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RECENT ADVANCES IN IDENTIFICATION OF BINDING MEDIA IN PAINT LAYERS

Michele Derrick and Dusan Stulik

ABSTRACT

This paper focuses on analytical methodology used in binding media determination and presents some of the methods developed in the course of the GCI Binding Media Project. Examples illustrate the complementary nature of several analytical instruments (Fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), gas chromatography/mass spectrometry (GC/MS) and high performance liquid chromatography (HPLC)) for the specific identification of proteinaceous media. Infrared mapping microspectroscopy is introduced as a new method to locate and characterize various components in a paint cross-section based on an array of infrared spectra. Each of the analytical methods provide important information which, when combined, contributes to a clearer depiction of the sample.

INTRODUCTION

Detailed knowledge of the material make-up of paint layers on easel paintings and polychrome sculptures gives conservators necessary background information which he or she needs to design an optimum and safe conservation treatment strategy. The art historian can also profit from a knowledge of material issues when he or she investigates the artist’s technique or looks for supporting evidence in provenancing studies. For many years material studies of painting layers focused on identification of pigments and pigment stratigraphy in paint cross-sections. Information about the types of binding media was obtained mostly by simple solubility tests or microscopic staining methods. This approach may serve well in every day practice but fails when solving complex conservation problems, when complex binding media are studied, or when investigation calls for identification of minor components of the binding media.

Today a number of these questions can be answered using modern analytical instrumentation and analytical methodology developed to serve the art conservation field. It is very important for a conservation scientist to have a deep knowledge of artist materials, artist techniques and restoration and conservation procedures, in order to understand conservators questions. It is also very important for a conservator to

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understand what scientific methods can do and what are the current limits of the methods used in conservation science research. With this in mind, this paper will present few current binding media analysis methods in terms of applications to actual samples.

GCI BINDING MEDIA PROJECT

Binding media analysis is rather difficult due to several factors. The types of binders used in a paint cover a tremendous range from modern synthetic materials to complex natural products such as oil, egg, wax or natural resin. Also, the paint may contain one or more of these materials and, to make matter worse, even the various layers within the painting may vary in composition. There is no one technique, or magic box, that can answer all the questions about a paint binder; indeed it takes a combination of techniques to sometimes answer just one question. And because of this complexity, no one scientist can master all of the analysis methods. So, at GCI, a team of scientists have developed expertise in a wide variety of methods for binding media analysis.

Figure 1 provides a lists of analytical equipment versus the potential materials that it can be used to analyze. Over the past three years at GCI, eight scientists have been a part of the GCI Binding Media Project. We have re-evaluated methods used in the past for the analysis of paint binders in conservation and applied them to new equipment and current industrial methods. This examination covered sample preparation, detection limits and potential interferences. In addition to updating and optimizing the old methods, we developed several new methods which show very strong potential for application to artists materials. A book is being written which covers the historical aspects of binding media identification as well as covering the current 'state of the art' techniques in binding media analysis.  

Identification of components is based on the comparison of an unknown sample with a known reference material. Thus, correct interpretation of the analytical result depends strongly on the quality and breadth of the reference collection. At GCI, through the help of several conservators, scientists and friends, we have collected of 1200 reference materials for binding media. This includes eggs from over 15 sites around the world. The age of the materials is dated from 1834 to the present. This collection is accessible for research purposes. Separate collections containing over 2000 materials are also being made of artist/conservation materials and dyes/pigments.

The analytical methods mentioned above are used interactively to support each other and provide confirmatory information. The following applications will illustrate use of some of these methods.

APPLICATION 1

For a typical analysis scheme, a small cross-section (< 1 mm²) is removed from the painting and placed in a clean glass, single depression microscope slide and covered with
Figure 1. Analysis methods plotted versus various binding media groups analyzed for at GCI.

<table>
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<tr>
<th>ANALYSIS METHOD</th>
<th>Oils</th>
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another slide. Care must be taken to eliminate any source of contamination which may give erroneous analysis results on the sample, such as fingerprints or gelatin capsules producing false oil or protein tests. Once the sample is returned to the lab, approximately one-third is embedded in a polyester medium. From the embedded sample, microtomed slices are taken for infrared analysis\(^3\), then the remainder of the block is used for SEM-EDS analysis and/or staining tests. The unembedded portion is used for other analysis methods, such as GC/MS or HPLC.

The first sample is from center main panel of a late 14th c. Tuscan triptych by Cenni di Francesco (J. Paul Getty Museum of Art, Aq. #71.PB.31). The analysis scheme combined the techniques of infrared microspectroscopy (IR), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) and gas chromatography/mass spectrometry (GC/MS) to determine the binding media in each of the paint layers.

Figure 2 shows a cross-section sample along with five infrared spectra from the sample. While only three paint layers are visually discernable, the method of linear mapping was applied to pick up compositional differences which were not visible with optical microscopy. This is a method in which a set analysis window is automatically or mechanically stepped across the sample in set increments\(^4\) and an infrared spectrum is collected at each position.

Infrared analysis indicates that all the layers contain a protein binder (1650, 1550, 1430 cm\(^{-1}\)). Additionally, the infrared spectrum for the bottom layer (ground:A) of the sample contains bands corresponding to gypsum (calcium sulfate dihydrate: 3545, 3410, 1620 and 1110 cm\(^{-1}\)) while the spectra for the middle layer (C) contain bands which correspond to calcium carbonate (1800, 1450 and 870 cm\(^{-1}\)). The spectrum for middle layer (C) also contains absorption bands which correspond to wax (2920, 2850 cm\(^{-1}\)). These bands are also found in lesser intensity in the spectrum for the adjacent layer (B). While the spectrum for layer B appears different than either A or C, close examination shows that it is a composite of the two (A and C) and not a distinct layer in itself.

The spectrum for the top red layer (E) in the sample contains bands which are associated with oil (2926, 2854 and 1745 cm\(^{-1}\)) which are not present in the spectrum for the dark brown proteinaceous layer (D) immediately below. It is not possible using infrared spectroscopy to determine whether the protein/oil combination found in the red layer is due to a mixture of the two materials or to the presence of egg yolk which naturally contains the two components. Thus, other analysis methods were used to provide supplemental information.

Using the same embedded cross-section, SEM-EDS analysis was done on several points in each of the layers.\(^5\) While SEM-EDS is usually used for the identification of inorganic pigments, our focus for these samples was to examine them for the presence of phosphorus. The presence of phosphorus in a protein binding medium is a strong indication that the binder contains either egg yolk or casein.\(^6\) Neither albumin or glue naturally contain phosphorus in amounts detectable by SEM-EDS. While bone black does contain phosphorus, it is not likely to be in these non-black samples. The results of the
Figure 2. Photo and infrared spectra for paint cross-section from Tuscan triptych by Cenni di Francesco.
analysis found that the lower two layers did not contain measurable amounts of phosphorus while the phosphorus band in the top layer was strong (shown in figure 3). This indicates that the top layer contains either egg or casein.

A separate non-embedded sample was then prepared for GC/MS analysis of the fatty acid composition of oils as well as for the detection of cholesterol. The fatty acid compositional analysis provides information on the source of the oils based on the proportion of the palmitic (P), stearic (S) and azelaic (A) acids. High amounts of azelaic acid relative to the amounts of palmitic and stearic acid are indicative of a drying oil while low amounts of azelaic acid are present in egg yolk. As shown in Figure 4, this sample contained low amounts of azelaic acid in proportion to the other acids. In addition, cholesterol was analyzed for and found which is a positive indicator that egg yolk is present.

Combining the results for all three methods, shows that the egg yolk (or whole egg) was used as a medium only in the top red paint layer. The protein binder in the bottom two layers, does not contain egg yolk or casein (from SEM-EDS) and thus is probably glue, since albumin does not make a good binder. Positive identification of this protein would require manually removing the red layer from the sample, then analyzing the remainder by amino acid analysis.

APPLICATION 2

Andrea Mantegna was an Italian artist in the late 15th and early 16th centuries. Numerous of his paintings have the very characteristic appearance of glue or distemper are on a fine quality linen and have a matte finish which was never meant to be varnished. This technique, called tuchlein, was popular in the Netherlands and Germany but had not been associated with any other Italian artists. In the advent of the Mantegna exhibit in London and New York, Andrea Rothe, Head painting conservator at the J. Paul Getty Museum, began a detailed investigation of techniques in Mantegna’s paintings and collected over 30 samples from 10 paintings for binding media analysis. We used FT-IR microscopy, SEM-EDS, GC/MS and HPLC analysis to characterized the components in these samples.

One exemplary cross-section of this type of technique came from the "Adoration of the Magi" (JPJM, Aq.# 85.PA.417). The infrared analysis consistently showed protein as the major component in all the paint layers. SEM-EDS analysis of the samples found that phosphorus was below the detection limit in each of the layers. GC/MS analysis of the sample was negative for cholesterol, but did find that wax was present in the sample. While the negative presence of phosphorus and cholesterol in a proteinaceous medium is a indicative that egg was not used as a binder, we went a step further and did HPLC analysis of the amino acids in the protein (Figure 5). Significant amounts of hydroxyproline (OH-PRO at 3.0 minutes) with a glycine peak (GLY at 4.7 minutes) that is approximately three times larger provided a strong indication that animal glue is present in the sample. Thus, all the techniques working together for the analysis of this set of samples were able to confirm that Mantegna produced several paintings using distemper as...
Figure 3. SEM-EDS spectra for three points (A: top red layer; B: Middle white layer; C: Bottom ground layer) on the paint cross-section sample from the Tuscan triptych by Cenni di Francesco. The SEM-EDS spectrum for dried egg yolk shows the strong phosphorus (P) peak in egg yolk which corresponds to the phosphorus in the spectrum for the top red paint layer.
Figure 4. GC (A) and GC/MS (B) analysis of a paint cross-section sample from the Tuscan triptych by Cenni di Francesco. The top chromatogram (A) shows the analysis of the fatty acid content of the sample, while bottom (B) total ion count chromatogram shows that cholesterol is present in the sample.
Figure 5. HPLC amino acid analysis of a sample from a painting by Mantegna. The presence of relatively large amounts of hydroxy-proline (OH-PRO) in the sample shows that it contains animal glue.
This same sample was also analyzed by a new method called infrared reflectance mapping. In this method, a polished embedded cross-section is placed in the infrared spectrophotometer and an analysis grid is selected (in this case, 10 x 15) with an automated X-Y stage (Figure 6 and 7). The spectra are collected by reflection of the infrared radiation off the surface of the sample. The beam passes through a rectangular aperture at a remote focal which isolates the area to be analyzed at each grid point. The effective resolution of the components in the sample is determined by the size of the analysis aperture and the density of the grid. The size of the aperture for the following analyses was 20 x 40 μm. The selection of size is a trade-off between resolution and energy throughput. The window was moved in approximately 20 μm steps. The overlap of the windows in the X direction provided an effective increase in the resolution of the components in that direction. Each spectrum is the sum of 50 scans which takes approximately 1 minute for collection and processing.

From this array of spectra, contour maps may be produced which provide information on the concentration and location of a material. This is done by selecting a wavelength of interest, such as a hydrocarbon band, and plotting its intensity versus its position in the grid where it was collected. This produces an area map of the intensity of that specific band which is plotted as a contour map where lines connect the areas of similar value. In these black and white plots variations in line thickness have been used to represent the changes in band intensity. The thickest lines correspond to the areas of strongest band intensity, i.e. highest concentration of the material. The intensities are relative to each other and the background intensity may not be zero due to other absorptions in the region. In these particular samples, because previous extensive analyses has been done to determine their components, the selected infrared absorption band and corresponding functional group can be related specifically to actual components in the sample. On other samples, it would be precarious to identify a material based on only one infrared absorption band.

Figure 8 shows a photomicrograph of the Mantegna sample along with four infrared reflectance maps. Map A is a plot for the carbonyl band at 1730 cm⁻¹. The bands is due to the polyester embedding media surrounding the sample and provides a general indication of the area analyzed. Also the absence of a carbonyl band in the region of the sample corresponds to the previous analyses which determined that the binder did not contain oil. Map B is a plot of the carbonate band from the 1416 cm⁻¹ region of the spectra. This indicates that the entire sample contains carbonates with the exception of the surrounding media and a central point in the second layer. Map C corresponds to sulfates or silicates in the region of 1092 cm⁻¹. The highest concentration of this material is in the third layer of the sample. Map D is a plot of the hydrocarbon band at 2919 cm⁻¹ which corresponds to the wax which was found in the sample by GC/MS. The infrared reflectance map indicates that highest concentration of the wax occurs in the first (bottom) layer of the sample. This may be due to the original mixture of the paint or to a later relining procedure.
Cross-section with analysis grid

Figure 6. Example diagram of grid selection for an infrared area map. The circles designate XY stage location for the center of an analysis aperture (example on right). The resolution of the components in the sample is directly related to the size of the aperture and the density of the grid.

Figure 7. Example graph of 225 spectra collected on a $15 \times 15$ grid with an aperture size of $20 \times 40 \text{ um}$.
Figure 8. Microphotograph and infrared reflectance contour maps for painting cross-section from "Adoration of the Magi" by Mantegna. Functional groups mapped are: A-Carbonyl band (1730 cm\(^{-1}\)); B-Carbonate band (1416 cm\(^{-1}\)); C-Sulfate band (1092 cm\(^{-1}\)); D-Hydrocarbon band (2919 cm\(^{-1}\)). The thickest lines correspond to the highest intensity absorptions.
Figure 9. Microphotograph and infrared reflectance contour maps for paint cross-section from "Allegory of Fortune" by Dosso Dossi. Functional groups mapped are: A-Carbonyl band (1725 cm⁻¹); B-Carbonate band (1424 cm⁻¹); C-Sulfate band (Gypsum: 1152 cm⁻¹); D-Hydrocarbon band (2927 cm⁻¹). The thickest lines correspond to the highest intensity absorptions.
Another example of infrared reflectance mapping is shown in Figure 9. The microphotograph of the paint cross-section is marked to illustrate the area of the sample which was analyzed. Map A is a plot for the carbonyl band at 1725 cm$^{-1}$ which again shows that the highest concentration is due to the polyester embedding media surrounding the sample. However, the area of the sample also has consistent level of intensity which is due to the adjacent carbonyl band for oil. Map B is a plot of the carbonate band from the 1416 cm$^{-1}$ region of the spectra. This indicates that upper layer of the sample has the highest intensity of carbonates which corresponds to the azurite in that region. The remainder of the sample also contains lead carbonate and some calcium carbonate in the second layer from the bottom. Map C is a plot of the sulfate or gypsum band in the region of 1152 cm$^{-1}$. The highest concentration of this material is in the first (bottom) layer of the sample. Map D is a plot of the hydrocarbon band at 2927 cm$^{-1}$ which corresponds to the dark green layer in the sample. The relationship of this band to an actual component in the sample has not yet been made.

The method of infrared reflectance mapping shows potential for the determination of materials and their locations within a cross-section sample. At this point, the method has two major limitations. The first limitation is the use of specular reflectance as an analysis method which places a minimum size of 20 x 20 μm on the analysis window due to energy restrictions. Specular reflection can also result in band distortions and shifts which are difficult to compensate. A new technique, which is soon to be tested, is called micro attenuated total reflectance and should eliminate these problems. The second limitation is that a material cannot be reliably identified based on one infrared absorption band. Thus, additional analyses are required to supplement the map and provide interpretation. Future computer programs should allow a map to be created based on the selection of multiple absorption bands which can help identify specific compounds.

CONCLUSION

Binding media can be complex mixture of materials and its identification is often hinder by the addition of pigments and the effects of time. The analysis of binding media requires several types of analysis methods. The information generated by the different methods can work together to provide a more complete picture of the sample. This paper illustrates the use of the multiple techniques to provide information on a paint sample. A new method for infrared reflectance mapping shows potential for characterizing materials and their location within a cross-section.

The GCI Binding Media Project is evaluating and optimizing several types of analysis methods for binding media. The collective results of this three year study will be published in a book in 1993. This will include a information on binding media chemistry, a historical summary of the use of binding media, a review of previously used techniques and a set of methods for currently optimized techniques of analysis. Many new techniques, and new focuses on old techniques will be presented.
ACKNOWLEDGEMENTS
The authors thank Frank Preusser for his support and encouragement of the binding media analysis program. We also thank Nathan Bower, Eric Doehne, Cecily Grzywacz, Andrew Parker, Michael Schilling and Harry Sobel for their contributions to the analytical results and development of methods mentioned in the paper. These scientists, along with Henry Florsheim, Herant Khanjian and Mary Striegel, have worked together as part of the GCI binding media analysis team.

BIBLIOGRAPHY


BRONZINO: MASTER OF MYSTERY
by Scott A. Heffley

Abstract: Bronzino's "Portrait of a Young Man" was evaluated technically and subsequently restored. Extensive scientific analysis revealed much about the artist's working technique. The most surprising discovery was that Bronzino painted three completely different versions of the sitter on top of one another in this 1550's Mannerist panel painting. The painting's first version shows the young man wearing armour; in the second version he wears a crimson tunic and in the final version the young man wears a deep purple doublet with cape, hat and sword (see illustrations below). Hand and arm changes accompany each version change, although only the final version was taken to a full level of development. X-ray radiography, infrared and ultraviolet imaging, paint cross sections, x-ray fluorescence, FTIR, and selected pigment analysis were used to decipher this complex painting structure.

Innovative use of painting materials by Bronzino probably resulted in the darkening of the deep purple doublet paint. Infrared analysis done by Michele Derrick and Dusan Stulik at the Getty Conservation Institute suggests that the media of the dark purple and crimson paints contain oil, protein and natural resin. This emulsion results in a strong autofluorescence under ultraviolet light and a dark, nearly opaque appearance under visible light (whether the protein is glue or egg remains undetermined at this time). Originally, the greater transparency of the medium would have revealed the richness and brightness of the purple color that Bronzino intended.

Paint cross sections reveal that a layer of glue was polished into the gesso surface as a final panel preparation. This would have provided Bronzino with a very smooth non-absorbent surface onto which he could create his marble-like images. Unfortunately, this has resulted in a somewhat poor bond between the paint and gesso. Loss of small paint flakes, a problem evident on other Bronzino paintings, may be traced to this studio technique. Identification of this feature in other Bronzino panels could help with authentication issues.
REWEAVING OF DAMAGE IN COLORFIELD PAINTINGS

Ronnee Barnett

This paper focuses on techniques I have used to reweave damaged areas within color field paintings, where there were no paint or priming materials on the canvas.

I was initially approached to do this task with the explanation that traditional methods used by painting conservators to repair holes and tears were not adequate in this type of painting, that the infills do not allow for a smooth transition from original to repair, and that there are visible seam lines. The feeling of the painting conservator was that perhaps actually reweaving directly into the canvas would be a remedy for the inadequacy of solutions to the problem at that point.

I preface this discussion with my feeling that I consider the work that I have done so far very much still in the experimental stage. And, to this point, I have always worked in conjunction with a painting conservator, as there are questions about how the painting will respond to my inserts considering the various unique stresses that paintings undergo.

I will be describing three treatments, two on separate paintings, and another on an experimental sampler.

Let me take a moment to point out to you a characteristic of the canvas of these paintings. Frequently in weavings, the warp threads are the straighter and sometimes stronger threads which are extended taut on a loom. It is this tautness and strength on which one depends around which to weave the perpendicular direction threads, the weft. And for the same reason, in reweaving one also tends to insert the warp threads first.

However, in the painting canvas I worked on it was the weft thread that was straighter and the warp threads wavy. In my reweaving, I had to insert the weft threads first in order to duplicate the appearance of the corresponding threads and get the tautness needed around which to weave the perpendicular threads. This was no problem, since the warp and weft threads appear to be identical in size in this #12 cotton canvas, which is what I worked on. The warp count (approximately 50 ends per inch) is greater than the weft could (approximately 36 ends per inch).

The next questions I considered were:

How to connect my new threads to the original,
How to get a smooth transition from original to new,
How to keep the original broken threads from unraveling any further,
How to achieve a tautness with my newly inserted threads around which I would then weave the perpendicular threads,
What method to use to create the least stress on the painting.

(photograph #1) The first example is of an area near the tacking edge of a painting. To be re woven was 1 inch of this 3-1/2 inch long tear, the remaining 2-1/2 inches of which would be hidden by the frame. It was 3/4 inches wide.

The long strands going north to south are the remaining warp threads before my work, some of which had to be replaced. The condition of the canvas surrounding this torn area was basically sound, and similar in texture to the rest of the painting. In a collaborative effort with the painting conservator and her staff, we arranged for me to have accessible unraveled threads from canvas of a similar gauge.
If you study the threads from this type of canvas, you can see that there are actually two threads twisted around each other. Two single strands of fiber are each loosely spun in one direction, then plied together in the opposite direction to make the thread. My idea was to separate the two threads at each end of the new two-ply threads replacing each horizontal row, so that I could continue weaving with a thinner thread at the point where it connected with the original.

