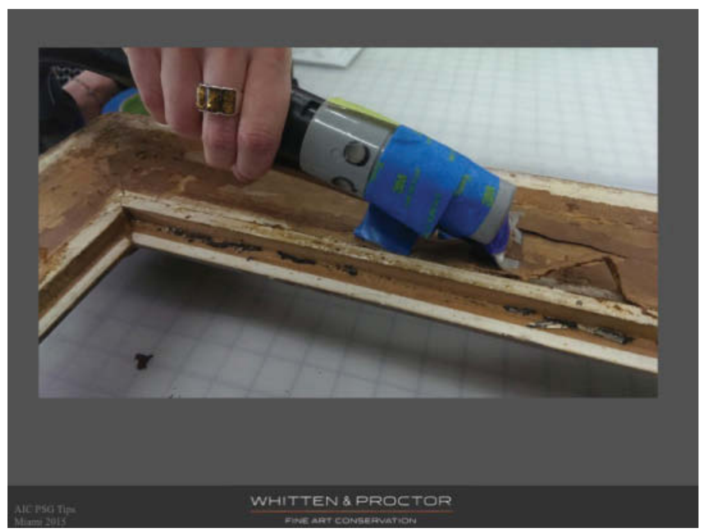

Figure 2. Scraper attached to vacuum

STUDIO TIP: Making Light Stands for Inpainting and UV Photography

Salvage the wheels and base from old rolling office chairs and stick a pole in them (for example a replacement broom stick can be bought at a hardware store) then attach either a track light, or a black light on the pole (figs. 1, 2). Black fome core board can be added to the black light as a "barn door" to shade the camera (and eyes) from the UV light (fig. 3).

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Figure 1. Salvage wheels and base from office chair for light stand

Figure 2. Track lights and ultraviolet light attached to mobile light stand

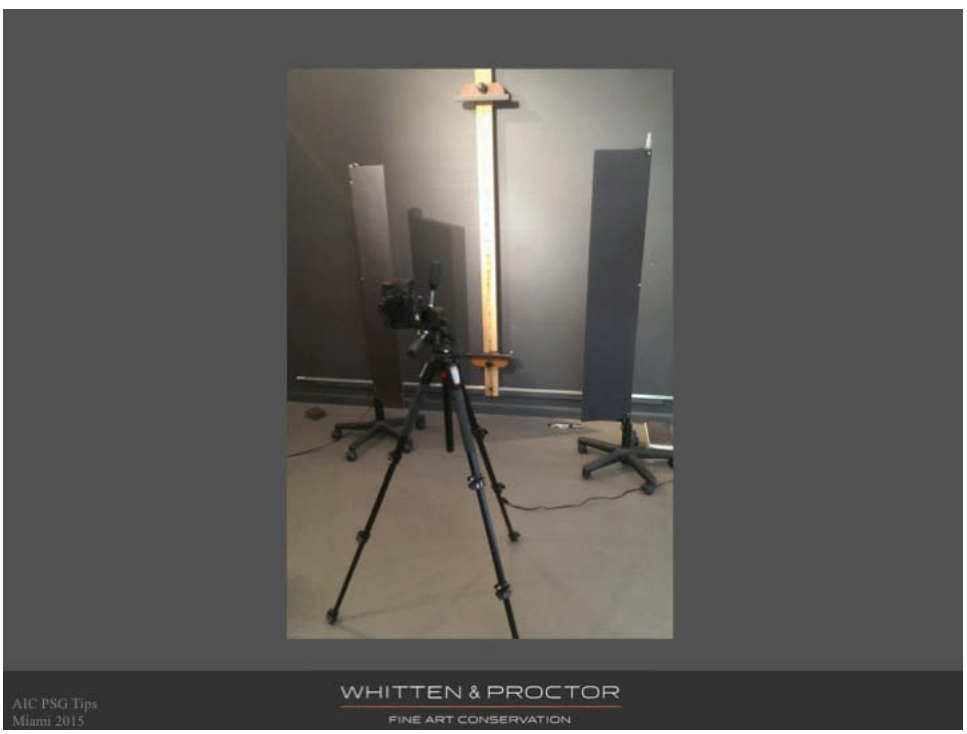

Figure 3. Example of set-up for photography with UV light on rolling stand with "barn door" attachment

ERIN STEPHENSON

STUDIO TIP: Removal of a Fieux Lining

Treatment of Max Ernst's *Surrealism and Painting* at the Menil Collection involved the removal of an outdated lining system known as a 'Fieux' lining. The method involved a pressure between the painting and a proprietary lining fabric called Fabri-Sil, which was designed by Robert Fieux. The fabric consisted of glass cloth impregnated with Teflon® and coated with a silicone-based pressure sensitive adhesive on one side (CAMEO. Museum of Fine Arts Boston. Web. 28 February 2014). The system was designed to be applied without heat or solvents and to be reversed in the same manner. Unfortunately, those advantages proved to be disadvantages as well, and the lining fell out of use.

This tip was presented in a video format as a point of interest to the general audience, especially for those who may never have had the opportunity to see or treat a painting with a Fieux lining. In this case, the lining was still generally adhered to the painting, but needed to be removed due to potential future failure and to facilitate the rest of the treatment. The lining was removed through mechanical action by pulling gently on the canvas in a low position away from but parallel to the original canvas, which was weighted to keep it in place during the removal (figs. 1–3). This process took approximately one hour and left no obvious damage or residual adhesive on the original canvas.

Figure 1. Image taken during the removal of the lining

Figure 2. Image showing the adhesive pushed away from the lining fabric

Figure 3. The full lining fabric, adhesive side up, after it was removed from the painting

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STUDIO TIP: Use of the *CCI Octoprobe* with the Willard Multipurpose Table

When using the Willard Multipurpose Table for controlled humidification and flattening treatments for paintings on canvas, it is useful to know the humidity levels under the painting being treated in order to avoid levels which may cause shrinkage of the canvas support (fig. 1). The moisture introduced into the table is controlled by a wet-bulb/dry-bulb system in response to a sensor placed in the duct work of the table (fig. 2). However, when using the table with low heat in the duct work, it is quite easy to get higher than desired humidity levels under the painting, due to a temperature gradient between the ducts and the cooler surface of the table.

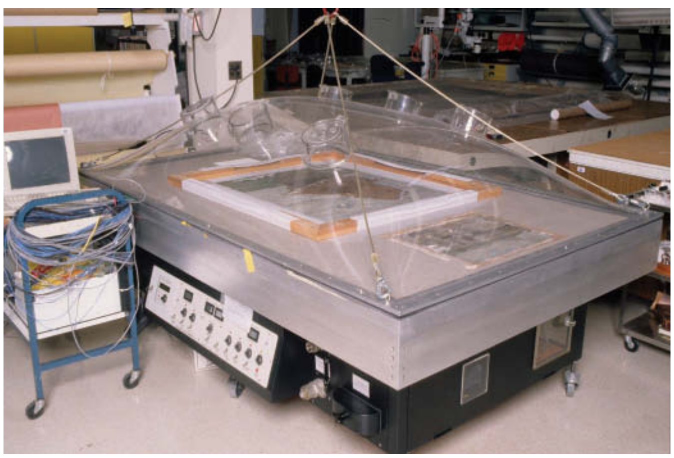

Figure 1. The Willard Multipurpose Table with early surface RH & T monitoring equipment. © Government of Canada, Canadian Conservation Institute

Figure 2. The humidification in the table is controlled by a wet-bulb/dry-bulb system in response to a sensor in the ductwork. © Government of Canada, Canadian Conservation Institute

When using the Willard Table for relaxation and flattening treatments of paintings on canvas, I usually try to maintain the humidity around 79% RH. Higher humidity levels are in the region in which linen canvas can start to shrink. In the early years of using the table, to monitor the humidity level under the painting being treated, we borrowed a monitoring system designed by Tom Strang, Senior Conservation Scientist at CCI. Temperature and humidity probes were placed under an experimental painting, which was placed to the side of the painting being treated (fig. 3).

It was alarming to see the RH under that painting rise to dangerous levels, even with a small temperature difference between the air in the ductwork of the table and the surface of the table. An early graph shows that even with the table set at 76%, and with the edge heaters and duct heaters set at 35°C and 30°C respectively, the humidity below the painting can rise beyond 90% due to the cooler temperature at the table surface (fig. 4a). This monitoring system allowed the conservator to

Figure 3. In the early monitoring system, temperature and humidity probes were placed under one or more experimental paintings, placed to the side of the painting being treated. © Government of Canada, Canadian Conservation Institute

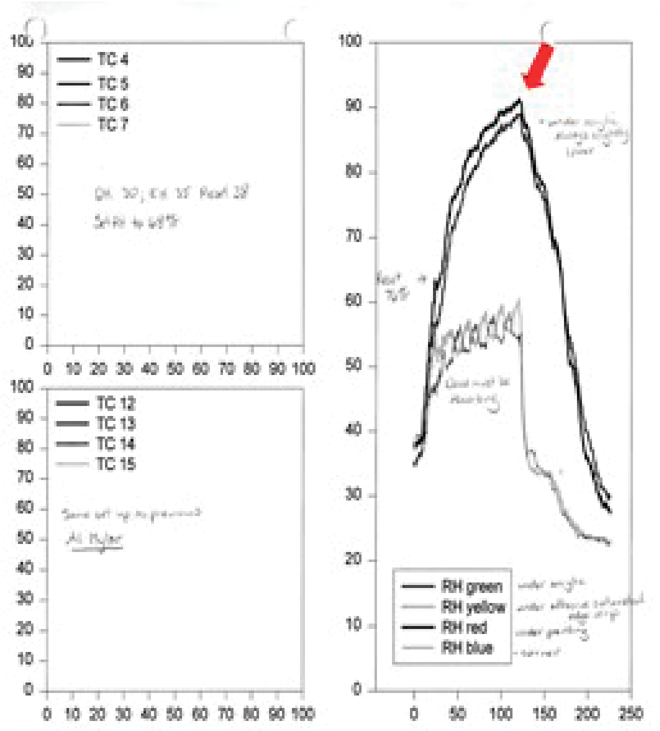

Figure 4a. Graphs of the conditions under the test painting, clearly showed the humidity rising to levels at which there is risk of shrinkage. © Government of Canada, Canadian Conservation Institute

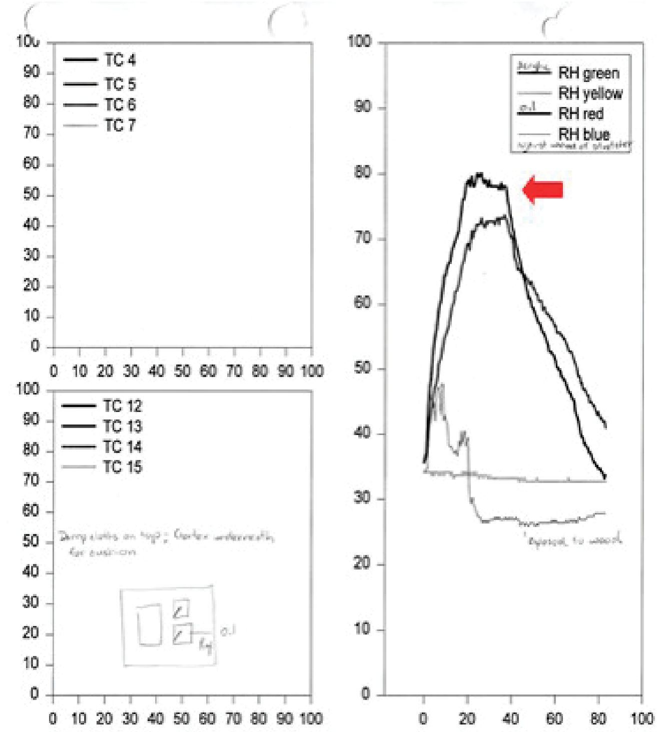

Figure 4b. At the desired RH, the table setting can be turned down to maintain the desired level. © Government of Canada, Canadian Conservation Institute

quickly glance at the computer screen during the treatment and adjust the table settings to maintain the desired humidity (fig. 4b).