To summarize the first technique, facing front, and starting from the right side of the tear, at the point of the uppermost missing horizontal thread, I took a complete new thread and duplicated the weave in the horizontal direction, that is weaving over and under each adjacent vertical thread, until I met up with the broken thread from the original of that line. I unplied the tail end of my new thread, twisted each thread while moist, dried them, and continued weaving with one of those threads. I did this for about an inch and kept the tail of this thread on the surface of the painting. The other thread from the untwisted two-ply floated behind the painting, was brought to the front at the same spot, and knotted at the ends. (You can see this at the point where there are colored threads also attached, which I did to help me later distinguish line from line.) This was repeated down the one side of the tear. I then began to insert my threads into the left side in the same way (photo #2)

Since the painting had been on the stretcher frame with this tear for some time, the canvas had begun to bow at the point of the damage, so that the warp and weft threads were no longer perpendicular to each other. It had been decided not to attempt to block the canvas before I worked on it, but I gently tried to adjust and work with this bowing while inserting my new threads into the second side by controlling the length of the new horizontal threads before they were connected with the painting.

Up to this point, I did this work with the painting under no tension, loosely lying on the table. Tension was not yet important.

Once I had done this for a short distance, I began to weave the wavier threads, the threads in this case in the vertical direction. In order to be able to do this, I had to extend the tails of my inserted threads taut. I stretched the unplied tails of my newly-inserted threads onto a board.

Some of the original vertical threads were still usable, and some had to be replaced. The method used to replace them was the same.

In the above case, the bowing affected the appearance of my reweave; I could not make my threads perfectly perpendicular and fill in the hole adequately. If it would not endanger the textile, initial blocking of the damaged area would help integrate the reweave.

Also, the reweave had a softer feel and was somewhat hairy looking. We had experimented with coating the threads with silicone, klucell, household starch, rabbit skin glue, but to the extent of our experimentation, none of these surfaces created a better texture with which to work, or could present potential problems like future discoloration or stretching.

As regards the reverse side, the newly-inserted thread ends were brought to the back, plied together, and then spread out spider web fashion to minimize the chance of bulging on the front.

Photo #3 is a closeup shot of how the reweave looks. This particular damage was easier than some of the others we tackled.

On another, a very fragile surface, I attached the new straighter threads very differently
from the first instance. In this case, which was a hole approximately 2-1/4 inches x 1 inch, I wanted to get as far away from the damage as possible and connect the new threads with healthier canvas in the original. The painting had been subjected to serious water damage and was dry, brittle, discolored, and badly abraded for several inches surrounding the hole.

I used a single thread at a time from unplied threads unraveled from new canvas, and inserted long floats behind the painting, attaching to the front approximately every half inch just overlapping one stitch. I would start from about 3 inches below the hole, leave a tail substantially long on the front, leave a 1/2 inch float behind the back, insert over one stitch on the front, repeating this to a total of three times. This was little enough for me to be able to adjust the tension later. The plan was that in the end I would insert these outer tails into the canvas a few more times, further into healthier parts of the painting once I had the proper tension.

I then attached the thread to the top of the hole in the same way. My new threads were extended beyond the periphery of the original hole. The edges of the hole were just too fragile to insert directly into.

Once I had inserted a new single thread into the weft line, I then inserted another single thread in the same line, for the purpose of attaining a two-ply thread in the hole, duplicating the original. I began in the same way but staggered where I brought the threads to the front to avoid creating a thickness on the surface of the painting where the new threads overlapped the original. When I reached the hole, I wrapped the second thread around the first one to duplicate the spins per inch (20) of the original (photo #4).

Particularly in the case of the weakened canvas fabric, I considered these reweaves to be attempts at cosmetic improvement only, and wondered and worried about whether in the future they would create new points of stress for the painting to tear further, or whether hopefully the choice of insertion of new threads was spread out enough to avoid encouraging further deterioration.

Photo #5 shows the back with all the floats.

This leads me to another issue to consider. In all of the reweaves, it was not considered appropriate to place a backing fabric behind the areas to be rewoven. It is my understanding that placing a small piece of fabric just behind the damaged area could eventually create an imprint of its outline onto the front of the painting. If, however, complementary backing fabric could be properly attached so that there is created an even distribution and transition of strength from this connection to the original, (particularly in a weakened area relative to the rest of the textile), I believe it would be worth experimenting to see whether this would create a safer reweave, meaning there would be less chance of eventually stressing the painting where the new threads are attached.

In this particular very difficult assignment, in general, the reweaving itself matched the original quite nicely, but to varying degrees, there was some change in plane where the original and new met. I mentioned that I overlapped my new threads over the periphery of the hole, but perhaps if the threads had been staggered more where they were inserted it might have helped with the transition from new to old. In certain lights the reweave was hard to detect from viewing distance; in others it was visible. Again, the rewoven area is a very small part of the painting.

In this situation, the work was done with the painting stretched out on a working frame, with the area just below the hole released from the work stretcher, as the extension would pull on the hole while the straight threads were being inserted.
When it was time to insert the horizontal threads, the working edges of the painting below this area were weighted down in a pouch.

There was a bowing problem with this painting as well, due to having been left on a stretcher with the hole for some time. Again, blocking was not done before working on the hole, and adjustments were made in the form of adding some rows while weaving in the perpendicular direction, but this condition was difficult to work with and adjust for.

Leaving this project, we experimented further for a while, attempting to simulate the types of damage to canvas and see what methods we might come up with that would be even better. One ideal was reached, but to my knowledge, still remains an ideal and cannot be attempted unless the canvas surrounding the damage is not weakened. I will interject here that although I have always worked with experimental samplers nearby to test and predict the effects of the developing techniques, I have found that it is difficult to actually duplicate the types of damage of the real thing, thereby ensuring more predictable results.

For this series of projects, we ended up using mercerized sewing thread for the threads inserted first, which was much easier to work with, being stronger and smoother to introduce into the original. This thread I inserted into the channels above and below the hole for about 1/4 inch, replacing line for line each missing weft thread. The one strand of sewing thread was to be the only item inserted into the original (photo #6).

The broken ends of the original vertical and horizontal threads that were being replaced were left in the back of the painting and coated with nonacidic polyvinyl emulsion. The canvas was stretched onto a stretcher frame, and as I inserted new threads for about a quarter inch, I then extended the thread around a pushpin attached to the stretcher frame, to get the tautness I would need to weave in the perpendicular direction. Then a small flat formica loom was made around which I strung a second level of thread, another strand of mercerized cotton. This was attached in such a way to the canvas so that, although these second threads were not inserted in any way into the original, they lined up with the sewing threads that were inserted into the original in order to achieve more thickness to the weft.

With both sets of threads, the inserted one and the ones strung around the formica loom, in line with one another, I then inserted new perpendicular thread, the wavy threads, following each missing line. The original broken horizontal threads were unraveled from the canvas in staggered amounts, sometimes 1/3 inch, sometimes as much as 1 inch, with the unraveled thread left loose in the back. I unraveled and replaced one line at a time. One new thread was used to replace each row, and great care was taken with each weave stitch to make it close in tension to the original.

Of all the reweaves, it had the smoothest transition from new to old. After being wetted and left to dry, it still has the smoothest plane and continues to remain flat and taut on the sample frame (photo #7).

From my experiences, I have learned that there is no one method that can be relied on as a solution to all problems, but rather a flexibility and compilation of techniques, like a variation on a theme, is necessary. I also believe a great deal more research needs to be done on the long-term compatibility of the reweave with the original.

I would like to acknowledge Margaret Watherston for her creativity in some mutual brainstorming during these projects. I also thank the kind and friendly colleagues (LaTasha Harris, Terence Mahon, Patsy Orlofsky, the entire Textile Conservation staff at the Met), who let me practice this talk on them, and provided invaluable input.
AN AID TO INPAINTING

Bettina Jessell and Mary Whitson

1. Introduction.

This paper describes a method of inpainting which has gradually evolved over the last twelve years. Although technically not a "painting" technique, since it uses color pencils, the aim is the same: the return of the paint layer, as closely as possible to its original appearance. The method does not replace traditional inpainting techniques, because it is limited in its application. It is an aid to inpainting, born from an increasing reluctance to burden the painting with much overpaint.

2. History.

Tudor and Jacobean painting tend to be in very bad condition. (Fig.1) The skin tones are mere translucent glazes, clearly revealing the elaborate underdrawing. In areas of losses, we found that a fine pencil is the best way to imitate this underdrawing, similar to the old method of using pencil to imitate the fine cracking patterns of old master paintings.

This led to the idea of restoring the often very abraded rigging on ship paintings with pencil, aided by the use of a ruler or flexible curves. (Fig.2) Pencil lines have one disadvantage: they tend to be too shiny. We discovered that color pencils do not have the same sheen. From there it was a short step to taking advantage of the many other desirable characteristics of color pencils as an inpainting method: water solubility (and therefore easy and total reversibility), a dry medium, a fine point where required, virtually zero mass when applied frugally and the surprising fact that the texture and characteristics of the original paint layer appear unchanged.

Color pencils are invaluable for paintings where the medium is such that they cannot be satisfactorily inpainted with traditional methods. True miniatures fall into this category, also paintings in gouache, pastel or chalk. Miniatures, for instance, can be destroyed by inpainting with a water-based paint, and other media leave a shine. Gouache, pastel and chalks turn permanently dark when touched with any liquid due to their dry, powdery texture. (Figs. 3 and 4).

3. Where to Use Blending.

The usefulness of blending falls into four major categories:

- Where the original paint layer is basically in good condition, but some passages have undergone a disturbing color change.
- Where the original paint layer has been injured.
- Where there are additions to the original paint layer which cannot be removed without endangering the original paint.
- Where the painter's technique is faulty in some respect.
4. Why We Use Blending.

We find that blending with color pencils is immensely useful in all cases mentioned here, where conventional methods burden the painting with layers of alien paint which frequently seems to us quite unacceptable. One is confronted with a choice of two evils: either covering a possibly large proportion of original paint, and so creating something which on occasion comes dangerously close to a forgery; or leaving the painting only partially inpainted, and so interfering with the painter's expression of color, form, space or movement. If the task of the conservator, as we believe, is to bring back the painter's intention, both these alternatives are unattractive. Using color pencils frequently offers a better way.

5. How to Blend.

We apply color pencils in a variety of ways, nearly always in thin layers. We mix colours, scumble if appropriate, moisten to a wash or apply dry. The layer is then spray-varnished to anchor it.

There are some problems: If the paint surface is too smooth, the color particles will not hold; there has to be some texture. Very dark colors cannot easily be achieved, for instance, it is difficult to match a really saturated black. (See appendix for characteristics of available color pencils). The final varnish has to be applied by a spray gun.


(a) Color Changes in Original Paint Layer: Staining, Blanching, Pentimenti. (Figs. 5 and 6)

In this category, the original paint layer is in good condition, but for one reason or another, passages have suffered a color change so that they no longer harmonize with the surrounding area. A light scumble with color pencils is amazingly effective, without covering the cracking pattern or other characteristic of the paint layer.

Pentimenti are an ethical problem, both paint layers being by the hand of the painter. We compromise with a color pencil layer slight enough for the first version to be visible from close to, but covering enough not to disturb the overall impression of the painting.

(b) Injuries to Original Paint Layer: Cracking, Abrasion and Overcleaning, Burn Damage. (Figs. 7, 8, 9 and 10)

A fine or medium cracking pattern which is too disturbing can be alleviated by covering the area with a layer of matching color pencil, rubbing it into the cracks, and then wiping it off the surface of the paint layer. Wider cracks usually need an additional application of traditional inpainting.

The inpainting of very abraded or overcleaned paint layers is often an example of too much alien paint. Such small but all-over losses can often be dealt with more tactfully with color pencils. (Figs. 4-7)

The brown singing and blistering of burnt areas is, as we all know, one of the worst problems facing a painting's conservator. We apply many thick layers of color pencils and rub them in well
Fig.1  Tudor panel with damaged underdrawing

Fig.2  Replacing lost rigging using flexible curve and color pencil

Fig.3  Gouache and chalk painting with serious losses

Fig.4  After color pencil inpainting
Fig. 5 Water staining in gouache on canvas painting

Fig. 6 After color pencil inpainting

Fig. 7 Serious abrasion on tempera panel

Fig. 8 After color pencil inpainting
in a not always completely successful attempt to bring back the color and smoothness of the original paint layer.

(c) Additions to the Original Paint Layer Which Cannot be Safely Removed: Deeply Ingrained Varnish, Residual Overpaint.

Old dark varnish which has sunk into the interstices of a heavy canvas and cannot be safely removed even with resin soaps can easily be made invisible by color pencil scumbling. The layer is dampened to form a watercolor layer which sinks into interstices. The surface is then polished with a slightly dampened cloth to remove all superfluous color from the top of the paint layer, leaving the color in the hollows.

Irremovable overpaint on paintings on canvas causes problems because it lacks the abraded look of the original paint layer. It can be made to harmonize very quickly by first inpainting in the right color if necessary, then holding a color pencil matching the color of the ground or underpaint parallel to the paint surface, and lightly touching the tops of the canvas threads to imitate abrasion.

(d) Problems Caused By Artist's Faulty Technique, as, for instance, Streaky, Grainy, or Spiky Grounds. (Figs. 11 and 12)

Many 19th century landscapes are disfigured by now deeply discoloured preliminary sizing having bled through the ground and paint layer. It can be scumbled out with color pencils more quickly and discreetly than with inpainting.

Very uneven grounds cause the wet paint layer to settle in the hollows, leaving a thinner layer on the heights, where the paint layer naturally abrades away. You find a snowstorm pattern on the grainy grounds, and light and dark bands on the streaky grounds. One could not, and would not wish to, inpaint the whole painting. With the snowstorm effect, holding a very sharp color pencil parallel to the picture plane and just hitting the tops of the ground is very successful. With the streaky pattern, the bands can be subdued by color pencils, usually applied in the hollows.

7. Color Pencils.

We have tried eighteen manufacturers' color pencils with varying success. Important considerations are, of course, color, degree of solubility, degree of shine or matness, and reversibility. See chart of characteristics below.

8. Conclusion.

It must be emphasized again that blending is not a substitute for inpainting, it is merely an aid in cases where inpainting is not desirable because it interferes too much with the painting. In fact, it is just one part of the new "minimal" thinking in painting conservation, by attempting to bring back the quality of the painting without overburdening it with alien paint.
Fig. 9  Abrasion of painting in oil on copper

Fig. 10  After color pencil inpainting

Fig. 11  Abrasion caused by ground texture

Fig. 12  After color pencil inpainting
<table>
<thead>
<tr>
<th>BRAND NAMES OF COLOR PENCILS</th>
<th>SPREADABILITY</th>
<th>REMARKS</th>
</tr>
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<tbody>
<tr>
<td>CARAN D'ACHE PRISMALO I</td>
<td>Medium High</td>
<td>Very good for all supports and media.</td>
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<tr>
<td>CARAN D'ACHE SUPRACOLOR I</td>
<td>Medium High</td>
<td>Useful. Too shiny for paper supports.</td>
</tr>
<tr>
<td>CARAN D'ACHE SUPRACOLOR II SOFT</td>
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<td>Useful. Too shiny for paper supports.</td>
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<tr>
<td>STAEDLER KARAT</td>
<td>Low High</td>
<td>Good for all media. Good deep black.</td>
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<tr>
<td>BEROL PRISMACOLOR</td>
<td>Low Low</td>
<td>Excellent range of skin and sky tones.</td>
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<tr>
<td>CONTE A PARIS PASTEL PENCIL</td>
<td>High Medium</td>
<td>Good for pastels, aqueous. Good blues.</td>
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<td>OTHHELLO</td>
<td>High Medium</td>
<td>Good for aqueous media.</td>
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<tr>
<td>REXEL CUMBERLAND DERWENT WATERCOLOR</td>
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<td>REXEL CUMBERLAND DERWENT STUDIO</td>
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<td>BEROL VERITHIN</td>
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<tr>
<td>REMBRANDT AQUARELLE</td>
<td>Medium Medium</td>
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**NOTE:** This list only contains brands that the authors are familiar with.
### CHOIX DES COULEURS

#### COLOUR AVAILABILITY

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<th>Shade</th>
<th>Notes</th>
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<td>Blanc</td>
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**COULEURS A LA LUMIERE**

- * resistance moderee / moderate resistance
- ** resistance forte / good resistance
- *** resistance excellente / excellent resistance
Authors
Bettina Jessell and Mary Whitson are private conservators working in a partnership (The Art Restoration Center) in Maryland and Virginia.

Bettina Jessell was trained by Helmut Ruhemann and has worked in England and the United States, and lately in Australia, mostly in private practice with interludes as a museum consultant. She has published numerous papers in the AIC and IIC Journals and has trained many interns.

Mary Whitson studied at Wellesley with a degree in Fine Arts from Barnard College. She apprenticed with a number of Washington area conservators before joining Bettina Jessell.
THE MECHANICAL BEHAVIOR OF ARTISTS' ACRYLIC PAINTS
WITH CHANGING TEMPERATURE AND RELATIVE HUMIDITY

J.D. Erlebacher, M.F. Mecklenburg, C.S. Tumosa
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ABSTRACT

Acrylic paints are commonly found in modern art. The mechanical properties of strength, modulus, and ability to elongate of a large sampling of artists' acrylic paints were studied in the temperature range of -8° C to 33° C, and from 5% to 50% relative humidity (RH). Data derived from the stress-strain curves suggests that acrylic paints lose the ability to plastically deform in response to applied force below temperatures of 5° C at 50% RH, and below 11° C at 5% RH. The brittle behavior of acrylic paints below these temperatures suggests a glass transition temperature that is RH dependent.

INTRODUCTION

Acrylic paints have been commonly found in modern art since their introduction slightly over fifty years ago. The widespread use of these paints makes the chemical and mechanical properties of acrylic paints important to study so that one can avoid conditions that might make paintings using these paints prone to damage from impact or vibration.1

Acrylic paints are polymer emulsions in water. Pigment particles, or dyes bound to transparent carriers, are suspended in the emulsion. The most commonly used emulsion in contemporary acrylic paints is a copolymer of methyl methacrylate and ethyl acrylate marketed under the brand name Rhoplex AC-3 or Rhoplex AC-34.2 The properties of artists' paints can differ significantly from industrially used paints because, in general, they have larger pigment to volume concentrations (PVC). The properties of the acrylic polymer emulsions may also be altered by the addition of dryers, plasticizers, and fillers by individual manufacturers.

The dynamic mechanical properties of acrylic paints were studied in a temperature range from -8° C to 33° C and in a relative humidity (RH) range from 5% RH to 90% RH. These properties are useful in the analyzing the risk of transporting and handling modern acrylic paintings. The research indicates that the risks at certain environments can be considerable.

EXPERIMENTAL

The mechanical properties of strength, modulus, and ability to stretch of artists' acrylic paints were found through tensile testing in sealed environmental chambers. The paint test samples were 10-12 years old. The strength of a material is the magnitude
of stress required to break it. The modulus of a material is a measure of its stiffness. The stretch or strain is a measure of the materials ability to deform prior to breaking. If a material has an increasing stiffness and a decreasing ability to stretch when loaded, it is said to become increasingly brittle. Relative humidity was maintained for each testing chamber by buffering the environment with conditioned silica gel. Loading rates ranged from 0.001 to 0.01 in/in/sec. and these are in the range of rates commonly experienced by art objects during transit or handling.

THE EFFECT OF RELATIVE HUMIDITY OF THE MECHANICAL PROPERTIES OF ACRYLIC PAINTS AT 23°C

Figures 1 and 2 show the relative strength and stiffness of nine acrylic paints at 5% RH and 50% RH, at 23°C. At 5% RH all acrylic paints were found to be significantly stiffer and stronger. Figure 3 shows the comparative ability of acrylic paints to stretch at 5% RH and at 50% RH. Acrylic paints, in general, are much more flexible than other commonly used artists' paints. For example, traditional artists' oil paints are rarely able to stretch over 10% under the ambient conditions of 23°C, 50% RH. All tested acrylic paints, however, were able to stretch over 50% at 50% RH, and four of nine tested types of acrylic paint stretched well over 200%.

![Figure 1. Strength of acrylic paint at 23°C.](image1)

![Figure 2. Stiffness of acrylic paint at 23°C.](image2)

![Figure 3. Ability of acrylic paints to stretch at 23°C.](image3)
At 5% RH there is a dramatic loss of the acrylic paint's ability to stretch at 5% RH when compared to 50% RH. This trend is dramatically exemplified by an acrylic titanium white that stretched 255% at 50% RH, with strength and modulus of 820 psi and 21,000 psi respectively. At 5% RH this same paint stretched only 40%, but had correspondingly large increases in strength and stiffness to 1900 psi and 140,000 psi. While it is important that the acrylics are getting stronger with desiccation, the loss of their ability to deform demonstrates their trend to glass like behavior. This should be taken as an indication of probable damage resulting from impacts, both on their edge and on their surface.

THE EFFECTS OF TEMPERATURE ON THE MECHANICAL PROPERTIES OF ACRYLIC PAINTS AT 5% RH AND AT 50% RH

Temperature can have an even greater effect on the mechanical properties of artist materials than relative humidity. The strength and stiffness of acrylic paints was found to be higher at lower temperatures than at 23° C. Figures 4 and 5 show the variation in strength with temperature at 50% RH and 5% RH. At temperatures below 5° at 5% RH and below 11° C at 50% RH many of the acrylic paints exhibited only elastic deformation, deforming nearly linearly until failure.

At lower temperatures, below approximately -1.5° C at 50% RH, and below 5° C at 5% RH acrylic paints often seemed to break early, failures were often catastrophic, with samples shattering into multiple pieces. These observations indicate that at low temperatures acrylic paints may become fracture sensitive, that is, rather than distributing stress evenly across the volume of the sample, the stress is concentrated around impurities or defects within the sample. Multiple areas with stress concentrations greater than the materials' strength can lead to multiple failure points.

Figures 6 and 7 show the variation in stiffness (modulus) with temperature of acrylic paints at 50% RH and at 5% RH. At 50% RH, the modulus of acrylic paints is relatively constant between 15° C and 23° C, and drops to zero near 33° C. As temperatures drop below 15° C, the stiffness of acrylic paints rises rapidly. At 5% RH, the modulus begins to rise at the same rapid rate beginning near 23° C. Referring to Figures 4 and 5, it is seen that these rises in modulus are accompanied by similar rises in strength under 15° C at 50% RH, and under 23° C at 5% RH.

Larger strengths and stiffnesses in acrylic paints at low temperatures are accompanied by their decreased ability to stretch, shown in Figure 8. At temperatures of 5° C at 50% RH, and of 11° C at 5% RH, some types of acrylic paints are brittle. By brittle is meant that acrylic paint samples showed no plastic deformation before failure. When brittle, acrylic paints generally stretched less than only 1% before breaking. All the acrylic paints tested were brittle below -1.4° C at 50% RH and 5° C at 5% RH, the same temperatures at which fracture sensitivity was seen for certain
types of acrylic paint.

Figure 4. The strength of acrylic paints at 50% RH.

Figure 5. The strength of acrylic paints at 5% RH.

Figure 6. The stiffness of acrylic paints at 50% RH.

Figure 7. The stiffness of acrylic paints at 5% RH.
The examination of the temperature at which acrylic paints become brittle may be an examination of the glass transition temperature \( T_g \) in mechanical rather than thermal terms. In fact, the \( T_g \) of both Rhoplex AC-33 and Rhoplex AC-34 is calculated to be about 9° C. Both of these \( T_g \)'s are near the measured temperature at which acrylic paints are brittle. The addition of plasticizers to a polymeric system is thought in most cases to lower the \( T_g \). The temperature at which acrylic paints are brittle at 5% RH, \( \approx 5° \) C, is less than the calculated \( T_g \) for the co-polymers, possibly due to the addition of plasticizers by the manufacturers. The \( T_g \) of Ivory Black acrylic and cobalt Blue acrylic as measured by differential scanning calorimetry (DSC) was found to be 4.7 and 5.5 °C respectively.

The results indicate that acrylic paints become brittle at higher temperatures in low RH environments than at 50% RH. This suggests that the addition of atmospheric water to the environment of the acrylic paint samples (which may be considered thin films) lowers the \( T_g \) of these samples from approximately 5° C to -1.5° C. In this case, water is acting as a plasticizer. This type of phenomenon is found in many polar polymeric systems, nylon being an example.

CONCLUSION

Acrylic paints were found to be significantly stronger and stiffer at 5% RH than at 50% RH, at 23° C. Although the ability of acrylic paints to stretch at 5% RH is less than at 50% RH, all
tested samples still stretched over 20% of their original length at 5% RH.

The modulus and strength of acrylic paints rise with decreasing temperature. At 50% some acrylic paints became brittle at 5° C, and all acrylic paint types were brittle below -1.4° C. At 5% RH, some acrylic paint types became brittle at 11° C, and all had become brittle below 5° C.

Correlation of the brittleness of acrylic paints with the $T_g$ of acrylic paints perhaps indicates that acrylic paints pass through a $T_g$ near 5° at 50% RH and 10° C at 5% RH. Atmospheric water would then be acting like a plasticizer and would lower the $T_g$.

The test results indicate that temperature and relative humidity play a more important part in the behavior of acrylic paintings and painted objects than previously believed. Low temperatures, especially, may be hazardous environments during the transportation of acrylic painted objects.

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The authors would like to thank Dr. Mary Baker for measuring the glass transition temperatures of the acrylic paints by DSC and Mr. Eric Brown for performing some of the stress-strain curves.

REFERENCES


Nineteenth Century Academy Boards and Canvas Boards:  
A Re-evaluation  

Alexander Katlan

This paper will attempt to clarify our understanding of academy boards and canvas boards, as great confusion exists with these supports, especially in trying to define exactly when they were invented. Fifty years ago in 1942, Rutherford Gettens and George Stout published their monumental work Paintings Materials A Short Encyclopaedia. This book is a wonderful reference source which many of us have used and still use today. However, it is like a musical instrument that has fallen slightly out of harmony due to lack of review. It is not inappropriate to do some slight revision, specifically to the section "Academy Board and Canvas Board."  

When George Stout wrote this section, he based much of his research on personal correspondence "...with several of the older artist's supply dealers in England, the Continent, and this country."  

The published literature states, "Reeves & Son, Ltd. and Winsor & Newton Company Ltd., London, first listed this board (academy boards) in 1850. The records of George Rowney and Company Ltd., London, carry it (academy boards) back as far as 1852. When it reach the continent cannot be stated exactly. The old firm of Lefranc in Paris, founded in 1775, has no records concerning it. It was manufactured in America by E. H. & A. C. Friedrichs Company, New York, in 1868."  

The statement here is that academy boards were introduced in England ca. 1850 and in the United States by ca. 1868. The published literature is inaccurate. My research shows that the academy boards were available from Winsor & Newton as early as 1835, and were probably available when the company was founded in 1832. It probably can be stated that academy boards were available in England at the turn of the century and definitely by the late second decade.  

Although it is true that in the United States academy boards were manufactured by Ernest H. Friedrichs Co. in 1868, the firm was founded in 1868 and only began advertising in the city directories in 1870, while the E. H. & A. C. Friedrich Co. of New York mentioned in the Stout text did not come into existence until after 1900. More importantly, other American colormen firms offered academy boards to American artists at a much earlier date.  

The Edward Dechaux catalogue of 1860 lists this board although the ca. 1840 catalogue does not list it. The early Goupil & Co. catalogues of 1854 and 1857 also list academy boards, the source being from Winsor & Newton of London. They are also listed in the early William Schaus catalogues of the 1850's with no source given.  

As its name implies, academy boards were an inexpensive, thin flexible support, created to be used by schools, academies, or universities, for use by students (and not originally by the professional artist) for quick oil sketches and studies. Its popularity arose as the art curriculum began to be included in the educational programs of the academies. It was a cheaper, disposable alternative for an oil painting support than prestretched canvas or wooden panels. It was probably composed of pulp board and coated with a thick priming on the surface, generally a pale gray or white ground of lead pigments to stiffen the board. In most cases it was coated on the back with the same gray priming. Pulp boards were a variety of thick cardboard of inexpensive grade, made of pulp rolled into sheets, as opposed to pasteboards, which are formed by pasting sheets together.
This difference in structure (from millboards) explains why academy boards were initially limited to smaller sizes and rarely offered in a variety of thicknesses. As previously mentioned, by mid-century "extra sizes" or larger sizes were commonly being offered, 22 x 27 and 23 x 30 inches. According to the Winsor & Newton catalogues, academy boards were "for studies," not finished paintings, and were available in only two sizes, 24 x 19 inches and in "half size" (9-1/2 x 12). In many cases the "half size" was simply a 24 x 19 board cut down upon request. This explains why many labels on the back of the boards are cut. This is an important point, as it explains why many of these boards have no labels or markings, as the artist or colorman firm could simply cut down larger boards to whatever size was desired, just as one cuts down a piece of cardboard today. Initially in the early 1800's these boards were thin, although by the 1850's they had thickened, called "stout," making it harder to distinguish between millboards.\(^7\)

I believe that the American colorman firms purposely blurred this distinction in order to offer academy boards at higher prices. Initially they were sold per dozen, as seen in the 1857 catalogue of Goupil & Co. By the 1890's academy boards were being sold individually, although still in limited sizes, from such geographically diverse firms as Frost & Adams of Boston, and A. H. Abbott of Chicago.

Academy boards were widely accepted by the professional artist with the increasing popularity of on-site oil sketching. However, the professional artist began to notice problems with the support. With the heavy layering of the preparation and a heavy layering of oil paint, the thin paper board tended to warp and sometimes even twist. Mechanical damages and dents easily caused the thick preparation layers to crack and flake, and thus the reasoning for coating the back of the board in an attempt to thicken and stiffen the board. However, there was no consistency from American manufacturers in coating the back of the board. Because of these problems, by the end of the century, academy boards were gradually being replaced by canvas boards. In fact, Winsor & Newton's London-Oil Sketching Board (a canvas board) was advertised as "superior to academy boards."\(^8\)

Similar confusion exists about the invention of canvas boards. This interest in the texturization of the board surface explains the development of canvas boards, i.e., to achieve a canvas weave on a board. Previously published literature states, "Canvas Board, a paper board with primed canvas fastened to one face, was put on the market by George Rowney & Co., Ltd. in 1884. C. Roberson & Co. Ltd. think it was introduced in 1875 and 1880."\(^9\) This published literature is also inaccurate. Although it is possible that canvas boards were introduced in England in ca. 1875-80, in the United States there are indications that canvas boards were introduced at a much earlier date. This confusion about the dating is probably due to the great popularity of the American Russel canvas board which was widely marketed by Frederick Weber & Co. of Philadelphia in 1879.

However, on August 25, 1863, a good fifteen years before Rowney catalogue listings, and before the "Russell Board," Albert G. Collins of Washington, DC patented an "improvement in painter's panels," No. 39,632. This patent consisted of the application of canvas to pasteboard in order to prevent the panel from "warping, cracking or wrinkling." Obviously by 1863 academy boards were beginning to exhibit warping problems recognizably due to the thinness of the cardboard supports and the hygroscopic glue sizing. Mr. Collins states, "...I take a heavy pasteboard...saturate it with linseed or other drying vegetable oil, with brush or otherwise. I then paint the board with white lead or Spanish whiting as thick as ordinary paste. I then cover the board with canvas--cotton is preferable--while the paint is yet wet. The first side is covered with a piece of canvas exactly the dimensions of the board or panel, and the opposite side is to be covered by a piece of canvas an inch larger than the board all round, so as to lap over upon a wet surface of white lead. Both sides of the board thus enveloped are to be painted, as before, with white lead or Spanish whiting and rubbed
with pumice stone and a spatula or trowel, in order to form an enamel.\textsuperscript{10} The Collins patent relates more to a smooth surface panel, imitative of an Academy board, than the later texturized canvas boards that we are more familiar with. It is unclear why cotton is preferable other than the supposition that linen or hemp fabric might be too strong and cause a thin paperboard to warp more rapidly.

The "Russell Canvas Board" was first patented on March 18, 1879, and assigned for marketing first to John W. Sheperd and later to the firm of Frederick Weber & Co., as stated above. The Russell patent differed from the Collins in that it "consists in first pasting canvas or other suitable textile fabric to strawboard or other pasteboard, then drying the same under pressure, then painting the surface of the tablet with any desired pigment, and finally stippling the same to form a grain...."\textsuperscript{11} This patent indicates that by 1879 in the American market a precolored (pretoned) and texturized surface was beginning to be applied to panels. On the one Russell canvas board that I have personally examined, the back is covered with canvas and red paint. The front surface is covered with a slightly texturized gray surface. The extensive popularity of this board can be found in the numerous trade catalogues that sold the Russell board, such as in the C. S. Samuel catalogue of 1890, A. Sartorius catalogue of 1890-94, and the A. H. Abbott catalogue of 1900. The Frost & Adams catalogue of Boston in 1895 describes the Russell board as "very desirable for outdoor sketching," while F. Weber in 1929 says it is for "outdoor sketching as well as studio painting." A. H. Abbott simply states, "it is prepared Linen on Heavy Board."

Numerous imitators of the Russell board began almost immediately. Winsor & Newton in 1884 advertises "canvas boards," while George Rowney in 1892 catalogue describes their boards as "a neat and portable form." The James Newman firm of London in 1910 describes their board as, "Best quality millboards covered with prepared canvas." Interestingly, S. & H. Goldberg of New York (successors to A. Sussman) advertises a canvas board in 1884; however, it is unclear whether this board is of their own manufacture or a Russell board.

In summation, it can be stated that academy boards were available in England definitely by the late second decade, a good twenty years before the Gettens & Stout listing, and that canvas boards were an American invention dated to 1863, fifteen years before the Stout listing.
Figure 1: Winsor & Newton Catalogue, ca. 1835.

Figure 2: Collins' Patent

2. Ibid.

3. Ibid.


UPDATE: CONTINUING RESEARCH AND TECHNICAL ANALYSIS OF PAINTED TEXTILES
Nancy R. Pollak, Getty Advanced Intern in Painting

As part of a Getty Advanced Internship in Painting at The Williamstown Regional Art Conservation Laboratory, the author is undertaking special research on painted textiles. This paper briefly outlines research plans and the present state of the project.

Firstly, to define the topic: what is a painted textile and why study it? The techniques and materials of traditional paintings have been studied extensively and are documented through a rich body of literature. For decorative and utilitarian textiles, a well-documented history of manufacturing techniques and materials also exists. Textile meets painting in documented examples such as Chinese painted silks, thangkas, theorem paintings and mourning pictures. Other perhaps less well-known objects also fall under the heading of painted textile, such as decorative fabrics, window shades, painted silk fans and flags and banners. While there are many examples of these types of painted textiles, a corresponding body of literature describing techniques and materials does not exist. However, through a combination of secondary resources and study of the objects themselves, a greater understanding of the construction of these objects can be achieved.

Present research is focused on objects, in which the textile is not restrained as in traditional paintings, and the painted design forms an appreciable thickness on the surface of the textile. With this definition of painted textiles as a framework, perhaps one of the largest and most accessible groups of such objects is painted flags and banners. Military flags, political banners, fireman’s and organization’s parade banners are historically important objects that have been saved throughout American history. Many states have well-documented collections of military flags, and practically any historical society has at least one important painted textile. While the maker of such an object may be known, records do not give details on materials or techniques of manufacture.

The long-term goal of the research is to create a data base of materials and techniques used in these painted textiles which combines analysis of objects with historical references. The initial phase of the research has two priorities: to compile a comprehensive bibliography of literature pertaining to painted textiles, and to determine appropriate analytical techniques for the unusual compositions of materials found in painted textiles.

To gather information, a survey was sent to randomly selected painting and textile conservators. The responses provided important sources of bibliographical information, the location of some collections which include painted textiles, and the names of conservators who have worked with these materials. Using information from the surveys and bibliographic data searches, a bibliography of painted textile references is presently being compiled. Predominately, literature concerns the history of painted flags and banners from the viewpoint of their use, such as books chronicling political history, or volumes on flags belonging to a specific military unit. Period handbooks and ladies home books have also provided related information, such as recipes for waterproofing fabric. Conservation articles primarily offer information on the treatment and examination of specific painted textiles. Hopefully, with the continuation of interdisciplinary programs such as the joint painting and textile session at the 1991 AIC Meeting, conservation literature in this area will grow.

The second aspect of the research will identify the most practical methods of sample preparation and analysis for determining layer structure and materials used to create these painted textiles. Just as cross-sectional analysis is used to unpack the layers of a painting’s surface to study technique and treatment history, analysis of painted textiles can unpack the construction sequence of these complex objects, can aid in identifying materials, and can document treatment histories. Among the questions that can be addressed, cross-sectional analysis may aid in determining if the fabric was sized or a

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ground layer was applied before the paint layer, if multiple paint layers are present and whether similarities exist between the paint medium and the size used for gilded areas. Since both fine artists and sign or coach painters decorated flags and banners, medium analysis may also indicate if the training of the painter made a difference in the artist's choice of materials. Historically, these questions not only offer insight into how the piece was made, but also may indicate if certain embellishments, such as battle honors, were applied when the flag was made or after the flag was in use. Looking at the textile, cross-sections also serve to confirm fiber identification, and in the case of a completely painted textile, could aid in determining thread count and weave structure, both of the original textile and subsequent backing layers.

While much of the analytical techniques for painted textiles can be adapted from methods used to analyze cross-sections of traditional paintings, the unique construction and materials of painted textiles, particularly those that have been extensively restored, require some adaptation of preparation techniques in order to gain the maximum information from a sample. Generally, painted textiles provide ready opportunities for sampling. This is often a result of piercing from previous treatments, or from aging, use, or furled storage. While some fragments are so small that they are suitable for mounting as is, other fragments are too large to be permanently mounted intact, and a smaller sample must be removed for mounting. The often brittle nature of the paint film and the fabric can make the removal of a microscopic sample difficult. In these cases, a small corner of a large fragment can be mounted, and when the mounting medium has cured, the bulk of the fragment can be removed. This guarantees that a small sample will be mounted with all its representative layers intact. Other techniques for handling large fragments includes the use of a temporary padded support to hold the fragment while one edge is cut on a microtome to render a flat plane suitable for examination. In this technique, only a few microns of material have to be removed from the fragment, and after examination, the entire fragment can be returned to the object practically intact. Visible and ultraviolet light examination and related staining techniques can be used in analyzing these samples. Methods of preparing thin section samples for other types of media analysis are also being investigated.

After bibliographic information has been compiled and techniques have been established for sample preparation and analysis, a long-term program of research can begin with analysis of historic painted textiles and indepth research on documentation concerning specific artists or objects. As photodocumentation of objects and cross-sections is accumulated, it can be combined with written resources to document the materials and techniques that have been used in these painted textiles. Information concerning painted textiles, as well as comments or suggestions are welcome as the project is developed. The author would like to thank those who responded to the survey, as well as the staff at Williamstown, for their help and suggestions.
THE IDENTIFICATION OF SUPPORT INDUCED DISCOLORATION IN ACRYLIC MEDIA

Ben Gavett and Jim Hayes, Golden Artist Colors, Inc.

Water based acrylic paints and media have been in use for almost 40 years. Since their introduction, there have been sporadic reports of discoloration, particularly in works using the unpigmented acrylic gel or fluid mediums for coatings, adhesives, or texturing. These cases were often attributed to atmospheric pollution or something inherent to the medium itself. However, when we observed rapid discoloration of test pieces in our laboratory, we were able to rule out atmospheric pollution. And our collection of free film castings of the acrylic resins we use did not support a possibility of the acrylic itself being the culprit. Lack of a good explanation prompted a series of investigations to determine the cause of the problem.

An initial test was designed to isolate component(s) which might be responsible for discoloration observed in a clear medium. Numerous variations of the formula were produced and the test batches were applied to cotton canvas. Results revealed the discoloration occurred even when everything except acrylic dispersion was deleted from the formulation.

Another study used an accelerated weathering tester to subject raw acrylic dispersions, as well as different brands of clear and matte mediums, to a combination of ultraviolet radiation and heat. The result was significant discoloration. In subsequent tests, the addition of Ultra Violet Light Stabilizers to the gels demonstrated excellent effectiveness in preventing UV induced discoloration.

However, the realization soon followed that under certain ambient conditions, the materials were still discoloring. To compound matters, the color change was greater than that experienced in the accelerated test. Antioxidants were then tested, without success.

Finally, in March of 1990, gels applied to glass were compared with identical gels applied to canvas. Although the storage conditions were slightly different, the astonishing amount of discoloration observed with the canvas indicated that the true cause for most of the discoloration was probably due to the support. A simple test designed to eliminate the variable of storage conditions, in which identical gels were applied side-by-side on cotton canvas, with one isolated with release paper, quickly confirmed this. The cause of discoloration was the moisture from the drying gel soaking the support, allowing contaminants to migrate from it. Subsequent tests have revealed that using even four or five coats of some gessos will not prevent Support Induced Discoloration.