The psychrometric chart can be used to determine the eventual humidity at different temperatures, but a quick calculation can also be undertaken using a software calculator, based on basic hygrometric equations, designed by Eric Hagan, Conservation Scientist, CCI (fig. 5a). In the example shown in Figure 5b, with the table set to achieve a humidity of 78%, the temperature in the ductwork at 32°C (89.6°F) and the temperature at the table's surface at 22°C (71.6°F), the calculator shows that saturation levels can be reached under the painting.

In order to have my attention on the painting being treated, and not doing calculations, I appreciate being able to glance at a computer screen to monitor the conditions under the painting. Paul Marcon, Senior Conservation Scientist, Tom Strang and Eric Hagan collaborated on creating a new monitoring set-up with more up-to-date sensors, computer hardware and customized software. This *'CCI Octoprobe'* is a small, portable unit, which can be hooked up to a laptop. In 2008, the parts were easily obtained and purchased for under $350 (fig. 6). The humidity sensors on this unit are smaller than the Vaisala probes and are much less expensive. The unit runs on software developed by Paul Marcon. As before, with the sensors placed under an experimental painting, to one side of the painting being treated, the conservator can glance at the graph and humidity values displayed on the computer screen and turn the table humidity setting down in order to maintain a safe level under the painting (figs. 7, 8). Figure 9 provides information on the parts and construction details.

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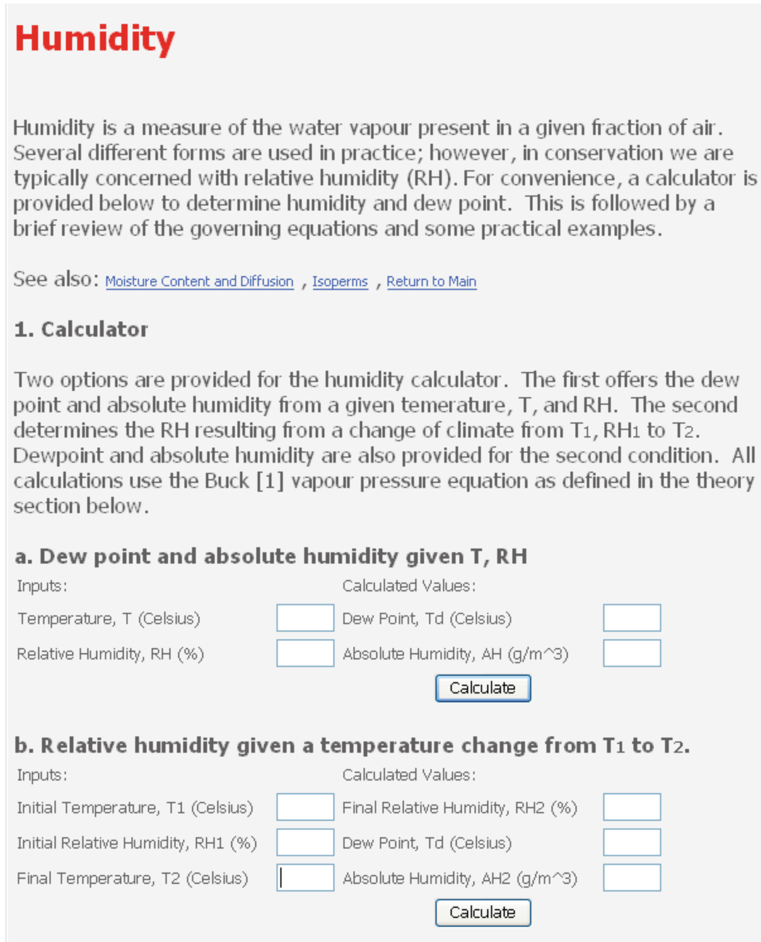
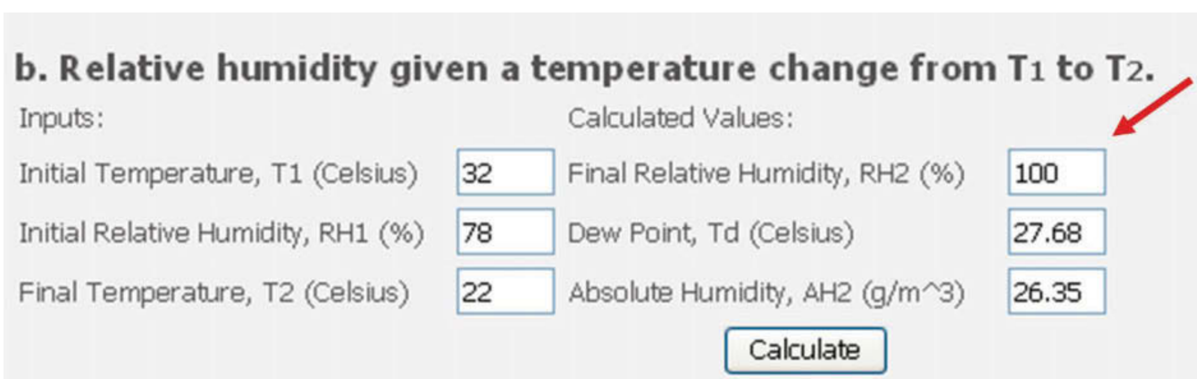


Figure 5a. A software calculator makes it easy to see the impact of the temperature gradient during a humidity treatment. © Government of Canada, Canadian Conservation Institute



Temperature in ducts: Initial Temperature, 32°C = 89.6°F

Temperature at surface: Final temperature, 22°C = 71.6°F

Figure 5b. This software calculator, or a psychrometric chart, will show the humidity that can result under the painting from the specific table settings. Under the table conditions in this example, with the humidity set at 78% RH, the duct-work at 32°C (89.6°F) and the table surface at 22°C (71.6°F), (which is below the dewpoint of 27.6°C), 100% humidity can be reached at the table surface, under the painting. © Government of Canada, Canadian Conservation Institute