Focus then shifted to exploring different factors associated with S.I.D. It was found that the discoloration occurs during the drying phase, which lasted from a few days to several weeks, depending upon the thickness the medium was applied. The amount of discoloration occurring during this relatively brief period was found to be largely dependent upon the composition of the support. Different cottons, linens, wood-based boards and polyester behaved differently from one another, but each one affected different brands of gel similarly. The polyester canvas evaluated exhibited little, if any, discoloration.

While effective restoration techniques were not identified, there are measures available to prevent the problem. Washing or scouring the support prior to use effectively reduced the amount of subsequent discoloration. In addition to the type of support used, its source can make a big difference. Also, some primers effectively isolate the support, preventing migration of contaminants into the media. If the materials and techniques to be employed by the artist suggest the potential for S.I.D., simple mockups can help determine what preventative measures, if any, would be needed.

1 Hamm, Gavett, et al., "The Discoloration of Acrylic Dispersion Media", Saving the Twentieth Century, CCI 1991 Symposium Postprints
"It'll Be Right Mate"
A Mobile Art Conservation Laboratory Service in Australia

Gayle S. Clements*

Summary - The Australian art conservation mobile laboratory program known as "Conservation On The Move" has an ongoing history. The organization responsible for the Australian mobile art conservation program was Regional Galleries Association of New South Wales. This organization staffed the mobile laboratory through a Skills Exchange Program which proved to be advantageous. Choice of the laboratory's itineraries depended upon the needs of the collections and available funding. General laboratory specifications provided here in this article will describe how the laboratory operated. Arrangements are being made for the art conservation mobile laboratory to serve the west coast of Australia.

HISTORY

The mobile art conservation laboratory known as "Conservation On The Move" was initially part of the first phase of the Australian Bicentennial project. In 1980, the Regional Galleries Association of New South Wales received funding from the Division of Cultural Activities and the Visual Arts Board of the Australian Council to employ a Curator of Conservation to oversee the art conservation mobile operation.

The Regional Galleries Association of New South Wales was founded in 1973 by fifteen local government councils and incorporated in 1981. It promotes the development of public art galleries and museums, by assisting with collections management, including conservation, exhibition, and documentation services for works of art. Of its 34 members, 27 have public art galleries.

The Association is run by an annually elected board of directors representing local government and independent cultural organizations in the state of New South Wales. It employs professional staff to manage services covering aspects of arts management, funding, design, and professional development. Association staff positions include an executive director, secretary/administrator,

exhibitions and special projects officer, senior conservator, paper conservator, and a paintings conservator.

The Association also adopted a multi-phased conservation program for the member galleries in the State of New South Wales. The conservation program began with an evaluation of collections for each member gallery. In this initial phase, storage facilities were assessed, disaster plans implemented, exhibition and handling procedures reviewed, and environmental controls measured, followed by advice for achieving optimum performance. The second phase entailed a more in-depth, detailed survey of each collection, with works prioritized according to immediacy of treatment needs. Phase three involved equipment purchases for use on the mobile laboratory as well as for the home base facilities at the Art Gallery of New South Wales. In phase four, treatment commenced on the major artworks for all member galleries in the region.

In 1983, after submitting an economic feasibility study, the Regional Galleries Association obtained funding for a mobile conservation laboratory from the New South Wales Council of the Australian Bicentennial Authority. The proposal was supported by studies of regional conservation centers in England, Canada, and the United States.

In October 1985, "Conservation On The Move" commenced operation. The Australian Society of Archivists, the Libraries Association of Australia, the Museums Association of Australia, and the Institute for the Conservation of Cultural Material formed a financial relationship with the National Australia Bank. "Conservation on the Move" provided on-site treatment facilities for paintings, works of art on paper, sculptures, and decorative art. Workshops, seminars, and clinic days were also conducted. The program operated also as an outreach service with an on-site operation that identified artworks needing major conservation treatment. Artworks were then referred to the home-base laboratory at the Art Gallery of New South Wales. Minor treatments were performed on the mobile laboratory. Other functions of the mobile unit included promoting the importance of conservation and educating regional gallery staff about conservation ethics. In order to allow rural galleries with limited funding to request services in remote outback areas such as Broken Hill, the usual fee structure was subsidized to a rate of up to 50%. For many galleries, using the mobile laboratory was a venture that required planning and saving funds

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for years, even though services offered were considerably below cost.

STAFFING

The Association contracted conservators to work ten months out of the year. Since it was difficult to find conservators willing to travel to a different site each month, the Association initiated a Skills Transfer Program enabling conservators from overseas to go to Australia to work on the mobile laboratory. This ensured both that Australian conservation standards would meet international requirements and also that techniques and procedures would be shared with the Art Gallery of New South Wales conservation staff. During the period 1987-1991, five conservators from Australia, Scotland, England, and the United States worked on the mobile laboratory.

ITINERARIES

Venues were chosen according to the demands of each collection and availability of funds. Because each site visit usually lasted a month, it was necessary to quickly prioritize the collection's needs. The conservators worked with each Director and museum staff to improve storage, implement disaster plans, critique environmental controls, and upgrade exhibition standards. Artworks selected for treatment were documented with photography and written records. The conservators also gave educational workshops for museum patrons, local artists, and museum staff. Since the mobile laboratory did not have living quarters, staff were housed in local hotels, motels, and caravan parks.

LABORATORY SPECIFICATIONS

The mobile laboratory was constructed by Special Purpose Vehicles PTY. LTD. of Lidcombe, N.S.W., Australia. It consisted of a 40'x 8'x 8' pantechnicon structure, fully equipped and outfitted with a photographic studio, office space, a paper conservation laboratory and a paintings conservation laboratory. It was permanently attached to a trailer equipped with air cushion suspension. The laboratory was constructed of lightweight non-flammable materials, and was insulated to reduce heat gain and loss. Entrances were located on the laboratory's left side and rear. The rear doors were constructed of plexiglass to allow the entry of daylight into the paintings conservation area. The rear doors allowed a painting of up to 2 meters height to enter without difficulty. All entrances were secured with
tamper-proof locks. The main entrance at the rear was secured with outer metal doors. A motion detection system with a battery backup power source provided security.

The floor was covered with a non-slip, solvent resistant material that enabled easy cleanup. Reverse cycle air conditioning was used to maintain a constant environment within the laboratory work space. Power was usually supplied by each site to operate air conditioning, extraction facilities, and lab equipment. A gasoline powered AC generator was also capable of supplying the lab's main electrical requirements as a backup. Water was stored in tanks under the chassis and supplied after filtering via a small pump. A backup water tank was also provided for locations that did not have a convenient supply. Hot water was removed by means of a hose connected to a drain. Solvents were stored in small amounts under the fume cabinet and vented through the cabinet to the outside.

General lighting was provided throughout the laboratory by skylights and side windows. The latter were blacked out with Venetian blinds during photography. Daylight fluorescent and incandescent spotlights were installed for color matching during inpainting. Blacklight fluorescent tubes mounted on stands were secured to the laboratory's walls for ultraviolet examinations.

Darkroom facilities were located at the front end of the laboratory, which had no windows. The area was outfitted with a long, shallow sink, bench space, an enlarger, a refrigerator, and a safelight. A light-proof exhaust fan removed photographic chemical fumes.

A temporary spray booth could be set up at the far end of the laboratory around a wall easel. Spraying, strategically conducted at the end of the work day, allowed minimum exposure of fumes to the staff. A small chamber compressor with a pressure of 100 psi was used to spray varnish paintings.

Works of art on paper were washed in a large, shallow sink 1 M x 1.5 M x 10 cm. This area had a solid movable top which enabled it to be used as a work bench when not used as a washing sink. Mat boards, oriental papers, and foamboards were placed in a flat storage cabinet above the wash sink area.

Roll storage for materials was mounted on a wall. Office furniture included a built-in desk, draftsmans' chairs, a built-in filing cabinet, and bookshelves.
Storage cabinets, located under the workbench area, extended along approximately two thirds of the left wall. A mobile vacuum suction table with locking castors was bolted to the wall when not in use. The vacuum suction table had a solid movable top which provided additional work space for the painting conservator. A microscope was mounted with a retractable arm to the wall over the paper conservator's work bench.

Outside storage bins located under the body of the lab provided storage for a large easel, water hoses, distilled water storage tanks, and maintenance equipment. Detachable aluminum steps for the rear and side doors were stored inside the laboratory during transport.

The laboratory was transported between regional galleries by a local contractor. Long distance transportation to areas outside of New South Wales was arranged through a national company.

CONCLUSION

The mobile conservation laboratory program provided a greater awareness of the need for conservation, which resulted in increased financial support. Currently, the mobile laboratory program is proposing to serve the conservation needs of Australia's western states. For further information concerning the art conservation mobile laboratory, contact Janie Raffin, Director, Regional Galleries Association of New South Wales, Art Gallery of New South Wales, Art Gallery Road, Domain, Sydney, New South Wales, Australia 2000. FAX 02 221-6226/Phone 02 225-1702.

1 Stone, T.G., "A Mobile Conservation Laboratory Service", Studies In Conservation, 28 (3), 97.

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This paper discusses the restoration and reconstruction of the St. Anne Altar, by Gerard David and Workshop. The very long treatment was assisted at every step by the enthusiastic collaboration of the curator of Northern Renaissance painting, Dr. John Hand. The triptych, given the National Gallery of Art as a part of the Widener Collection, was painted in Bruges in the early sixteenth century for export to an as-yet-undetermined Southern European location. The central panel, an image of the enthroned St. Anne holding the Virgin and the Infant Christ Child, measures just under eight feet in height, and slightly over three feet in width. The wings, of St. Nicholas on the left and St. Anthony of Padua on the right, are each just under three feet wide, which establishes that they were not intended to fold over the central panel, but rather to be affixed in a rigid format at either side. It is among the largest Netherlandish altarpieces extant—for comparison, the top register of the Ghent Altar is slightly smaller. Tradition holds that the triptych formed an even larger altar together with six predella panels, the Miracles of St. Anthony, in the collection of the Toledo Museum of Art, and the three panels depicting the Miracles of St. Nicholas in the National Gallery of Scotland. Although the predella panels are only two feet in height, the grouping is suggested by the common provenance of the assemblage of panels in the early nineteenth century in the collection of Cardinal Antonio Despuig y Dameto of Palma, Mallorca, as well as the fact that the predellas depict episodes from the lives of the saints featured on the wings. A seventh panel, the Lamentation, now in the collection of the Art Institute of Chicago, was also owned by the Cardinal, and may have had a place in the assembled altar. We were fortunate in having all seven smaller panels join the triptych in a focus exhibition at the Gallery this past spring.

The three large panels entered the National Gallery in 1942. There is no record of previous treatment in the files. In 1982, Sarah Fisher examined the panels for the systematic catalog and found them in need of cleaning. Sarah was only able to remove the varnish before
ever-increasing duties and treatment priorities pulled her from the work on the triptych, which was then given to me to complete. The overly generous retouching had yet to be removed, as well as the uneven residue of darkened material in the sky and on the white robe of St. Nicholas. There was a non-original black toning glaze over St. Anthony's robe, probably applied to disguise the tiny fissures which had opened along the wood grain, revealing visually disturbing strips of white ground.

Beyond these rather straightforward treatment operations, several more complicated problems remained to be solved, which will comprise the bulk of this discussion. Briefly, they are as follows: A murky, gray-mottled brown which was the major feature of the cloth of honor behind St. Anne's throne and the landscape vistas beyond the Saints was also present in St. Anne's belt, on the carpet beneath the throne, bordering and embellishing St. Nicholas' chasuble, and unevenly distributed throughout the Virgin's robe and St. Nicholas' gloves. The upper eight inches of each panel is a later addition, attached and painted to compensate for an unknown amount of missing original. Finally, the frame the Gallery had for the triptych was an awkward early twentieth-century invention.

The appearance of the altarpiece is deeply affected by the numerous areas of unarticulated gray-brown. We began the investigation of this problem in the area for which the intended color relationships could be most securely determined--the carpet beneath St. Anne's throne. This carpet is a close copy of the one in Jan van Eyck's *Canon van de Paele* altar, possibly an example of good marketing strategy on Gerard David's part. The areas in Jan van Eyck's carpet which correspond to the brown-grey in the *St. Anne* Altar are green. David used the same carpet pattern in the Philadelphia *Virgin and Child with Two Angels* and either David or his student Ambrosius Benson employed it again in the *Virgin Enthroned* in Darmstadt. The color relationships of the Philadelphia picture's carpet are hard to determine due to its unfortunate condition, but the Darmstadt painting shows clearly green details. Having established that the affected areas were intended to be green, we could move on to deciding why they were brown—that is, did we have an example of discolored copper resinate glaze? Although the brown material passes over cracks in the underlying paint, since copper resinate glazes are reputed to remain soft and pliable, that characteristic alone could not prove it to be a later addition. A sample was given to the Scientific Research Department, where it was analyzed by hot stage melting point, the Ninhydrin test, Fourier Transform Infrared Spectroscopy, and mass spectrometry, all of which detected only palmitic and stearic acids, and no resin components. Calcium carbonate was the sole material identified with X-ray diffraction, and chemical microscopy detected only trace amounts of copper. We concluded that the brown material was a drying oil, possibly bulked out a bit with calcium carbonate. The brown layer was removed by softening it with DMSO, followed by mechanical removal with a scalpel, and finally thorough rinsing with Stoddard Solvent. When the removal was complete, the drape of the carpet over the edge of the dias and toward the viewer was seen to have been articulated with varying shades of green.

Although it may have been reasonable to conclude that the appearance of the brocade behind St. Anne was due to a similar darkened oil, we felt cautious in light of the knowledge that the appearance of the cloth of honor in the National Gallery of London's *Mystic Marriage of St. Catherine* was due to alteration of the red and blue paint mixture. Pigment scrapings showed that the black areas of the gold borders at the lateral edges of the cloth...
The brownish color in the upper green glaze layer which you saw in the cross-sections became evident after the removal of the discolored drying oil. Similarly, slightly irregular patches of a distinctly brown color remained in the landscape behind St. Anthony after the darkened oil was removed. Comparison with pig. 2 Before Inpainting the before treatment slide shows these patches, faintly visible beneath the obscuring oil layer. It appears that the drying oil was applied following an overly strong cleaning which had removed some of the modifying tones. The addition of a light brown glaze to the bright green areas re-established the progression of color-defined planes and hillocks, in the characteristic practice of the period.

The decisions to be made concerning the upper eight inches of each panel, blocked out in these before inpainting slides, had to be made before the first varnish could be applied and the inpainting begun. Several options are usually considered in cases such as this; preserving the repaint as it exists, framing the picture to mask the added portions, removal of the added parts, removal of the repaint with or without replacing it, and so forth. In our case, the existing repaint was unacceptable for a variety of reasons, including the fact that the color was badly off. Leaving the paintings without repaint, thus truncating the
architectural elements mid-spring, is intrusive to the concept of the painting--unnecessarily so, given the amount of evidence for the replacement of the missing areas.

The removal of retouching at the upper corners of the original supports revealed an exposed wooden spandrel in the corner. The same configuration, a semicircular upper paint profile on a rectangular support, is present in all six predella panels. Although the Chicago Lamentation has the unpainted upper spandrels, it is not clear that the upper paint profile was semicircular. If the upper edge of the Chicago picture was not semicircular, it is the exception in David's oeuvre. Every other extant painting attributed to him is either rectangular or a rectangle with a semicircular top. A semicircle drawn on the St. Anne triptych using the arcs visible at the tops of the wing panels exceeded the added oak bits by approximately 3/4". We decided that the arc could be very slightly truncated in the interests of practicality.

The repainting that had been applied on the wings created an M.C. Escher-like twist in the architecture. Most of the architectural arches in David's work are in small background buildings, but in the Munich Adoration of the Kings he features arches that are a rusticated version of those in the wings of the St. Anne. The addition was repainted following a drawing which extended the beginnings of the original painted arcs across the addition, using the Munich arches as a guide. The resultant effect leads the eye convincingly past the saints, establishing the viewer's position within the same chamber as the holy presences.

The central panel had no spandrels of unpainted wood. It is probable that it was much taller than the wings, also terminating in a semicircle. The height of the missing portion could have been estimated based on the relative relationships of other triptychs, but no internal physical evidence on which to base a reconstruction of the height remained. Rather than infer a height based on external evidence, or display the altarpiece with the wings towering over the central panel, it was decided to repaint the existing addition to the height of the wings. In most instances the cloth of honor would have terminated in a baldachine, but once again, insufficient evidence remained to justify the creation of an arbitrary size and shape baldachine. Therefore, the solution was to continue the design elements of the cloth of honor and the wall behind. A mechanical process for design transfer seemed appropriate for the recreation of an area of repeating pattern approximately eight inches by twenty-four. The reconstruction of the brocade was facilitated by tracing the shape of the gold embroidered areas, and the shape of the green damask, onto mylar. These patterns were used to cut an amberlith, then silkscreens were prepared of each. The verso of the silkscreen strainer was covered with felt, the original paint surface was covered with mylar, and registration was accomplished on the non-original portion with post-it-notes. It was important to recreate the irregular, slightly erratic appearance of the hand-painted original. Therefore, the green glaze could not be screened directly, but rather an airbrush was used through the screen to leave a faint pattern which could then be painted by hand. The brocaded areas are created by tiny lines of lead-tin yellow over a shaded ocher base. I screened the ocher base, then added the glazes and "lead-tin yellow" lines.

Finally, given the unaesthetic design of the previous frame and the need to cover the
unpainted spandrels in the wings, we decided to have a new frame constructed. The width of the frame between the separate members of the triptych was calculated by extending the orthogonals present in the wings to their common vanishing point. The solution to contriving a curved profile within a rectangular format was suggested by Paul Mitchell, a framemaker, following the design established in the painting of the Seven Sacraments attributed to Roger van der Weyden at Antwerp. The final appearance of the painting is shown in Fig. 3.

Fig. 3 After Treatment
The Ultimate Challenge for Radiocarbon Dating: The Paint Layer

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Introduction

Since the development of $^{14}$C dating by W. F. Libby in the 1940’s and 50’s, the method has proven to be the best absolute method for chronometric dating of organic and some carbon-containing inorganic materials [1]. Even broader application horizons have been opened to radiocarbon dating by use of the accelerator mass spectrometer which allows routine analysis of sub-milligram samples. Art curatorship and art conservation are two art research fields which directly benefit from such a development.

There are pronounced similarities between application of radiocarbon dating in archaeology and art research but there are also major differences which make it difficult to simply take a methodology developed for archaeological research and apply it directly to radiocarbon dating of art objects [2].

In both fields the application of dating techniques is focused on dating of an object of unknown age or on cross-checking of the age of an object previously dated by other methods.

Archaeological dating often takes advantage of newly opened archaeological sites and focuses on the identification of disjunctions, disparities, verification of the specimen association, and assessment of the magnitude of temporal
hiatuses between the date and the event [3]. Art research more often deals with an object which is for a long time removed from the place of its creation and for which provenance information is not available or which precipitated questions about its provenance and authenticity. If neither art historical research nor connoisseurship allows placing the object into well defined temporal relations and there is a suspicion that the object might misrepresent the time of its creation, radiocarbon dating can, together with a range of other scientific tests and methods, provide data which might help to prove or disprove a working hypothesis based on art historical research methods. For archaeological research the extension of datable range of materials from the currently feasible 40,000 years BP (before present) to the theoretically possible 70,000 - 100,000 years BP is a major challenge of AMS research. Fine art studies deal with relatively recent time periods (~ 2000 B.C. to present) but because the focus of the research is more on the work of an individual artist and time-limited artistic movements (co-measurable with a life span of a human being) rather than on production of civilization periods, such research would benefit from the results of high and ultrahigh precision measurements. Because the majority of art objects are unique, irreplaceable and relatively small, the ability to date a minimum amount of sample is an extremely critical issue.

**Radiocarbon Dating**

The impact of high energy primary and secondary cosmic rays on atoms and molecules of the upper layers of the earth's atmosphere (lower stratosphere and upper troposphere) results in many of nuclear reactions in which a number of neutrons, protons, α-particles and other subatomic particles are
produced (Fig. 1). The large portion of neutrons produced by the cosmic rays are slowed down by collision with atoms in the atmosphere. The resulting thermal neutrons react with $^{14}$N-nitrogen atoms to form a $^{14}$C atom and a proton (hydrogen nucleus) through a nuclear reaction:

$$^{14}N + n \rightarrow ^{14}C + p$$

In this way approximately 7.5 kg of $^{14}$C are produced and added to the world's carbon reservoir every year. Most of the carbon is in the form of stable isotopic $^{12}$C (98.9%) and $^{13}$C (1.1%). After formation, $^{14}$C quickly combines with oxygen to form $^{14}$CO and later $^{14}$CO$_2$. This carbon dioxide mixes throughout the atmosphere by air mass movements and turbulences. Once a radiocarbon $^{14}$CO$_2$ molecule reaches the biosphere it enters into the carbon exchange cycle. Life organisms are part of the equilibrium. Plants build $^{14}$C into their cellular structures by a process of photosynthesis. Other organisms obtain it by ingestion of plant material. The concentration ratio between radioactive isotope $^{14}$C and stable carbon isotopes ($^{12}$C + $^{13}$C) is approximately 1:10$^{-12}$. This concentration ratio stays approximately constant with time and represents the dynamic equilibrium established, on a global scale between $^{14}$C loss by radioactive decay and cosmic rays production [1].

Within a living organism the concentration of $^{14}$C is also constant and is continuously being replenished from the biosphere carbon exchange reservoir. When an organism dies the $^{14}$C intake process stops and a finite amount of the $^{14}$C fixed in the organism faces the slow process of radioactive decay.
$^{14}$C is radioactive and it decays back to $^{14}$N by emission of a beta particle (electron) and antineutrino.

$$^{14}\text{C} \rightarrow ^{14}\text{N} + \beta + \nu$$

The death of the organism sets a time zero ($t = 0$) on a "radiocarbon clock." The decrease of concentration of $^{14}$C in a dead organism follows the exponential radioactive decay law (Fig. 2). This law relates the number of radioactive atoms $A$ left after time $t$ to the initial number $A_0$ of radioactive atoms (at $t=0$):

$$A = A_0 e^{-\lambda t}$$

Where $\lambda$ is a constant equal to the reciprocal value of the meanlife $\tau$ of the radioactive isotope. The meanlife is related to the half-life of the radioactive isotope by the equation:

$$T_{1/2} = (\ln 2) \tau \quad \text{or} \quad T_{1/2} = 0.693\tau$$

Both half-lives and meanlives are specific constants for a given radionuclide. The Libby half-life $T_{1/2} = 5568$ years and Libby meanlife $\tau = 8033$ years are conventionally used in the calculations of radiocarbon age.

From 1949 till the late 1970's the only experimental method for measurement of $^{14}$C concentration in a given sample was based on the measurement of the radioactive decay rate, the same principle which was originally developed by Libby. Several other important improvements have been made to increase
sensitivity, improve precision and accuracy of the measurements and decrease sample size requirements. Despite all of these improvements the conventional counting techniques face the problem of low specific activity of $^{14}$C (disintegrations rate per gram of radioisotope).

Typical sample sizes needed for conventional gas and liquid scintillation counting are equivalent to about 5-10 grams of pure carbon [4]. The sample needed for dating of material older than 50,000 years is even greater. The dating of older samples is very important for archaeological research but not so critical for fine art research which deals mostly with later periods of civilization development. In art research a much more critical issue is the problem of minimum sample size. Over the past decades several attempts have been made to date small samples by conventional counting methods. The mini-gas counters that have been introduced are able to work with sample sizes as small as 100 mg of pure carbon. To achieve the same quality of counting statistics as we can achieve for samples of ordinary sizes, the reduction in sample size has to be compensated by approximately equivalent multiplication of counting time from the usual 24 or 48 hours to several weeks or months. In most of the cases the sample sizes needed for mini-gas counters exceed the amount of material which might be available from the art object or which museum curators or fine art or antique collectors might agree to provide for such an analysis [5].

**Accelerator Mass Spectrometry**

A new era of application of radiocarbon dating came with development of the alternative method of $^{14}$C determination based on direct analytical
determination of the concentration ratio of $^{14}\text{C}$ and stable carbon isotopes in the analyzed sample [6].

The conventional $^{14}\text{C}$ counting methods provide information about concentration of $^{14}\text{C}$ in the sample based on radioactive decay and measurement of $\beta$ particles emitted from the sample. A more efficient method for $^{14}\text{C}$ measurement would be a direct analytical determination of the isotopic $^{14}\text{C}/^{13}\text{C}$ and $^{14}\text{C}/^{12}\text{C}$ ratios of $^{14}\text{C}$ and $^{13}\text{C}$ or $^{12}\text{C}$. There are about $5 \times 10^{10}$ $^{14}\text{C}$ atoms in one gram of modern (1950 A.D.) carbon. To detect 1% of $^{14}\text{C}$ in a sample using $\beta$-counting technique would require 80 years of counting time. To detect 1% of $^{14}\text{C}$ atoms in a sample using AMS usually takes less than an hour. Analytical chemists know that one of the most sensitive methods which can be used to measure isotopic ratios is mass spectrometry. In a mass spectrometer the isotopes are separated according to their mass-to-charge ratio. All attempts to use "the analytical mass spectrometer" for carbon dating have failed. This failure was due to the fact that $^{14}\text{C}/^{12}\text{C}$ concentration ratio ranges from about $1.2 \times 10^{-12}$ for modern carbon to about $3 \times 10^{-16}$ for samples 70,000 years old. The background of a mass spectrometer does not allow measurement of isotopic ratios smaller than about $10^{-9}$. This is due to spectral interferences of $^{12}\text{CH}_2^+$, $^{13}\text{CH}^+$ and $^{14}\text{N}^+$ and molecular ions which have practically the same mass to charge ratio as measured $^{14}\text{C}$. A special experimental strategy has to be used to achieve a practical elimination of the instrumental background and spectral interferences. Several intricate steps are needed to achieve such a goal.

A schematic diagram of the accelerator mass spectrometer is shown in Figure 3. A solid sample containing carbon is bombarded by energetic (several keV)
cesium ions in the ion source. The impact of the primary ions causes the emission of secondary particles from the surface of the bombarded sample. Because the cesium bombardment produces relatively high proportions of negatively charged C\(^{-}\) ions, such an ion source is called the negative ion source. It is used because negative ions are needed for the function of the tandem accelerator and also because it provides the first step in background suppression by discriminating against \(^{14}\)N contamination which is known not to form stable N\(^{-}\) ions. A strong positive electric field draws the negative ions from the ion source into a low energy mass analyzer. Using a magnetic field or combination of magnetic and electrostatic fields, a chosen carbon isotope is preselected for the accelerator tube (second step). Selected C\(^{-}\) carbon ions are accelerated in the first half of the accelerator tube to reach the energy of several MeV (2-8 MeV). In the middle of the accelerator tube the energetic carbon ions pass through a gas (Ar, Xe, O\(_2\)) or thin film “stripper.” During this interaction several electrons of energetic carbon ions are removed (stripped off) and charge reversal of the carbon ion beam (high proportion of C\(^{3+}\) ions are formed for 2-3 MeV accelerators) are achieved. The resulting C\(^{3+}\) carbon ions are accelerated in the second part of the accelerator tube to even higher energies.

No molecular ion can survive electron stripping to 3+ state and during the stripping process all molecular ions disintegrate (third step) [7]. After the ion beam passes through the accelerator, molecular fragments are removed from the beam by mass spectra (fourth step). Then an ion beam to be analyzed is directed to a detector where its intensity is measured (step five). Abundant stable isotopes (\(^{12}\)C, \(^{13}\)C) are measured using Faraday cup detectors. \(^{14}\)C\(^{n+}\)
ions are detected using a gas ionization chamber or silicon surface barrier detector.

The major advantage of AMS for carbon dating of art objects is its ability to achieve conventional counting precision on sub-milligram samples. Samples of this size are comparable to samples taken routinely by restorers and conservation scientists for pigment and binding media analysis.

Reality of radiocarbon dating

As described, the principle of the radiocarbon dating is simple enough to provide information on the age of dated organic materials. Such an ideal situation in reality does not happen very often and there is not an analytical method which would not face problems of sample quality, limited validity of basic assumptions, interferences and data interpretation. Issues critical for radiocarbon dating are:

- sampling and contamination
- corrections for isotopic fractionation
- relations between measured and calendar age

Sampling and sample contamination

Analytical chemists know that results of any analysis cannot be better than the quality of the sample used for the analysis. This is also true for $^{14}$C dating and namely for its application in dating of museum artifacts. We can get meaningful radiocarbon data only if dated sample of organic material is
indisputably the material which was removed from the live carbon cycle
during the time which corresponds to the the time of creation of the artifact.
This sounds very logical but without fully realizing what this means, there is
a substantial potential for interpretation error or overinterpretation of
radiocarbon data.

Radiocarbon dating is indifferent to the creative force of the artist or the
artist's methods. Radiocarbon dating "sees" only organic materials used
during the creative process. Radiocarbon dating cannot provide information
about when or by whom a given artifact was created. It can only provide
information as to when different organic materials found today as parts of the
given artifact were removed from the live carbon cycle. For example, if a
baroque wooden sculpture was carved from an old wooden beam taken from
a destroyed Gothic church, the radiocarbon dating would not provide
information about the date of the carving or the date of the Gothic church,
but only about the ages of individual tree rings found in the wood sample.
We would not even be able to say when the tree was cut down (t=0 for
radiocarbon dating) because the peripheral tree ring under the bark (the last
ring grown before cutting) probably would be removed by a carpenter to shape
a beam. We would be able to extrapolate our data to provide at least an
estimate when the wood was used as a building material in the church. But,
in this case, we have to realize that this estimate might be quite misleading if
the wooden beam was a later addition or replacement, or if the original tree
was "dead" long before it was used to make the beam (natural causes or
storage for later use). Sampling of artifacts have to be done with deep
understanding of materials (origins of different materials, their participation
in the live carbon cycle, and their practical "shelf-life"), artist techniques
(mixing of materials of different origins) and prevailing customs in handling materials for artistic use (wood aging before use as a support material for panel painting or the tendency to recycle materials for later use). It is also critical to sample a site of the artifact which has a high probability of being part of the original structure of the artifact (part of panel painting could be a latter addition needed to fit a painting to a new frame, paint sample could be a later overpainting or restoration). A decision on sampling strategy should not be done without a consultation with art conservators and art historians involved in the project. If there are any doubts about the originality of the sample site, several samples should be taken from different areas of the artifact. It is better to refuse working with bad or inadequate samples than to risk sampling error, misinterpretation, or overinterpretation of radiocarbon data. There is also practically no museum artifact untouched by other artists, restorers, or object conservators. Numbers of museum objects have a long history of successive cleaning, repairs and restorations. There is a high probability that these treatments have changed the original $^{14}C$ make up of the object. For example, paraffin wax treatment or acrylic varnish coating represents the introduction of “dead” carbon material and makes the object apparently “older.” Treatment with newly produced beeswax or natural resin varnishes would introduce “modern” carbon material resulting in the positive shift of the apparent radiocarbon dates. The detailed knowledge of past conservation or restoration treatments (very seldom available) or detailed chemical analysis is needed to prepare a ground for a development of a successful sampling strategy and proper sample pre-treatment prior to the radiocarbon dating. The majority of historical museum objects containing organic materials are composed of complex natural materials (cellulose, oils, proteins, waxes, natural resin) and their mixtures (egg tempera-pigment, oil,
protein, carbohydrates, natural dyes, vitamins, steroles, and inorganic salts). Detailed knowledge of materials used to create the art object helps to design pre-treatment needed to remove sample contaminations or to identify a component which is the least effected by contaminations and suitable for more reliable age determination.

In the sample preparation step the pre-treated sample is transformed into a sample compatible with the radiocarbon dating procedure. Carbon dioxide, or volatile hydrocarbons are used for gas counters, scintillating liquid soluble organic compounds for scintillating counters. For AMS measurements the organic material is transformed to make a small target of graphitic carbon [8,9]. Special care has to be taken that sample pre-treatment and target preparation steps do not change the carbon isotope composition of the original sample and do not introduce further contaminations [10].

**Correction for isotopic fractionation**

Knowing the concentration of $^{14}$C in a sample, Libby's mean life for $^{14}$C and the fact that radioactive decay follows the first order kinetic equation should be enough to calculate the age of the sample. In reality this cannot be done without correction for isotopic fractionation of carbon isotopes [11]. Each organic material used for radiocarbon dating has a distinct biochemical history. There are small but still measurable differences in physical and chemical properties of compounds of different carbon isotopes. For instance, plant material assimilates $^{12}$CO$_2$ more easily than $^{13}$CO$_2$, and $^{13}$CO$_2$ more easily than $^{14}$CO$_2$. Resulting isotopic shifts have to be corrected for before the
equation describing the radioactive decay is used to calculate the conventional radiocarbon age of the sample (given in uncalibrated years BP).

**Relations between measured and calendar age**

The basic assumptions of radiocarbon dating are the constant rate of radioactive decay uninfluenced by external factors and constant concentration of $^{14}$C in the biosphere. The first assumption has been found correct. The second assumption has been found only approximately correct. The rate of $^{14}$C production depends on stability of cosmic-ray flux. Dendrochronology (tree-ring dating method) together with high precision $^{14}$C dating allowed for measurement of variation in $^{14}$C production back to about 9000 years ago. Long term variation of $^{14}$C production (a sinusoidal variation with a period about 11,300 years) can be correlated with changes of the earth's dipole moment. The short-term variations are due to changes in solar activity [1]. Even activities of man himself were able to create noticeable changes in $^{14}$C concentration within the earth's biosphere. Since the beginning of the Industrial Revolution, coal and oil combustion have injected steadily increasing amounts of "dead carbon" into the atmosphere. This so-called fossil fuel effect in combination with the solar activity effect gives recent organic material a false age of up to about 160 years. In the 1950's and 60's the fossil fuel effect has been overshadowed by an increased concentration of $^{14}$C produced by neutrons released during a series of nuclear and thermonuclear bomb tests (bomb effect). Since the moratorium on atmospheric testing in 1963, the concentration of $^{14}$C in the atmosphere is gradually decreasing.
Correction for all of the above mentioned $^{14}$C concentration variations can be done using internationally accepted calibration curves derived from radiocarbon and dendrochronological experiments [12]. Fig. 4 shows a section of the high precision calibration curve (without curve error terms) developed by Stuiver and Pearson [13] which covers several time periods important for art research. The calibration curve is not a monotone function and two examples show the effect of the shape of the calibration curve on the width of the calibrated age ranges obtainable from radiocarbon measurements when experimental error terms are included. Calibrated age ranges are not the central dates with error terms but the range of statistically equally valid dates. This age range can be relatively narrow when the calibration curve has a steep slope or wide when the slope is flat or wiggly.

The shape of the calibration curve for the relatively recent past (~ 1650 A.D. to 1950 A.D.) is such that for non high precision data the calibrated age range covers the whole period form about 1700 A.D. to 1950 A.D. (Fig. 5a). This makes the use radiocarbon results for dating of the last two hundred years before 1950 A.D. very difficult. The situation would improve only marginally with the application of high precision measurements. In such a case, Figure 5b there are several calibrated age ranges corresponding to one conventional radiocarbon age and some other means (complementary scientific methods, art historical analysis) have to be used to provide more plausible interpretation.

Applications of AMS

The Bust of Queen Nefertiti
The bust of Queen Nefertiti is one of the best known Egyptian portraits, shown in almost all books on art history and books on ancient Egyptian art. The bust was found in 1912 in Tell El-Amara during excavations carried out by the German Oriental Society. Generations of art lovers have been enchanted by its beauty. The bust dates back to the reign of her husband, King Amenophis IV-Akhenaton (1364-1347 B.C.) who ruled during the XVIII dynasty of the New Kingdom [14]. The bust is made of a soft limestone supplemented by plaster. The portrait seems to be finished to the last details with rich color decoration. A great mystery is the absence of the left eye. The eye could not be found during excavation in spite of a very careful search. The pupil of the right eye is made of a shell of rock crystal attached to the bust using an organic material which was identified as a beeswax [15]. A sample of this beeswax was taken for radiocarbon dating. The small sample size precluded an extensive sample pre-treatment which was limited to a gentle acid, alkaline and deionized water wash. Results shown in Table I prove the ancient origin of the beeswax and can be used as supporting documentation against several attempts to use some discrepancies in the bust’s recent history (namely, its move to salt mines at the end of WWII) to discredit its ancient origin [16].

The Wooden Sarcophagus

A wooden sarcophagus from the J. P. Getty Collection consists of a simple wooden chest made of pieces of cedar wood. The surface of the wood is richly decorated. The lateral side of the sarcophagus is partially covered with canvas covered with a fine gesso and a paint layer. On the scene painted on
the side of the sarcophagus depicts the death supper with a number of side figures. A young male figure lies on a couch with three small figures of donors or efferents on each side. Based on art historical analysis the painting and the sarcophagus was dated back to the late fourth century A.D. [17]. Small samples of canvas and wooden support from damage areas were extracted for radiocarbon dating. Both samples were thoroughly cleaned using a repeated acid, alkaline and deionized water treatments. The AMS results from both samples are shown in Table I. Results of radiocarbon dating of canvas provide support for the original art historical analysis of the sarcophagus. The wood sample appear older but that is consistent with the life-span of the cedar trees prior to its use as a carpenter's material.

Renaissance Painting

A painting, "Ecce Homo," currently at Musée Jacquemart-André in Paris came to France from Italy through the antique dealer Bardini of Florence. The art historical analysis attributed the painting to a school of a famous renaissance painter Andrea Mantegna (~1431-1506 A. D.). There are several opinions about the exact attribution but a general consensus is that the painting is very close to Mantegna’s manner toward the end of the fifteenth century [18]. The painting is made on a very fine linen canvas with no signs of a gesso ground under the paint layer. The canvas is glued by the edges to a thin wooden panel. The well preserved edges of the canvas indicate that the panel is the original one [19]. To support this working hypothesis AMS radiocarbon dating was used to analyze samples from the wooden panel. Direct sampling of wood was not possible, but a piece of paper tape removed from the back of a panel contained several splinters of wood. The splinters
were freed from the tape using a hot deionized water wash which was followed by a series of acid and alkaline washes to remove the organic adhesive from the tape. The AMS results are shown in Table I. The small splinters (microscopic to about 1 mm in length) originated from different tree rings across the wooden panel. The obtained age range thus cannot be assigned to an individual tree ring but represents kind of a tree ring average of the panel. The calibrated age range for the wood sample corresponds to dates expected for a wood used during the second half of the fifteenth century.

Medieval Documents on Parchment

The collection of medieval charters and documents on parchment was obtained by the Getty Conservation Institute as a testing material for development of methodology for dating of medieval art objects containing protienaceous materials [20]. Parchment samples satisfy this application because parchment was often a starting material for the preparation of animal glue which was widely used as a general adhesive and as a binding medium for a special type of tempera painting called “distemper.” Parchment was also used as a substrate for lasting documents, illuminations, and miniature paintings as well as a material for book binding. The collection includes a number of legal documents whose age ranges from the late part of the thirteenth century to the middle of the seventeenth century. Several documents are dated and these can be used as secondary standards for AMS method development. Small samples of several square millimeters were cut from the edges of the documents. Prior to chemical treatment the parchment samples were cleaned mechanically using a sharp scalpel. A number of parchment samples were treated with a calcium carbonate wash prior to their
use. This was done to make writing on the parchment surface easier. The presence of inorganic carbon from CaCO₃ would shift the radiocarbon age (dead carbon effect) and all measures were taken to remove inorganic carbon from the sample prior to combustion procedure. After the mechanical cleaning the samples were cleaned using a standard acid-alkaline-deionized water wash. AMS results for one of the samples is shown in Table I. There is a very good correspondence between the calibrated date range and the date of parchment used in 1420 A. D.

Conclusions

AMS dating shows great potential for art research. The fact that the sample size needed for AMS dating is comparable to the size of samples routinely taken by conservators or conservation scientists for cross section analysis and for binding media determination opens a number of new and exciting applications. One of the most important applications is a direct radiocarbon dating of paint layers on paintings and polychrome sculptures. The limiting factors which make such an analysis difficult are the complex nature of paint materials together with the very severe problem of contamination due to the frequently long history of restoration and conservation treatments which are common to almost all important paintings and polychrome sculptures found in art museums, churches and private collections. The number of artifacts which have not been restored or repaired is very limited. The radiocarbon dating of a paint layer requires a detailed knowledge of the chemistry of the paint layer. It is important to identify the material used as the original binding medium and develop an experimental strategy which would be able to separate the original material from other materials which were applied
later or which permeated the paint layer during restoration and conservation treatments. The current collaborative project between the Getty Conservation Institute and the University of Arizona in Tucson centers on the development of this strategy. Results of the GCI's Binding Media Analysis Project are used for analysis of organic portion of both historical and modern paint layers. Advanced methods of analytical separation are used to isolate the critical organic component in the paint layer for AMS target preparation. Scientists of the NSF Radiocarbon Laboratory at the University of Arizona concentrate on the development of a method for measuring submilligram samples and achieving high precision results from small samples of binding media. The results of our combined effort are very promising and we believe that the methodology developed for radiocarbon dating of binding media in paint layers will bring a new dimension to current and future art historical and art conservation research.