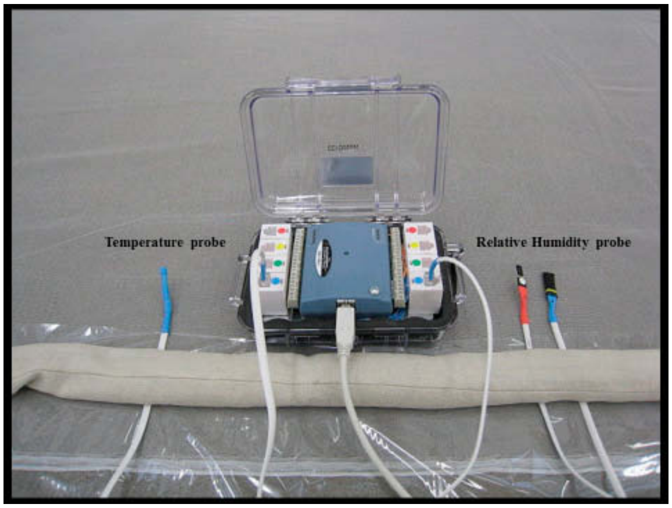


Figure 6. The Octoprobe is small and can accommodate 4 temperature and 4 humidity probes. On the right, one humidity probe is covered with its protective synthetic 'sock'; the other is shown without the cover. © Government of Canada, Canadian Conservation Institute

Figure 7. The Octoprobe setup during a treatment on the multipurpose table. © Government of Canada, Canadian Conservation Institute

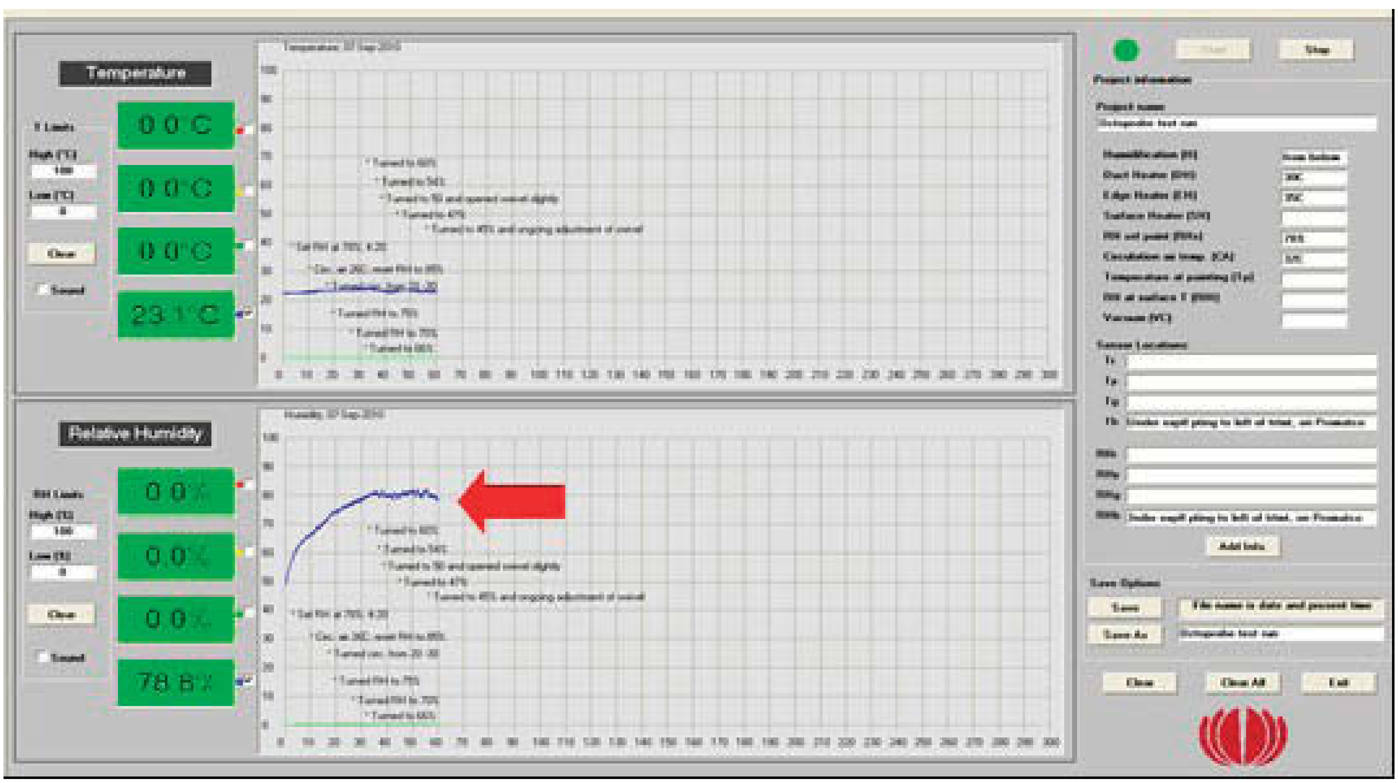


Figure 8. The graphic display on the computer screen, during a humidification treatment on the multipurpose table. © Government of Canada, Canadian Conservation Institute