References


17. M. Elston, private communication.


<table>
<thead>
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<td>BC 1305 - 1105</td>
<td>BC 1390 - 1030</td>
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<td>BC 95 - AD 50</td>
<td>BC 165 - AD 112</td>
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<tr>
<td>AA 5534</td>
<td>MJA &quot;Ecce Homo&quot; - Wood</td>
<td>475 ± 45</td>
<td>AD 1410 - 1450</td>
<td>AD 1390 - 1490</td>
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<tr>
<td>AA 5549</td>
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<td>539 ± 45</td>
<td>AD 1310 - 1415</td>
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Figure 1. Production of $^{14}\text{C}$ and its movement in the Earth's biosphere.
Figure 2. Decay curve of $^{14}$C.

$A_0$ = number of $^{14}$C atoms at $t=0$

$T_{1/2}$ = half-life of $^{14}$C
Figure 3. Schematic of an accelerator mass spectrometer.
Figure 4. Calibration curve (from Stuiver and Pearson) for the last millennium. Two examples show the effect of calibration curve shape on range of calibrated dates.
Figure 5. The advantage of high-precision measurement in dating relatively recent samples: (a) low-precision measurements; (b) high-precision measurements.
THE CONSOLIDATION OF DISTEMPER PAINTED CEILINGS IN THE MICHIGAN STATE CAPITOL

Kenneth B. Katz

The construction of the Michigan state capitol took six years to complete, from 1872 to 1878. The original structure, built scandal free and for only 1.5 million dollars was constructed of brick, Ohio sandstone and capped with a cast iron and sheet metal dome. Almost every area of interior space had been decorated in the Victorian style which included stenciling, gilding, metallic paints and freehand designs. To keep the costs down, marble and expensive hardwoods were only simulated with wood graining techniques and faux marbling. Over the next one hundred years, the interior changed drastically. Not only were walls repainted, interiors that had 18 and 20 feet ceilings were made into two rooms by overflooring. Restoration began in 1987 with two goals; one to return the capitol as accurately as possible to its original historic appearance allowing it to take its rightful place in the history of American decorative arts and two; to keep it a functional center of government for at least the next hundred years.

The role of Conservation and Museum Services began as a telephone call from the project Conservator, Darla Olson, asking me if I could consolidate distemper paint. She explained that previous attempts with a 2% spray of Acryloid B 72 were not successful and that the lack of consolidation was holding up other aspects of the Capitol restoration. Time was also a factor, she said since it had taken her almost one month to find a Conservator willing to help her. Using sawdust on cardboard as a sample, I applied, by spray, Adam Chemical CO. EVA, Rohm and Haas Acryloid B 72, Conservator’s Products CO. Beva 371, and Lascaux 750 Hydrosealer. Initial tests revealed that the EVA and B 72 dried too glossy. The mixtures were in xylene and were about 15%. This percentage appeared to correlate to the cohesive strength of the mixtures of CPC Beva 371, (1 part Beva/3 parts xylene by weight), and Lascaux 750, (1 part Lascaux 750/5 parts acetone by volume). Years of aging and constant changes in humidity had caused the paint to become friable and flake in the western corridor of the Capitol building. The original appearance of the ceilings was one of a matte dry look and that is what we were asked to produce; a consolidated ceiling that changed as little as possible with respect to saturation and gloss. Based on the first tests, I started testing the Beva 371 and found that a
mixture of CPC Beva 371 mixed with xylene, 1 part Beva 371 to 3 parts xylene by weight satisfied the criteria set forth by Darla and the architects in charge. [Fig 1,2,3] Although the Lascaux consolidated the structure, it was a bit more glossy than preferred. We began in a small area and let it dry followed by a larger one and finally began the ceiling consolidation. Following our consolidation, losses were filled and inpainted by the decorative painting contractor. Following the treatment, we were asked to help with the Governor’s reception area. This treatment was complicated by the many construction activities going on at the same time that we were to be carrying out our treatment. The Governor's reception ceiling was generally in tact, but had suffered much more cleavage than the western corridor and had more colors and decorations to be concerned with. In addition, the plaster ceiling support was delaminating from its ceiling joists, and would have to be rescrewed up for security. Our task was to carry out the consolidation in conjunction with all the rest of the contractors. Tests were redone. The Lascaux caused too much of a gloss and also resulted in tide lines. A mixture of CPC Beva 371 in xylene 1:4 by weight was used. [Fig. 4,5] Part of the construction restoration was the reattachment of the plaster support to the ceiling joists. This was to be done by drilling holes through the decorated ceiling and then screwing the ceiling back up. For this reason, a facing was used in areas of drilling.

The facing consisted of University Products L tissue and the Beva mixture. Small squares of tissue were cut, their edges feathered and then adhered to the painted surface by brushing the consolident through the dry tissue. After the holes were drilled, they were filled by the decorative painting contractor. The facing tissue prevented overfilling. The facing tissue was removed with mixtures of xylene and acetone depending on the success of consolidation. In areas that had been secure, prior to treatment, xylene was used for its efficiency. In more fragile areas, mixtures of acetone and xylene were used to accelerate evaporation and avoid reactivation of the remaining adhesive. This was followed by the removal of the excess adhesive and grime with the same mixtures, a procedure that couldn’t have been carried out previously due to the insecurity and extreme water sensitivity of the distemper paint. Again, the filling and inpainting was done by the decorative painting contractors.

One aspect of the Conservator in the restoration of the
One aspect of the Conservator in the restoration of the Michigan State Capitol was that of problemsolver. The other was persuading the powers that be to do the right thing, namely preserving as much of the original as possible. Whether fine art or decorative art, I feel we have the responsibility to help when and if we are called to do so. In some rare instances, artistic or architectural intent does not need any help and is best left alone, but in others, such as the state capitol, going out of our way to work cooperatively with contractors, owners and other professionals is and was essential.

Acknowledgments:
Darla Olson, Steve Seebohm; Project co-ordinators
Kerry Chartkoff; Michigan State Capitol Committee
Lonora Flores, Margaret Burnham, Mara Ignatious;
Conservation and Museum Services staff

Suppliers:
Beva 371: Conservator's Products Company, P.O. Box 411,
Chatham, N.J. 07928 Lascaux 750 Hydrosealer
Rohm and Haas Acryloid B 72: Conservation Materials
Ltd., 1165 Marietta Way, Sparks, NV 89431
L Tissue: University Products Inc., 517 Main St., P.O.
Box 101, Holyoke, MA 01041
Adam EVA: Adam Chemical Company, Inc., 3320 Sacandaga
Road, West Charlton, NY 12010
A Low-Cost Rack for Rolled Storage.

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A Ceiling Mounted Inpainting Light Bank.

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VARNISHING PAINTINGS: PRACTICAL METHODS OF APPLICATION.

A Review of Varnish Application Fundamentals.

James Bernstein

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Chris Stavroudis

The Application of Mastic Resin Varnish. / Notes on the Application and Use of Arkon P-90.

Camilla J. Van Vooren

Up-date on Varnish Resin Research at the National Gallery of Art, Washington, D.C.

Suzan Lomax and E. René de la Rie
A Low Cost Rack for Rolled Storage

Anne Walter Zanikos, Paintings Conservator

A rack system for rolled storage is easy to make using the hollow aluminum top rails commonly used in cyclone fencing. The light weight rails are strong, inexpensive and of ideal diameter to slip into most suppliers’s tubes. The rails rest on hooks (vinyl covered bicycle storage hooks work well) which may be screwed directly into your wall, or in the case of dry wall, may be secured into a 2 x 4 stud. The system may be modified for more clearance (in the case of rolled material of larger diameter) by using free-standing 2 x 4’s or 2 x 6’s attached to the ceiling and floor. The rails come in 21 foot lengths but are easily sawed to length. Aluminum end caps, also fencing material, finish the ends for safety and a polished look. All materials are available at a large building materials store.

Approximate Total Cost: $ 16.00 / per Pole

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A Ceiling Mounted Inpainting Light Bank

Anne Walter Zanikos, Paintings Conservator

The uses are endless when you have an articulated moveable arm, commonly used in dental X-ray and examination equipment. A fluorescent light fixture may be mounted onto the end of the arm for an inpainting light that provides a wide range of movement. These arms are usually designed to mount into the ceiling or onto the wall leaving the floor in your inpainting area clear. Your local dental equipment repair person is a good source for used or out of date arms and your electrician should be able to rewire it and attach the fluorescent fixture of your choice. When selecting fluorescent tubes, look for lamps with a high color rendering index (92 or higher); you may wish to use a combination of different tubes to achieve a balanced light mixture. Articulated medical instrument arms may also be used to mount an exhaust tube or to hold other cumbersome pieces of equipment overhead.

Approximate Total Project Cost: $ 525.00

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* Color rendering index 92

(mounting to roof beam, rewiring with switch, attachment of fixture)

c/o Anne Walter Zanikos, 1880 Nacogdoches Road, San Antonio, TX 78209
An Inpainting Taboret Exhaust Design

David A. Miller, Paintings Conservator

An exhaust system was designed for an inpainting taboret in response to inadequate ventilation which caused a build-up of solvent vapors. As xylene has been a common solvent for our inpainting media, experiments were conducted to find a solution to the problem. Fomecor® mock-ups of miniature fume hoods were fabricated and tested to produce workable designs for air baffles and exhaust ports. Plexiglas® was selected as the final construction material so that the inpainting materials and supplies could be easily seen and illuminated by the light that was used for color matching. A local plastics fabricator built the hood to our specifications. Next, a wooden housing collar was attached in-house, as was a hardboard (e.g., Masonite®) shelf to hold the inpainting supplies and the PVC plumbing fittings to connect the exhaust hose.

Originally, the exhaust hose was coupled to the closest available ceiling drop trunk and was very inconvenient. When new laboratory facilities were designed, an in-ground exhaust system was installed for easy hook-up of the taborets. The system has seven different inlet locations for flexibility, a variety of coupling caps or covers, flush to the floor metal doors, and a central on-off switch clustered with the other inpainting services (i.e., incandescent track light switches and compressed air controls).

Other than some background noise as air rushes past the plexiglass baffle to the exhaust port, the system removes vapors efficiently.

c/o Conservation Department, Indianapolis Museum of Art, 1200 West 38th St., Indianapolis, IN 46208

Tip-proof Solution Cups / Pigment/Paint Storage Compartments

Arnold B. Wagner, Paintings Conservator

Empty 35mm film canister containers are convenient working solution cups that become spill-proof when placed within the inner collar of an inverted plastic spray can cap (such as those from cans of spray enamel or varnish, e.g., Krylon®). When not in use, the solution cylinders can be capped with their snap-on lids. Most conservation studios have a continuous supply of new canisters to replace used ones; if needed, additional canisters can be gotten from professional photo studios on a free, “Please, take them away.” basis.

Other useful studio containers are rectangular pill storage ("weekly dosage") boxes available from drug stores. These polyethylene containers, with multiple rectangular compartments inside and snap-shut hinged lids, are extremely convenient for holding small amounts of pigments, inpainting colors, or adhesives. When taped onto a palette, materials are within easy reach, especially helpful for on-site work.

c/o 143 West 74th Street, New York, NY 10023
Tips from the Nursery

Kenneth B. Katz, Paintings Conservator

Tips From the Nursery actually should have been given 5 years ago when I was knee deep in diapers and situations that have long since passed. The ideas came from the quantum leap in materials associated with new bornism. To help stem the tide of garbage and to foster recycling, the following leftovers from my baby days are tips.

First, of course, are the baby food jars. Formula jars that you get from the hospital are the best since they are calibrated in liters and ounces, and have threaded caps. I still remember wondering how Leni Potoff was able to get so many jars from Oberlin Hospital. The reuse of the bottle warmer seemed appropriate. The next recyclable item was Wet Ones® containers that are used for hygienic reasons. They come with a nice opening that automatically releases the cotton head of a swab from an applicator stick. By using this plastic container that is emptied every night, one prolongs the absence of it in the land fill. Whereas glass and aluminum are also used, they of course can be recycled and do not necessarily end up in the dump. Speaking of dump, as my kids grew out of disposable diapers, I needed a use for the surplus: solvent spills. In fact, if left outside for a few days, the solvents dissipate and the diaper can be reused. Of course for the larger spills one can use Depend®, but that will be saved for the future Tips From the Geriatric Ward. One other recycling material, speaking of by-products, is the saliva excretions from the child's mouth. For those that must have their children with them, their drool is pure and probably not tainted with adult contaminants. I understand that Richard [Wolbers] is going to publish a bootleg recipe list of infants drool based on regions and socio-economic strata. As my children got a bit older, and began eating sort of real food, yogurt containers became useful as mixing cups that could be reused or thrown away; the larger one for larger varnish brushes. None of the solvents that are common in the lab seem to affect them. Of course, tuna cans or tin cans can be used, but there are recycling alternatives to them. Needless to say, the ecological factors should be considered when these materials are used, but there is also a cost factor too. Many of the aforementioned articles can be bought from medical supply houses and such, but at a greater cost; especially the diapers and yogurt cups.

I would like to thank Christine Cooney, my assistant, and her parents, Debbie the producer and Paul. Paul, who is staff photographer at the Detroit Institute of Arts was very instrumental in the taking of the pictures. One final note: When I was asked to present this talk, last year, I found it very difficult to round up the formula jars, since my supply had long since been used up. This year, however, I have been resupplied. It only took a little incentive like Micah Carroll Katz, born May 7. If anybody would like some jars, please write. The nurses at the hospital were only too willing to supply me with one day’s supply: 100!

c/o Conservation & Museum Services, 743 Baubien Suite 345, Detroit, MI 48226
Electric Bottle Warmer & Rheostat

Mark Van Gelder, Paintings Conservator

An electric baby bottle warmer, plugged into a rheostat instead of directly into an electrical outlet, is a convenient way to warm small working solutions of gelatin, sturgeon glue, solutions of heat seal adhesives, etc., that would typically be kept warm during use, such as in a pan of water on a hot plate. The Evenflo Bottle Warmer I purchased cost $18 and is model number 41201, made by Evenflo Products Co., 771 N. Freedom St., Ravenna, OH 44266; Telephone: (800) 356-BABY (in Ohio dial (800) 233-BABY). The well in the top of the warmer fits a 100ml beaker (and, of course, a baby food jar) very nicely. The original instructions call for adding 2 teaspoons of tap water to the well (distilled water won't work because it doesn't conduct electricity) and then plugging the warmer in. With that setup, the water will come to a boil in about 5 seconds, and any more than about 2 teaspoons of water will boil over. Frequently refilling of the well is therefore necessary if working for any length of time. However, with the warmer plugged into a rheostat, the temperature of the water can be almost instantaneously adjusted, and the well can therefore be filled to any level. Be sure that the rheostat you use is sufficiently rated to handle such heating devices. When setting up, I initially set the rheostat at 100% power until the water has almost come to a boil, and then reduce the setting to around 25% power to maintain the temperature. The Evenflo has a safety feature that automatically shuts the warmer off if the water completely boils away, and its double wall construction keeps the outside cool.

A related tip is to tightly cover the top of the adhesive container you are warming with aluminum foil and use the back end of a brush to punch a small access hole in the center of the foil. This greatly reduces the rate of solution evaporation from the warm solution, thus maintaining the original adhesive concentration for a longer period of time.

Modification to a Soldering Iron/Ruling Pen Tip

Mark Van Gelder, Paintings Conservator

Some of the small soldering irons which can be modified to hold a ruling pen, as per Studio Tips I (AIC Paintings Specialty Group Postprints, 1989), unfortunately have rather long metal shafts. On these irons, the length between the handle and the working end gets very hot during use, making the tool difficult to wield and work with precisely. The metal shaft can be insulated using a drilled out wine bottle cork. After the center of the cork has been drilled out with an ordinary drill bit, it can be slipped over the metal shaft to extend the handle area, or appropriately positioned to provide a rest for steadying the tip with the other hand.

c/o Huntington Gallery, Univ. of Texas, 23rd & San Jacinto, Austin, TX 78712-1205
A Scalpel Blade Tacking Iron Tip

James Bernstein, Paintings Conservator

A simple but effective apparatus is a heated knife, particularly useful in the separation, paring down or removal of old hardened fills, adhesives, or other stubborn materials, where both heat and sharpness are desired. To fabricate a hot knife with readily replaceable, vari-formed blades, a steel scalpel blade holder is sawed off above the handle, just below the region where blades snap onto the tip. The upper mounting bracket is then placed parallel (yet slightly pitched, e.g., at a 10 degree angle) against the barrel of a substantial soldering iron tip, and welded permanently into place. Since high temperature brazing is required and such equipment may not be on hand, a metals fabricator or objects conservation colleague may be sought out to perform the operation.

c/o Conservator of Fine Paintings, 4353 24th Street, San Francisco, CA 94114

A Small Portable Rheostat

M. Randall Ash, Paintings Conservator and Hays Shoop, Conservation Technician

An inexpensive and handy little electrical regulator for use with low-wattage tacking irons is the Heat Control Unit available from Mohawk Finishing Products. Heat is maintained at desired working ranges via a rotary dial, with settings 0 to 10, and an “off” setting as well. Product No. 900-H700, costs approximately $40 and comes from Mohawk Finishing Products, Rt 30 North, Amsterdam, New York 12010. Tel: (518) 843-1380.

c/o Rocky Mountain Regional Conservation Center, 2420 S. University Blvd., Denver, CO 80208

Rectangular Storage Bottles

Steven Prins, Paintings Conservator

To conserve precious materials storage space in the studio, we use square plastic storage jars, made of high density polyethylene. Their wide mouths make them useful for storing dry resins, adhesives, pigments, inert, etc. Our vendor provides them in 4 useful sizes:

- 16 oz. (41360EY) @ $21.05 / doz.
- 64 oz. (41364EY) @ $32.80 / doz.
- 32 oz. (41362EY) @ $27.80 / doz.
- 128 oz. (41366EY) @ $40.80 / doz.

The vendor is Consolidated Plastics Company, Twinsburg, OH. Telephone: (800) 362-1000.

c/o Steven Prins & Company, 1570 Pacheco Street, Suite E-13, Santa Fe, NM 97501
This studio tip is about a tool used during the consolidation of a painting, gouache on laminated paperboard, titled *Machine Sans Nom* (1915) by Francis Picabia. The black, white and silver metallic designs were stable, it was the red gouache which resembled tiny cornflakes with associated flaking and loss. The linear red design varied in width between 1/16" and 5/8". After local humidification (using the bottom of a Silo cup which was cut to hold a saturated blotter and topped with a urine specimen cup) the area was infused with the chosen consolidant (2% Klucel in denatured alcohol). The problem was what to use to 'tamp' the relaxed flakes back in place. The gouache was matte and typical small tools like probes, spatulas or Chinese bamboo ear wax cleaners tended to burnish areas; while very small cotton swabs tended to frazzle or fray picking up pieces of gouache.

Finally a magic marker was tried - specifically a Berol Boldliner F-30 manufactured by Empire Berol USA. The inky cartridge was removed from inside the markers barrel and the nib flushed with alcohol, followed by distilled water until it was clean. It was allowed to dry (tested against a blotter and a painted out sample of gouache to determine cleanliness and dryness before use). It was found that the extruded nylon nib was small enough, soft yet firm enough and did not burnish the matte gouache.

Different markers by other manufacturers were tried but it was found that some tended to split into the nib picking up bits of gouache.

1. outer cup
2. saturated blotter
3. inner cup - bottom cut to allow moist air movement
4. mylar with opening cut exposing area to be consolidated
5. Berol Bold-liner

---

1 Empire Berol USA, 105 Westpark Drive - P.O. Box 2248, Brentwood, TN 37027-2248. (ph. 615-371-1199)
I attended the Studio Tips session in Buffalo, New York essentially as a layman. I am not a Conservator, but rather a stretcher maker, an adjunct perhaps, to the field of Art Conservation.

From this vantage point, the general tenor of the session made me keenly aware of a striking lag in the state-of-the-art in stretcher design as compared to other tools used in the field.

For example, it was clear, even to a layman, that many of the practitioners at the session were on the cutting edge in the discipline of chemistry, embracing relevant developments as they surface in this major worldwide industry.

It occurred to me that there is no parallel major industry concerned with the stretching of painted canvas, perhaps explaining in part why some fundamental aspects of stretcher design have remained essentially unchanged for centuries. Consequently, design solutions to the unsolved problems of canvas expansion must come from within the field of Art Conservation.

The logical starting place for problem solving in stretcher design is the canvas itself. The childhood of canvas fibers may begin innocently enough in the sunny fields of Flanders, but the easy life, for some, comes to an abrupt halt at the weaving loom.

There the warp fibers are subjected to serious tension, hard labor, so to speak, while the weft fibers are shuttled back and forth under little or no tension. As a result, the warp fibers in canvas become prematurely aged in the weaving process, losing much of their "elasticity," while the weft fibers remain young and supple.
Surely this is a house divided, yet this disparate set of fibers must spend their lives together, supporting a sometimes precious and irreplaceable paint film. It is because of this disparity that canvas expansion is eccentric and is due most often to the "failure" of the warp fibers to "recover" from environmentally induced stress.

Logically then, maintenance of the paint film on a flat plane often requires keying-out in one dimension only, and the inevitable question that must be asked is, "Do conventional stretchers currently in use offer this option?"

To my knowledge, they do not, for the following reason. It was stated earlier that the canvas stretcher has remained fundamentally unchanged for centuries. The fundamentals referred to are: (1) The rectangle is constructed of four bars of wood, and (2) The rectangle is expanded by the application of force at the miters.

It may seem, at first glance, that there is no alternative to these design features, but, as we shall demonstrate, there is. Further, these two concepts, virtually accepted as stretcher truisms, are in fact the root cause of the inability to offer controllable one-way expansion.

Analysis of these two seemingly permanent features reveals that physical law gravitates against one-way expansion in this configuration. When two stretcher bars abut at the miter, each represents one of the two dimensions of the rectangle, one representing the height, and the other the width. The problem then becomes one of forcing open the miter by moving just one of the bars without disturbing its neighbor, for if both bars move in the process, we have two-dimensional expansion.

The crucial fact here is that in order to open the miter, each bar must push off the adjoining bar, for there is nothing else to serve as a springboard. When a wedge, for example, is driven into a miter formed by two adjoining bars, physical law mandates that both bars move. Of course, one can start by bypassing the miter and tap out a single bar without using the wedges. However, one is left with loose wedges, and the bar will not be able to maintain its new position unless the wedges are driven in securely. This is the moment of truth, when two-dimensional expansion will occur.

The wedge itself however, is not the critical factor. Rather, it is the application of force at the miter that is the real culprit. The contemporary expansion bolt stretcher, aside from its other advantages, is even more insistent on two-way expansion when keyed-out.

What is important about the option of one-way expansion?

Two-way expansion insists that weft fibers must be stretched when keying-out, whether they need it or not! This results in unnecessary stress, which in turn, is transmitted to the paint film. Clearly, this negates the principle of minimum stress.

One solution to this long-lived problem of stretcher design is to abandon the miter as the focal point of expansion. A neutral fulcrum has been devised that allows each bar to be moved independently without disturbing its neighbors.
Here you see a stretcher bar doing just that. (Figure 1).

Figure 1

If you sense something unusual about this conformation, you're right, for you're looking at a design that has abandoned both of the stretcher truisms mentioned earlier.

1. It is made of eight bars rather than four, and

2. It is not keyed-out at the miter, but along the length of each bar.

It works as follows: Four of the bars form a rigid internal frame permanently joined at the miters, a traditional strainer, in fact. This fixed frame is nested inside four abutting outer bars, each attached to its inner mate by internal dowels. Expansion
bolt inserts move the outer bars individually, thus expanding the stretcher. As can be seen, the miters open in the process, but adjacent bars stay put, for they are not physically involved in the applied pressure.

The option of truly moving one bar at a time results in full control of expansion, both in dimension and degree, eliminating frequent involuntary stress of weft fibers.

Further Ramifications of This New System
(1) Bars can be keyed out at just one end (Figure 2), so that the stretcher can be shaped to conform to out-of-square paintings or to respond to local problem areas.

(2) On larger stretchers with crossbars, there is a further option. At each juncture of crossbar and perimeter, an expansion insert is added (Figure 3). This is done for the usual reason, to support keying-out pressure over long spans. However, it serves an additional function as well, for if one keys out at the crossbar only, the outer bar is sufficiently flexible to bow out, offering the further option of curving the stretcher perimeter to conform to eccentric figures.

(3) The fixed internal frame enhances the structural rigidity of the unit as a whole, reducing the "floppy joe" syndrome associated with larger stretchers.

Conservators working with this new tool have already extended its applications. Any and all feedback from the field on a theoretical or practical level will be appreciated and given serious consideration.
A Review of Varnish Application Fundamentals

James Bernstein, Paintings Conservator

This session is about studio practices, our experiences with materials and methods, and the results we achieve -- both positive and negative. Perhaps there are no lessons better learned than those learned from direct experience. Two maxims come to mind regarding varnish application. The first is Joyce Hill Stoner’s recommendation, “If the system works, don’t monkey with it!” She was describing a wonderful 16 year old Chiron sprayer at Winterthur that, although “gooped up”, produced beautiful results as long as nobody fooled with it. The second timeless maxim comes from the late Professor Rostislov Holpoft, memorable Professor of Objects Conservation at the Cooperstown Graduate Program. I can still hear him admonishing his students (in a heavy Russian accent), “Oh my dears, how many times I ask myself, how many times ruined, ruined because I tried to do too much and didn’t stop when I was ahead. I beg of you, please don’t do it! Believe your beloved Professor when he tells you ‘Better is the enemy of Good’.

Today is a good day to ask ourselves, “how many times ruined”? Is there a conservator who has not experienced reticulation (orange peeling) of that one more application of varnish, necessitating the removal of all varnish and weeks of exhaustive inpainting? We can all agree that there is much to be said for getting to know one’s repertoire of materials and techniques intimately, knowing when and how to proceed, and knowing exactly when and how to stop. Let’s look at some of our experiences and procedures relating to varnish.

Because the topic of varnish application is so voluminous, I will only be touching upon selected principles, focusing upon the handling and studio aspects. Readers are referred to conservation and manufacturer technical literature for further discussions. For a lucid primer illustrating basic concepts of varnish application, Louis Pomerantz’s book Is Your Contemporary Painting More Temporary Than You Think? (Chicago, 1962) is an excellent starting point. The text Feller, Stolow and Jones, On Picture Varnishes and Their Solvents (Washington, D.C., 1985) illucidates varnish formulation and behavior in great depth and is a superb work for repeated reference. C.V. Horie’s Materials for Conservation. Organic Consolidants, Adhesives and Coatings. (London: Butterworths, 1987) is an excellent companion volume, also including Teas solubility charts for a variety of polymers. More recent findings and contributions appear in the IIC Preprints for the 1990 Brussels Congress, Cleaning, Retouching and Coatings. (London) and in selected articles in IIC’s Studies in Conservation (London) and AIC Bulletins, Preprints, and Postprints (Washington, D.C.) In addition, the series of informative booklets from the Federation of Societies for Coatings Technology, Federation Series on Coatings Technology and the New Series on Coatings Technology (Blue Bell [formerly Philadelphia] PA: FSCT,1973 - present) offer introductory material on varnishes and paints as used in the coatings industries.

VARNISH APPLICATION PRINCIPLES

Every varnish scenario has the following components or variables: RESIN, SOLVENT, ADDITIVES, APPLICATION SYSTEM, ENVIRONMENT, & THE UNIQUE CHARACTER OF THE PAINTING TO BE VARNISHED. For each subcategory there are further variables, making the subject of varnish application extremely complex and challenging. For the painting conservator concerned with the full scope of varnish effects, varnishing a picture is not, as much of the world may think, simply a matter of taking a solution out of a jar and brushing it on.

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Looking at the first component, the RESIN or primary non-volatile component of varnish, one observes physical properties that are directly linked to performance properties. For the most part, resins may be grouped or characterized according to the class (painting conservators being interested primarily in thermoplastic polymers) and size of the resin. Individual resin structures may be referred to as small, moderate, or large in molecule size. It helps to visualize a particular resin alongside other resins, to compare its size, behavior and properties. Feller’s three dimensional chart *Key Physical Properties of Thermoplastic Resins* {Figure 1 in Feller, *Problems in the Investigation of Picture Varnishes* [ in IIC, Conservation of Paintings and the Graphic Arts. Preprints of the Lisbon Congress 1972. London: IIC, 1972. pp. 201-205.] is an invaluable resource for this purpose, comparing sward hardness, solubility grade and viscosity grade of familiar thermoplastic resins. Observations from practical handling, studio experimentation, and natural aging confirm theoretical and laboratory induced predictions. While there are occasional exceptions, definite generalizations can be made that hold true for many varnish resins.

Typically, SMALL molecule resins have a low viscosity, are easy to handle, have good to excellent wetting properties, have a low initial solubility (dissolve in mild aliphatic/aromatic solvents), produce good gloss, may have a low glass temperature (resulting in cold flow or tackiness), tend to be brittle, have poor abrasion and fracture resistance, are susceptible to moisture and bloom, discolor with age, and may require increasingly aromatic and polar solvents to remove.

Conversely, LARGE molecule resin varnishes have a high viscosity, may be difficult to handle, may level and wet only moderately well, usually initially require more aromatic or polar solvents to dissolve, have greater plasticity, are more elastic and scuff resistant, grey upon aging, and while moisture resistant, can behave like a skin, that may on occasional instances delaminate with aging.

In addition to molecular weight, characteristics of resins include: solvency parameters, volatility, flash point, evaporation characteristics, surface tension, odor, and toxicity.

Conservators desire the best properties of all resin worlds. Frequently, traditional paintings are given a preliminary varnish of a small molecule resin to fully ‘wet’ and saturate the paint. Upon completion of filling, inpainting and additional varnishing, the painting may be given a thin application of a larger molecule varnish to provide enhanced ‘skin-like’ protection to the exposed outer surface. An alternate practice is to combine resins in solution, to produce a hybrid product; Binney & Smith’s Soluvar® Picture Varnish is such a combination. Getting two (or more) resins to work well together in solution and in film forming requires very special solvent blending and formulation, feats not easily achieved. An ideal would be to have resin structures designed and fabricated specifically for conservation picture varnish use. Conservators and conservation scientists have not explored these realms to their fullest potential, frontiers that may hold promise for the future.

FORMULATION AND DILUTIONS
A language problem, a veritable *Tower of Babel*, exists when conservators compare varnish formulations. Each practitioner has a favorite way of visualizing, preparing and describing varnishes. When assessing recipes and concentrations of solids, it is very important to ascertain the method of solution computation. Specifically, is the percentage of resin-to-diluent in a varnish solution a ratio of: 1) Volume/Volume (v/v), 2) Weight/Volume (w/v) or 3) Weight/Weight (w/w)? A 10% solution of a resin in a solvent computed in one manner, will be very different from a 10% solution formulated in another manner.

Conservators may also become confused when diluting an existing varnish solution. The math can get complicated, so it is handy to display a copy of Pearson’s Square for simplifying dilution calculations near the solutions workbench. This formula and examples of its use appear in Harold Plenderleith’s, *Conservation of
Oftentimes, varnish solutions are like porridge at the Three Little Bears' house. One frequently hears, "My varnish is too thick...", "My varnish is too thin...", and every once in a while, "My varnish is just right!" For each resin, there is ideal ratio of solids to solvent for favorable viscosity and handling. For instance, Acryloid B-72 works well as a brush varnish in concentrations from 10% to 15% solids (w/v); spray varnish concentrations have to be lower, e.g. concentrations from 5% to 8% (w/v). With a smaller molecule resin, such as damar, solids can be higher, such as 12 to 20% for a brush varnish and 6 to 14% (w/v) for a spray solution.

A thick varnish solution produces high gloss, good filling and saturation, but may not flow well due to the high viscosity of the solution. By contrast, a thin varnish solution produces a lower gloss and is easy flowing (due to the low viscosity). If excessively thin, however, the fluid can flow through a painting structure soaking and impregnating the canvas reverse. The particular painting structure under consideration is very important, since each picture has its own unique absorbency or non-absorbency of varnish.

**SOLVENTS**

Complicating things further, the behavior and handling properties of a resin may change depending upon the SOLVENT selected for solution. First and foremost, the solvent(s) chosen must fall within the ideal solubility parameter range for the resin under consideration. Next, the evaporation rate of the solvent will have a major effect on the handling. If a solvent is too fast evaporating, there will not be enough working time, resulting in dragging and brushmarks, or if spraying, stringiness or granularity. If excessively fast, condensation of moisture may occur on the cooled painting surface, producing a milky finish. Conversely, if the solvent is too slow, excessive running or creep may occur, or lower layers may become swollen or may actually move, resulting in reticulation throughout.

Conservators often varnish with individual pure solvents, e.g., 100% xylenes, or 100% toluene, so that they may predict the exact behavior of a particular solution. At times, less-than-ideal solvents may be used, such as turpentine, because an effective replacement providing the same working properties may require a complicated mixture of solvents. For varnish formulation, mixtures of a variety of solvents can be highly effective, approaching the swelling and solution of the resin from numerous solubility directions, and allowing more evaporation control, extended manipulation time, and improved film forming. The paint and varnish formulation industries use solvent mixtures to great advantage; conservators and conservation scientists need to research more sophisticated solvent mixtures for improved resin formulations for conservation.

Classification, solubility parameters, evaporation rates, toxicity, flammability, and other statistics are displayed in Shell Chemical Company's helpful Solvent Properties Chart (Publication # SC-83, available from Regional Offices in Atlanta, Chicago, Cleveland, Houston, Los Angeles and West Orange, NJ.). This chart is a must for every conservation studio!

**ADDITIVES**

Additives include ultraviolet absorbers, ultraviolet inhibitors, flattening agents and other substances. Recent research indicates that the life span of selected resins, particularly the smaller molecule types, are extended with the judicious addition of small (but critical) concentrations of ultraviolet absorbers or stabilizers. René de la Flie describes the tip of pre-diluting the stabilizer fluid to facilitate addition of the correct amount of stabilizer to a freshly prepared varnish solution. (see de la Rie, *Hals-Stabilized Dammar Varnish*, *AIC News*, Jan. 1992, p.16. Hypodermic needle cartridges, with numbered cc and ml demarkations, work nicely for accurate measurement of small quantities of fluid additives.
Siliceous pigments and other transparent or semi-transparent particle matting agents are frequently added to proprietary resin solutions to produce "matte" varnishes. These varnishes produce a satiny low sheen that hides a wealth of ills, but also can spell death to the color and luminosity of a painting. The same particles that produce the matte finish act as a colloidal veil, killing the character of the paint. I am not a fan of "matte" varnishes and my preference is to achieve matting by control of the varnish application, not by adding clouding particles. If to be used, "matte" varnishes should be used sparingly. Since matte varnishes usually contain a considerable amount of matting agent, diluting the "matte" varnish with the equivalent clear varnish product can produce an adequate, less extreme result. The addition of a small quantity of wax, either to the final varnish, or in an application on top of a fully set final varnish, is another surface modifying technique, often associated with "European" restoration traditions. For varnishes resistant to aliphatic hydrocarbon solvents, wax may be removed and then reapplied without dissolving the varnish, similar to rewaxing a table-top. Of course, there is the concern for the physical polishing action required to buff a wax polish. And there is always a certain dirt-collecting potential inherent with semi-soft wax surfaces.

Whether additives are added to a varnish or not, it is essential to filter every prepared varnish solution through very fine mesh sieves (e.g., the wide-mouth funnel sieves available from Binks Manufacturing Company) prior to application.

**BRUSH VARNISHING**

Brush varnishing is the classic method of varnish application and is ideal for the preliminary saturation and sealing-off of paint surfaces that are to receive varnishing in the "traditional" (a continuous, wetting coat of resin) manner. Because the varnish is moved about the painting surface by physical manipulation, brush varnishing (or padding, if a pad or textile wad applicator is used) allows for repeated feeding of lean or leached areas and filling of interstices to produce a continuous saturating coating with minimum specular reflection.

The technique I use for brush varnishing proceeds as follows. A varnish solution of appropriate viscosity is prepared and then transferred to a low profile, wide-mouth, weighty (tip-proof) vessel. The vessel is filled with only a shallow volume of varnish, so that the solution will wet only the lower tip of the brush (1/4 to 1/3 the total length of the bristles). Preferences for varnish brushes vary considerably. Some (the author included) prefer small, bright bristle brushes, 1 to 2-1/2 inches in width. Others prefer larger brushes, 3 to 5 inches wide. The behavior of the brush will vary depending upon the length of the bristles and the thickness of the bristle pack and ferrule. Short bristle, thick brushes are able to move thicker, more viscous varnish solutions, and are suited for physical working of the varnish, such as pushing the varnish into crevaces, or matting down the varnish with continued brushing as the varnish sets up. Long bristle, thin brushes work nicely with lower viscosity solutions, enabling the varnish to flow through and past the bristles, filling interstices and leaving a smoother, more level finish.

Smaller pictures are usually brush varnished lying flat to prevent sag; larger paintings generally require upright application. Prior to proceeding, a varnish application strategy must be determined. For this, the boundaries to be covered with each brush dip of solution need to be envisioned. At times, the varnish is applied in overlapping parallel rows, edge-to-edge across a canvas. Other times, varnish is applied in square or rectangular sections, following a grid of overlapping regions. Still other times, varnish is applied in free-form sections, following compositional features or outlines. Many conservators use a combination of these approaches, depending upon the picture, the varnish solution and considerations unique to each treatment.

Before dipping and brushing, estimate the amount of coverage possible for even distribution with each dip. When proceeding, always place the loaded (remember, only partially) brush in the middle of the section to be
covered. The solution is then spread out until evenly saturating the entire section. The next dip is placed in the center of the next area to be covered, not directly adjacent to previously varnished area. After filling the present section, the still wet application is often finished with quickly brushed, low angle strokes, lightly overlapping the wet varnish across the transition edge where it meets the previously applied, partially set varnish field. The painting is varnished thusly, going from section to section until complete.

When sufficient brushing time is possible, the varnishing may be finished with continuous light strokes across the entire length of the painting, using the same varnish brush without dipping again into the varnish solution, or finishing with a clean, thin bristle brush. My preference is to finish with strokes beginning from the bottom of the canvas, moving to the top. This can help to fill the undersides of the weave or impasto strokes, reducing banding, shadows and specular reflection (since paintings are lit mostly from above). Mark Leonard (IIC, Cleaning, Retouching and Coatings, London, pp. 174-176) describes the technique of picking up excess varnish with clean badger hair blender brushes so that a satiny, thin varnish film remains.

**SPRAY VARNISHING**

Spray application of varnish enables great control of the quantity, gloss and uniformity of the resin deposited. A major benefit of spray varnishes is that they may be applied without direct contact with, and physical disruption of, the painting surface. Instances where this is crucial are where paintings have friable or flaking paint, requiring introduction of a consolidating resin or varnish; or paintings with recently applied (or in-progress) retouchings, that would be altered or removed with the action of brush varnishing. For contemporary paintings, spray application is also used for the uniform introduction of extremely dilute resin solutions, where the “varnish” serves not as a surface modifier but primarily as a thin protective fixative or consolidant in an otherwise open and "unvarnished"-looking paint layer.

Many conservators favor a hybrid technique. A preliminary saturating coat of varnish is applied by brush, followed by successive, thinly built-up finishing spray applications of varnish.

Most spray systems depend upon compressed or accelerated flow air to draw, atomize and disperse a varnish solution. The type of spray system and equipment has a major effect upon the results. The most elemental is the atomizer, using either lung or hand-pump air pressure and Bernoulli suction to draw a solution up a tube, dispersing it into a spray. This method has largely been abandoned due to superior systems of atomization available. Small aerosol spray packs, powered by disposable propellant cans, also operate by external mixing and can be convenient for small jobs or on-site work. However, the atomizing mechanism remains primitive (the coarsely sprayed varnish may require brushing out) and some of the propellant compounds used for pressurization present environmental biohazards.

Electric compressors compress air to elevated pressures, and are rated for the CFM or cubic feet per minute they can deliver at a given PSI or pressure per square inch. The compressed air is frequently forwarded to an air reservoir tank, from which even flow of pressurized air is possible for a sustained spraying period. In the process of being compressed, the air is chilled and the relative humidity level increases dramatically. A moisture and oil filter trap, an air pressure gauge, and an air regulator are placed on-line to modify the air before it reaches the spray apparatus and artwork.