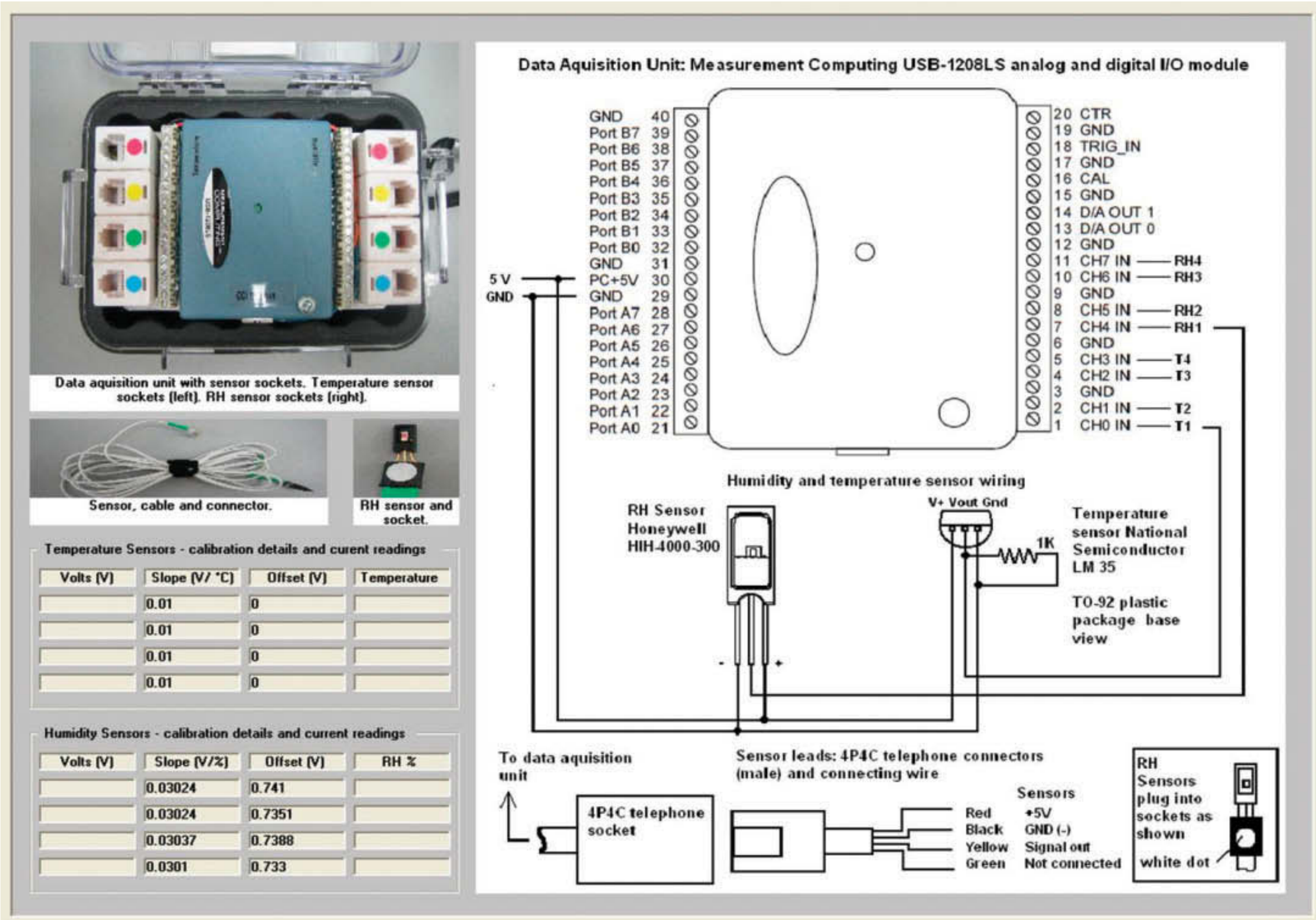


Figure 9. Parts and construction details of the CCI Octoprobe, RH & T monitoring system. © Government of Canada, Canadian Conservation Institute

BARBARA HELLER

STUDIO TIP: Leather Handles for Paintings

The Detroit Institute of Arts uses leather handles to facilitate the handling of paintings with strip or shadow-box frames and those without frames (figs.1, 2). The auxiliary handles enable the works to be supported and moved without touching the tacking margins. Even gloved hands can leave marks or planar distortions along the edges. The handles are secured with brass brackets directly to the stretcher reverse. Oversized works are fitted with two handles on each side for stability, balance and safety. The brackets allow the handles to lay flat against the wall when not in use.

The leather handles then became unavailable. Like many other museums, we created handles from 2″ wide cotton twill tape (used for upholstery). These are attached with screws and grommets at the top and bottom. The fabric handle loops need to be large enough for someone to grip, which then tends to buckle and fold behind the painting. The fabric can be doubled and secured along the top. These lay flat when not in use, however, they are harder to manage or grip on large and heavy paintings.

We finally located company in Maine that specializes in replacement leather handles for all types of suitcases. After comparing the existing handles and conferring with the vendor, we were able to identify which handles work best as a replacement. We wanted handles and brackets with a low profile so they are not visible when the painting is installed. The leather had to be capable of accommodating the weight of the larger paintings, which usually range from ~40–100 pounds. We determined that the small wide end handles TH-16 with LOOP4 small brackets were the preferred option (fig. 3). These are actually sewing machine and typewriter case handles. The handle is composed of two layers of leather so they are sturdy. The TH-16 handles are sold separately @ $10/each and the end caps/brackets Loop4 are sold in pairs @$8/each. USA shipping is included. Please refer to image three for options and dimensions.

Handles: http://www.brettunsvillage.com/trunks/howto/parts/handles.htm

Brackets: http://www.brettunsvillage.com/trunks/howto/parts/endcaps.htm#th16brackets