Air brush sprayers require low volumes of air flow (1 to 2.5 CFM) at pressures of 15 to 30 PSI, and are suited to small scale or detail work. Due to the fineness of the spray head and needle assemblies, air brushes enable very fine atomizing of low volumes of varnish solution and great control of the build-up and specific area being covered. While ideal for localized toning or building of varnish, they are not practical for large pictures where banding may result. For most painting spray applications, an industrial spray gun provides
the capacity and capability needed for a variety of varnish techniques. Spray guns require a minimum of 2.5 CFM to typically 4.0 CFM or higher; and a working pressure of 20 to 40 PSI. The gun and needle head housing may be small, medium or large and it is beneficial to have more than one spray head assembly to suit the requirements of different treatments. In addition to the size of the spray head, fineness of atomization and pattern of spray options, the type of air mix and type of solution feed vary tremendously. Other factors that affect spray results are the amount of air movement in the spray booth or outdoor setting (for those who spray out-of-doors), and the ambient temperature and humidity conditions. It is important to observe the weather and air conditions in your locale prior to commencing with any resin coating application. For example, on a cold or humid day, the amount of air (CFM) and pressure (PSI) must be increased as varnishes would otherwise be slow to dry. Conversely, on a warm or dry day the amount of air and pressure must be decreased to allow sufficient film forming before the solvent evaporates.

Always pre-test spray settings and solutions on scraps of board or discarded X-ray film sheet, to observe the handling and forming of the varnish before attempting to spray any art. Once adjustments are made, spraying is begun at a far corner of the painting, continuing across the surface in an uninterrupted linear pass. Constant distance is maintained (e.g., 10 - 14 inches) and spraying proceeds past the outer edge of the painting, where a turn in direction takes place for the next, slightly-overlapping, parallel pass of varnish. Spraying continues in this manner until the entire surface is covered. For subsequent varnish applications, the spray orientation may be switched by 90 degrees (e.g., horizontal passes for the first coat, vertical for the second, and so on) to ensure uniform distribution.

An important precaution is never to spray a picture first thing in the morning fresh out of cold storage. Allow the painting (and studio) to warm up. For certain paintings, it is actually beneficial to gently pre-warm the painting surface, particularly oils on non-absorptive hard surfaces, such as metal (copper or tin) or wooden panels (wood, laminate or hardboard). Also, on a cold day, one might carefully warm the varnish solution in a \textit{bain marie} (warm water bath). Precautions must be taken that there be no open flames, active heating or hot elements in conjunction with open varnish in the studio. Always preheat the water prior to opening the varnish, remove the pot of water from the heating source and shut the heat, and then perform the warming in an explosion-proof spray booth or vacuum hood. Carefully warm the varnish solution in a covered metal spray container, with the cover seal left slightly open to prevent vapor pressure build-up. Another tip is to place a slightly larger cardboard behind the painting, extending beyond the outer edges of the picture. This will slow down the evaporation and improve glossing at the edges, which often dry before the wetter center of the painting has had a chance to set.

Because of frustrations with traditional air compressor-spray gun equipment that has been either inadequate, very lavish but not appropriate for their purposes, not understood or properly maintained, or the scene of many an unhappy coatings disaster, a number of conservators have switched to and prefer the Chiron SG90E blower and PN2 Spray Gun (available from American Distributors, 3085 54th St., San Diego, CA 92105) or similar type unit (available from W.W. Grainger Inc., locations nationwide), which use a low pressure, high volume air flow, warming the air before mixing it with the varnish. Warm air spraying reduces ambient moisture and improves film forming properties, and the low pressure will generally produce less overspray. The light weight air pump pack (working like a canister vacuum, only in reverse) can be worn on the operator's back, handy for large paintings where one has to cover alot of territory.

**MANIPULATION OF VARNISH AFTER APPLICATION**

It is important to remember that there are actually a number of stages of drying within an applied varnish film, which progress from the first few minutes of rapid evaporation of solvent and preliminary setting of the film, to the gradual curing and hardening that takes place in successive days, weeks and months. The de-
gree of solvent retention and 'set' at any given time in the life of a recently applied varnish must be judged and taken into consideration when any manipulation of the surface is attempted.

Manipulation of the varnish immediately following application (as it is setting up and drying) enables a diverse range of effects. One technique for dulling down a fresh varnish is to rub down the just-set surface with a fine sponge or a pad of silk cloth (wrapped around a cotton ball) wet with deionized water. The aqueous interface with the still somewhat solvent-swollen varnish, results in a falling out of the uppermost resin from solution, accelerating set-up and producing a soft satin finish. Conversely, if greater gloss and luminosity is desired, a just-varnished painting surface can be warmed gently with the radiant heat of a photographic or work lamp (preferably one encased behind a protective lens; no studio explosions, please!). The elevated temperature drops the viscosity of the solution, drives off any entrapped moisture and improves varnish film forming and clarity. Obviously, with either of these manipulations, great care must be taken, being sure that the painting under consideration is sturdy and can withstand short-term exposure to moisture or heat.

Some adjustments of varnish configuration can be performed after a varnish is fully cured. In fact, hard varnishes can be polished, hopefully very carefully, with super fine abrasive compounds, reducing gloss, film thickness or undesirable features such as entrapped linters or reticulation craters. Abrasive polishing is sometimes performed with 00000 steel wool, but in many instances is most successfully performed with a very fine alumina or silica compound. The rubbing compound is first dispersed in a lubricating solution of deionized water, then applied on a soft, damp cotton cloth. After polishing, the surface is thoroughly rinsed with deionized water-dampened cotton wool, followed by thorough drying. Lastly, the painting is given a thin finishing spray of varnish to reform and resaturate the surface. This technique, requiring great caution and not for every painting (a substantial base varnish must be present to protect the paint from abrasion and to prevent foreign matter from entering cracks or interstices), can produce remarkable results with smooth surfaced, unforgiving pictures, such as panel paintings.

VARNISH SITUATIONS AND SOLUTIONS:

SOAKING OR SINKING-IN
Situation: The varnish is sinking-in and is not adequately saturating or glossing the paint.
Solution: The varnish solution is either too low in solids concentration, or too slow evaporating a solvent is being used. Increase the resin concentration substantially, and use a faster evaporating solvent mixture. Successive thin spray applications of isolating varnish may be required, alternating varnishes with slightly differing (and thus isolating) resin solubilities. Localized building of varnish and gloss may also be needed.

Note: Sinking-in is not always a problem and may actually be desired. For example, with lean, 20th Century paintings, one may wish to introduce a small quantity of varnish as a consolidant or pigment saturator, producing minimum surface build-up or alteration of sheen. In such instances, low resin concentrations (2 to 4%) dissolved in slow evaporating solvents can be effective.

EXCESSIVE GLOSS
Situation: The varnish is excessively glossy and possibly too thick.
Solution: First wait several weeks to see if the picture dulls down by itself. The coating may be retaining solvent and may still be relatively swollen and shiny. If not the case, the surface may be dulled down by manipulation (polishing with wet silk or gentle abrasive), or dulled by varnishing with a highly aerated, dilute resin spray. In certain instances, excessive gloss may be brought down with a solvent spray outside of the solubility of the resin; this is described in an earlier Bernstein Studio Tip (AIC, Paintings Specialty Group Postprints, 1989, p.8). In the future, control glossing before it occurs by applying thinner varnish applications with lower resin concentrations, faster evaporating solvents and higher air pressure and atomization.
STRINGINESS
Situation: The concentration of solids in the varnish solution is too high for this resin, the solvent too fast evaporating, the solvent may not be the correct solubility parameter for the resin, and/or the air pressure and quantity settings may be too high.
Solution: Add more solvent to reduce the concentration of solids, add a slower evaporating solvent or a solvent of more appropriate solubility parameter, and reduce air pressure and quantity settings as appropriate.

FOREIGN MATTER
Situation: Cotton linters or foreign matter (brush hairs, grit, etc.) have become entrapped in the varnish.
Solution: There are two options. The first is to remove the foreign matter immediately, while the varnish is still very fluid and forgiving. Remove matter with micro tweezers or point of a needle or scalpel. Alternatively, wait until significantly later, when the varnish has fully set. The foreign matter can then be readily removed mechanically, with minimal disruption to the surrounding finish. Any slight break in the coating can be restored locally by dotting with a viscous solution of varnish on the tip of a fine point brush.

MILKINESS
Situation: The varnish has a slightly cloudy or milky appearance due to moisture entrapment. The ambient humidity was too high, or the solvent was too fast evaporating resulting in condensation of moisture at the painting surface.
Solution: A slightly milky or cloudy spray coating can be clarified by warming the painting surface slightly (with lamps or warm air blowers) to drive off the moisture; or by spraying with a slower evaporating, more polar solvent, to act as a bridge, grabbing and releasing the moisture trapped in the film. Don’t spray varnish on humid days, or if in a high humidity environment, add small amounts of slow evaporating, polar solvent to the varnish formulation.

GRANULARITY
Situation: A sprayed varnish has dried in the air before reaching the painting surface. The environment may be very dry, the solvent may be too fast evaporating, and/or the CFM air pressure and quantity settings of the sprayer may be too high.
Solution: Use a slower evaporating solvent mix, reduce the CFM air pressure and air quantity settings on the sprayer; possibly increase the concentration of resin solids.

BANDING
Situation: Alternate shiny and matte horizontal or vertical bands appear in the sprayed varnish. There is insufficient ‘wet time’ between rows of varnish application; the solvent mixture is too fast evaporating, the weather is too warm and/or dry, the air pressure and quantity settings are too high, the spray width pattern at the spray head is too narrow, and/or the spray booth air flow may be too high.
Solution: Use a wider spray width pattern setting on the spray head, increase the distance of the spray head from the painting (by 2 to 6 inches), use a slower evaporating solvent mixture, reduce the air pressure and quantity of the spray system, and reduce the air flow setting of the spray booth (if possible).

SURFACE TENSION PROBLEMS / RETICULATION
Situation: A surface tension problem is taking place between a new varnish application and previously applied varnish, causing movement of either the upper layer, the lower layer or both. The varnish solution is too thick or too thin, holding too much solvent or allowing solvent to travel; and/or the solvent used is too slow evaporating, the solvent used is too non-polar, the weather may be too cold and/or too humid, the painting may be too cold or non-absorptive, and/or the air pressure and quantity settings may be too low.
Solution: Never spray on excessively cold or humid days. Instead of heavy or wet applications of varnish, apply multiple thin, almost dry sprays, increasing air pressure and flow, and the evaporation rate of the solvent. Trace additions of polar solvents to the varnish mixture may assist in bridging conflicting surface tensions. If reticulation has already taken place, a varnish reduction or polishing treatment may be required.

INPAINTING OVER READILY RESOLUBLE VARNISHES

Many conservators relate difficulties or disasters when inpainting over readily resoluble varnish coatings, such as resins Laropal K80 and Arkon P-90. In these instances, the solvent in the inpainting medium causes the underlying varnish to swell, creep and move, forming tide or crater lines. When this occurs, the brush is usually holding too much paint and solvent. To correct this, try using a smaller size brush, e.g. drop from size 2 to size 1 or 0; or from size 1 to size 0 or 00. I prefer to dot on the color with the point of the brush, not stroke on the color with potentially disruptive lateral or vertical movement. Also, the inpainting solvent may be staying on the structure too long, or may be too close in solubility to the underlying varnish. Try adjusting the diluent formulation, replacing slow evaporating solvents with faster evaporating equivalents; or experiment with solvent additives of very different solubility parameter (e.g., alcohols). As an alternative, a thin spray application of a larger molecule or differing solubility isolating varnish may be applied over the base varnish, shielding it (partially) from the inpainting solvents.

CONCLUSION

This introduction only scratches the surface (pun intended) of a topic critical to painting appearance and preservation. Hopefully, this Paintings Specialty Group Session will encourage follow-up sessions directed to the practical discussion of picture varnishing. And don’t forget to watch ‘What’s happening to the weather in your part of the country today’!

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A Varnishing Technique Used by Mario Modestini

Dianne Dwyer, Paintings Conservator. [Presented by Julie Barten, Paintings Conservator]

After cleaning, etc., the surface of a painting is brushed with Talens Rembrandt Retouching Varnish (Laropal K 80 in white spirit). This thin varnish can be diluted with purified turpentine or mineral spirits, or made more viscous by adding Talens Rembrandt Picture Varnish, the same resin in a higher concentration, depending on the absorbency of the surface. Usually just enough varnish is applied so that the colors are sufficiently saturated to match when retouching. After the retouching is completed, any matte areas are brought up to surface gloss by locally varnishing with either the medium, PVA AYAB in alcohol (the Union Carbide resin which is no longer produced), or the substitute, PVA Mowilith 20, or with retouching varnish. The surface is then sprayed with a solution of PVA AYAB or PVA Mowilith 20 in alcohol and acetone. [Note: these resins do not dissolve easily in ethanol. Usually they are dissolved first in acetone and then diluted with ethanol. If the solution becomes slightly cloudy when diluted in ethanol, add a little acetone. Common hardware store “denatured alcohol” dissolves the resin easily.] The solution is approximately 5%. It can be checked by painting out on the fingernail where, it should leave only a slight gloss when dry.

This is sprayed on the surface, a light spray, a few times. It dries almost instantly. If it leaves resin dust on the surface, the gun is too far from the surface or the air pressure setting is too high. On the other hand, the varnish should not wet the surface. As with any other spray, the distance and the amount vary with the size of the painting.

After twenty four hours, more or less, depending on the weather, the surface can be given a second brush coat of varnish, the viscosity chosen according to the characteristics of the painting and the surface desired. If necessary, these steps can be repeated to build up a third brush varnish.

One advantage of the technique is that the isolating spray provides a sort of floor, evening out different absorbencies of the surface, allowing a leached or damaged surface to hold a brush varnish, sealing up uneven cleaning which had to be suspended for some reason or left partially cleaned. It basically gives an evenly sealed, evenly absorbing surface and allows the conservator to apply a second or third brush varnish without picking up the previous varnish. As you know, this is otherwise not possible with any resin except mastic. Another advantage is that the restorations “stay put”; that is, they will not later either drop, become matte, or become glossier than the rest of the varnish.

If the final brush varnish is too glossy, it can be dulled with a spray of retouching varnish or a spray of fast evaporating solvent (trichlorethane, or preferably, a less toxic equivalent) containing a small amount of white bleached beeswax (a disc of beeswax about the size of a dime, in six ounces of solvent). After a few hours the surface can be polished, which will make it shiny but not sticky looking; or brushed fairly vigorously with a soft but firm dry brush, which will give it the look of an aged varnish. Alternately, a matting agent, wax or fumed silica, could be added to the final brush varnish.

In a survey of paintings in eighteen Kress regional galleries completed a few years ago, paintings varnished using this technique had held up exceptionally well. After nearly thirty years, the surfaces had retained a
pleasant sheen and the varnish had not noticeably discolored. (The varnish used was always Talens Rembrandt. The resin has varied over the years but seems always to have been a polycyclohexanone, e.g., AW2, Ketone N or, recently, Laropal K80.) By comparison, paintings varnished a few years earlier by the same conservators using damar varnish showed significantly more yellowing.

The fact that the varnish showed so little discoloration over the years is partly due to the fact that the new varnish applications were minimal, another advantage of this method. Except in unusual circumstances, the total amount of varnish used was two brush coats of retouching varnish with a sprayed interlayer of 5% PVA AYAB.

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Masking Varnishes: Questions Regarding Formulations and Ethics

Chris Stavroudis, Paintings Conservator

Having noted an apparent increase in the number of paintings with a deliberate, fraudulent "masking" varnish applied to their surface, the members of the Paintings Specialty Group were asked to share information on the materials, methods and ethics of masking varnishes. The exchange was interesting. Many colleagues had not noticed any increase in the incidence of deceptive varnishes. Other colleagues expressed that the practice was definitely prevalent, particularly in the commercial sector of the art market. Some reported they had recently been taken in or fooled by an apparently aged-looking, opaque green fluorescing (under ultraviolet light) surface coating, that concealed recent retouchings. A few conservators shared apocryphal information on deceptive varnishes.

There are two types of varnish that distort interpretation of ultraviolet fluorescence examination: recent varnishes that include a dye or other particle that fluoresces like aged natural resin; and varnishes that absorb UV and are non-fluorescent, blocking the fluorescence of underlying layers. The latter category could include the legitimate use of an ultraviolet absorber in a varnish formulation. Obviously, the use of a varnish to deliberately deceive is unethical and contrary to the spirit and goals of conservation.

One conclusion of the discussion was the recommendation that conservators advise their curators, clients, and collectors not to place too much emphasis upon ultraviolet light examination, especially if inconsistent with other indications of examination and analysis. It is hoped that colleagues will come forward with more information about the appearance and detection of additives in coatings.
At the Painting Conservation Studio of the J. Paul Getty Museum, mastic natural resin is used to varnish many of the paintings in the collection. The method used in its application is the key to obtaining a beautifully saturating varnish without a heavy, overly glossy appearance.

E. Rene de la Rie, Conservation Scientist from the National Gallery has, in recent years, been conducting research on new low-molecular-weight synthetic resins for their use in paintings conservation.\(^1\) Experiments with some of these materials were conducted at the Getty to compare the appearance of the new synthetic resins to the mastic natural resin.\(^2\) Following is a summary of these studies with notes on application methods of both mastic and Arkon P-90.

Test panels, prepared with oil paint and artificially aged at the Getty Conservation Institute, were used as surfaces on which to apply Arkon P-90, a hydrogenated hydrocarbon resin, an experimental aldehyde resin varnish manufactured by BASF\(^3\) and mastic. Due to the irregularity of the aging of the paint on the test panels, it was difficult to access the appearance of the different varnishes on them.\(^4\) A Dutch panel painting, Portrait of a Man by Govaert Flinck was treated and used to make side-by-side mastic/Arkon varnish comparisons.

Mastic resin is used in repeated applications of very thin solutions of approximately 5-10% in turpentine.\(^5\) A small amount of solution is brushed on the painting. The painting is then brushed out, using the same varnish brush, until the varnish is absorbed. Finally, a badger-hair brush is used to brush lightly and quickly across the surface to pick up any excess varnish. A drying period of several days to several weeks between brush coats is allowed. Subsequent coats are brushed out until a slight tackiness can be felt. Badger-hair brushing follows these coats as well.

After cleaning the Flinck, Portrait of a Man, the right half of painting was masked with mylar attached with drafting tape. The left side of the painting was varnished with mastic using the method described above.\(^6\)

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3 Ibid, de la Rie, p.169.


5 Ibid. Leonard discusses this method in detail.

6 Tinuvin 292, hindered amine light stabilizer, (2% by weight of the resin) was added to all the varnishes according to the recommendations of Rene de la Rie.
After experimenting with different concentrations of Arkon P-90, a 25% solution in Shell Sol 71 was applied to the right half of the Flinck portrait. Due to the slow evaporation of the Shell Sol 71, extensive brushing of the Arkon varnish and final badger-hair brushing (similar to the application method of mastic) was possible. Subsequent coats were sprayed, followed by badger-hair brushing.

The Arkon P-90 had excellent saturating properties; the two coatings were judged to be virtually indistinguishable.

Both varnishes were removed from the painting and the treatment was completed using the Arkon P-90 varnish. One difficulty encountered in the use of the resin was that, due to the ease of solubility, it was easy to pick up the resin as I inpainted. With some time and patience, I found I could control this tendency as long as I did not try to rework an area without thorough drying time between successive applications of inpainting. Excessive gloss can also be difficult to control. The use of matting agents may resolve this difficulty.

SOURCES:

Arkon P-90 is available from Arakawa Chemical (USA) Inc., 625 North Michigan Avenue, Suite 1700, Chicago, IL 60611.

Mastic resin can be obtained from specialty Greek food importers.

Shell Sol 71 is available from Shell Oil Company distributors. Contact Shell Oil Company, Houston, TX 77251.

Tinuvin 292 is available from Ciba-Geigy Corp., Plastics and Additives Division, Three Skyline Drive, Hawthorne, NY 10543.

Badger-hair brushes are available from New York Central Art Supply, Inc. 62- Third Avenue, New York, NY 10003 Ph. (212) 473-7705. (A four-inch brush is recommended.)

7 50% and 35% solutions initially applied appeared far too glossy.

8 On the Flinck portrait the inpainting medium was an undercoat of gouache followed by a spray Arkon varnish and Maimeri Restauro Colore glazes using Arkon as medium.

9 Chris Stravroudis, Paintings Conservator in Los Angeles, consulted with me on the use of the matting agent in Soluvar Matte: by successive rinsing in xylene and decanting off of the dissolved resin, the matting material can be separated and added to the Arkon solution. I have not yet experimented with the addition of silica, wax or other matting agents directly into the varnish solution.

Up-date on Varnish Resin Research at the National Gallery of Art, Washington, D.C.

Suzan Lomax, Organic Chemist and E. Rene de la Rie, Head Scientist

[Research to be published at a later date]

c/o National Gallery of Art, Science Department, Washington, D.C. 20565