Figure 1. Leather handle used at Detroit Institute of Art

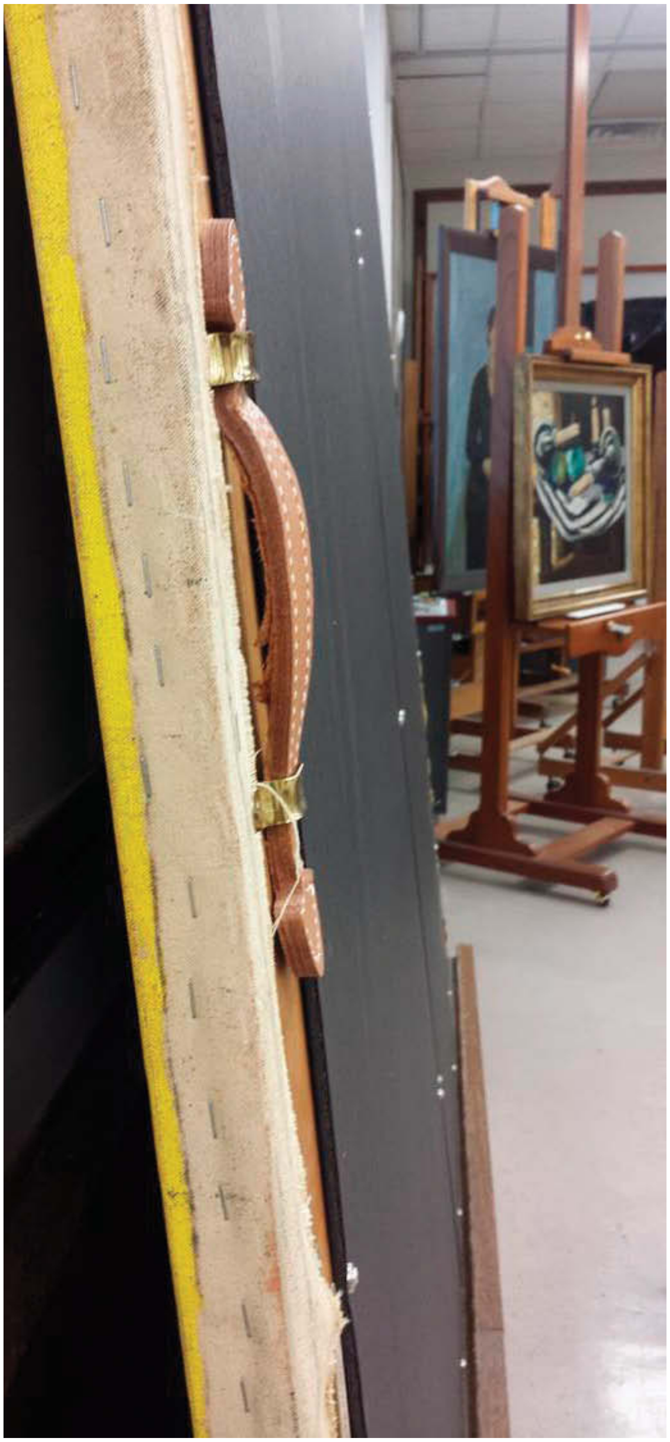


Figure 2. Profile when not in use

SOURCES OF MATERIALS

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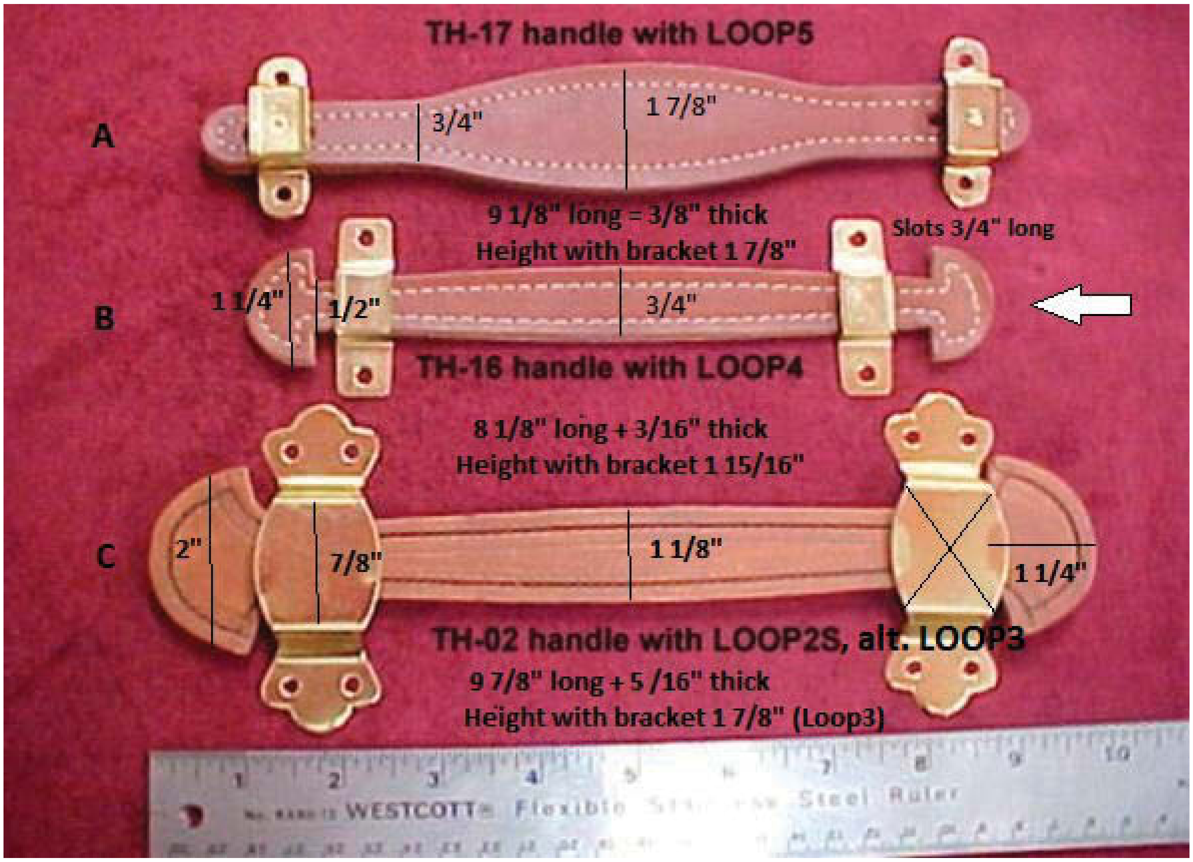

Figure 3. a) Suitcase Handle, Artist Boxes and Musical Instrument Cases TH-17 $14/each + Loop5 $8/pair brackets; b) Sewing Machine and Typewriter Case, Suitcase Handle TH-16 $10/each + Loop4 $8/pair brackets; c) Trunk Handle TH-02 $17/each with Loop3 brackets (not pictured) $8/set of four

MARY PIPER HOUGH

STUDIO TIP: Using Gellan Gum as a Poultice

This tip discusses the use of Gellan gum as a poultice to remove a paper label from the verso of a late 18th century painting which had been lined with glue-paste adhesive (fig. 1). Prior to acquisition, the label had been partially removed; the pieces removed were lost. This treatment was a collaborative effort between the paintings and paper labs at Library and Archives Canada.

Selected Bibliography

In 2010, Italian conservators Simonetta Iannuccelli and Silvia Sotgiu, from ICPAL, the laboratorio di restauro del patrimonio librario in Rome introduced the use of a rigid polysaccharide gel for wet conservation treatments of works on paper. Here was a material that could deliver moisture in a highly controllable way with minimal impact on the paper substrate. Aside from a brief introduction, I will not go into the detailed chemistry of gellan gum, and urge you to consult these excellent studies:

Figure 1. Label on verso of late 18th century painting

Iannuccelli, S. and S. Sotgiu, 2010. "A new methodology for wet conservation treatments of graphic art on paper with a rigid polysaccharide gel of gellan gum," *Graphic Documents Working Group Interim Meeting ICOM-CC, Choices in Conservation Practice versus Research, 6–8 October 2010,* ed. L. Watteeuw, (Copenhagen: Copenhagen Royal Library), pp. 47–51.

Iannuccelli, S. and S. Sotgiu, 2010. "Wet Treatments of Works of Art on Paper with Rigid Gellan Gels," *The Book and Paper Group Annual, American Institute for Conservation,* Volume 29, 2010, pp. 25–39.

Botti, L. et al, 2011. "Evaluation of cleaning and chemical stabilization of paper treated with a rigid hydrogel of gellan gum by means of chemical and physical analysis," *ICOM-CC, 16th Triennial Congress, Lisbon, 19–23 September 2011*, pp. 1–10.

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What is gellan gum?

Gellan gum is a high molecular weight polysaccharide produced by the fermentation of the bacterium *Sphingomonas elodea* (identical to the naturally occurring polysaccharide formed by the same bacterium on varieties of lily pad plants). It finds application as a thickening or gelling agent in the food, biomedical, and pharmacology industries. It is biodegradable and non-hazardous.

Studies conducted by by Sottgiu and Iannuccelli of various rigid gellan gels (Phytagel gellan, Gelrite and Gelzan CM) concluded that Kelco gellan gum was the most effective, and economical. Gellan gum also compared favorably in tests to agar agar, with higher transparency and greater water retention properties.

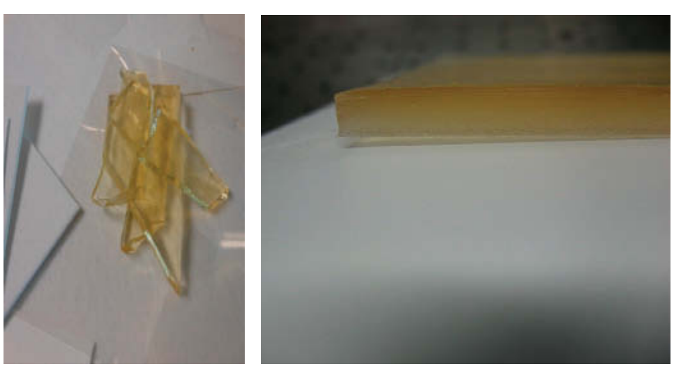
Gellan gum is available in two grades: high and low acyl content, which forms soft and hard gels respectively. It is the acyl groups that have a significant influence on gel characteristics. The high acyl form produces soft, elastic non-brittle gels, while the absence of acyl groups in the low acyl form produces firm, non-elastic brittle gels. For industry applications the two forms may be blended to give just the right product properties. The deacylated gellan gum is used for conservation applications. It forms a stronger gel, and sets at a much lower temperature range—between 30 and 50 degrees Celsius—while high acyl gels set at much higher temperatures.

Gel formation is also influenced by gel concentration, thickness of the cast layer, and by the type and concentration of mono or divalent cations. The gelling of low-acyl gellan is promoted by calcium, magnesium, sodium, or potassium ions.

How does it work?

Gellan gum gradually releases water molecules into the paper, and soluble degradation products are in turn absorbed into the gel (fig. 2). Because of the slow, constant introduction of moisture via gellan gum, the effects of aqueous swelling are minimized, a consideration that is critical when treating works with distinct dimensional qualities, like platemarks, embossings and surface texture.

In order to choose the appropriate gel percentage, the wettability of the paper support must be assessed (fig. 3). This can depend on the porosity of the paper, fiber type, sizing and coatings, and the state of preservation of the paper. In other words, the more absorbent (hydrophilic) the paper is, the higher the concentration of gellan gum used, as it will give off less moisture. Less absorbent (hydrophobic) paper needs a lower concentration gel, in order to give off more moisture.



a b

Figure 2 (a, b). Absorption of soluble degradation components into gellan gum

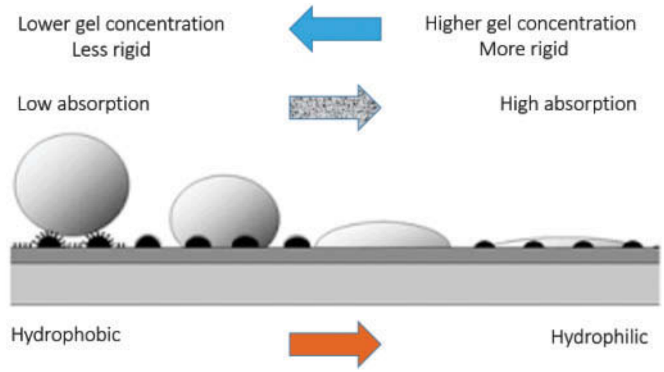
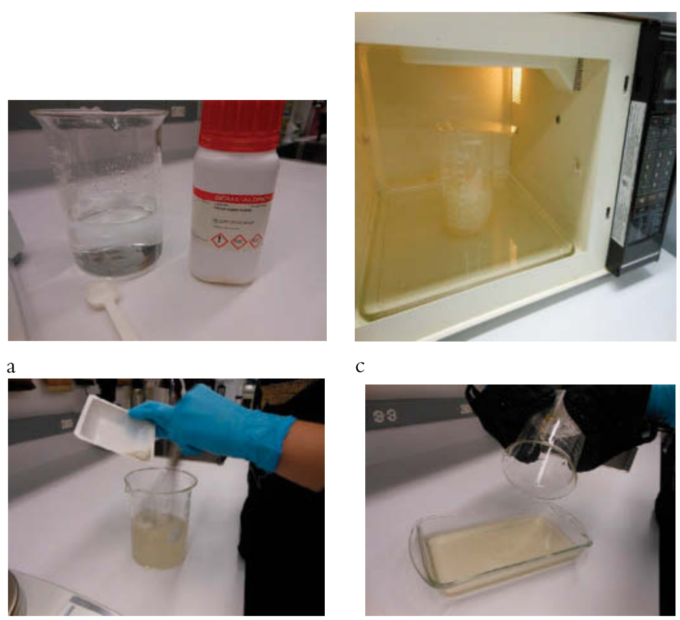


Figure 3. Calculation of gel concentration

For use with paper artifacts, the gellan gum is normally prepared in the range of 2–4% concentration to make a semi-rigid layer. Flexibility of the cast layer of gellan gum is variable and will depend not only on the gum and the ion concentrations used, but also the thickness of the cast layer.

Preparation is simple (fig. 4):

1. **Prepare aqueous solution of calcium acetate (0.4 g/L):** A saline solution made with calcium acetate is prepared, to which the gel is added. The calcium ions



a c b d

Figure 4 (a–d). Gellan gum preparation

are needed to stabilize the gel structure, rendering it more firm. It should be noted that the ionic strength of various sources of water will have a significant effect on the resulting gel characteristics.

2. **Add gellan gum to saline solution**: The gel powder is slowly whisked into the saline solution while stirring to create a colloidal dispersion.

3. **Heat solution to boiling point in microwave**: It is covered and heated in the microwave until the dispersion turns into a slightly yellow, transparent solution. Complete hydration of the gel occurs at 75–100 degrees Celsius.

4. **Pour into shallow tray**: The solution is poured into a heat resistant tray while it is still hot and runny. The rigid hydrogel film forms as the solution cools to room temperature. The gel can be covered and refrigerated for approximately 2 weeks.

Figure 5 hopefully illustrates the range of gel flexibility by showing a comparison of various gel formations prepared at 1%, 2% and 3% using Reverse-Osmosis water and calcium acetate solution. Gel strength can be increased by manipulating both gum and ion concentration.

Using gellan gum as a poultice

The gel works well as a poultice for humidifying and removing paper layers from various substrates. In this case, a paper label was successfully removed from the verso of the lined painting, with minimal dampening of the lining canvas (fig. 6).

Figure 5. Comparison of gellan gum concentrations with calcium acetate solutions

a

b

Figure 6 (a, b). Removing a label from verso of painting

The controlled release of moisture prevented over-wetting of the lining fabric.

- The inks in the label were tested for solubility, and the paper assessed for wettability.
- A 3% concentration of gellan was prepared and cast into a 1 cm thick layer.
- The Gellan gum was placed on a piece of heavy mylar and easily trimmed to size with a scalpel.
- The gum was placed directly on the label, covered with mylar and light weight and left for 10 minutes before the paper layers were peeled off with the aid of a microspatula. The gel delivered the adequate humidity needed to soften and solubilize the adhesive layer.

After treatment
The label was washed and lined with toned, lightweight Japanese tissue by our paper conservators (fig. 7).

Gellan Gum Summary
- Uniform, gradual + controlled release of water molecules
- Capacity to absorb water soluble degradation substances
- Safe and easy preparation and disposal
- Ease of application and removal
- Visco-elastic
- Transparent
- Stable to pH variations

SOURCES OF MATERIALS

CP Kelco Inc.
www.cpkelco.com

TALAS
www.talasonline.com

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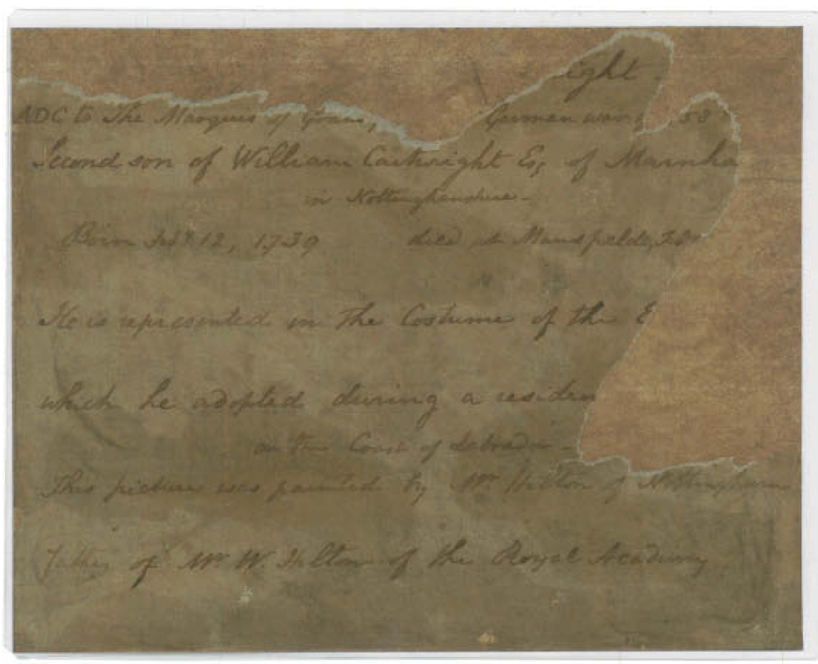

Figure 7. Label after treatment