Cross-section Paint Microscopy Report
Exterior Paints

Tobias Lear House
Portsmouth, New Hampshire

For: Stephen Foster
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South and West Elevations

Purpose:

The goal of this project is to use cross-section microscopy and pigment analysis techniques to analyze and identify the paints on the original trim and clapboards of the north elevation of the Tobias Lear House. The house was built in 1740 and expanded to the rear in the 1760s. The original paints on the 1760s north elevation that remain *in situ* will be color-matched for documentation and possible replication with a colorimeter/microscope.

Procedures:

Susan L. Buck met with Stephen Foster on August 5, 2019 to examine and discuss the house and the information that could be gleaned from paint analysis. The exterior and the interior of the building were studied and sampled during this site visit, and the exterior paints were deemed a priority because of the restoration schedule. The painted surfaces were first examined at 30X magnification with a monocular microscope. Samples (about 300 microns in size) were then removed with a microscalpel and placed in labeled polyethylene baggies for transport.

The samples were first examined at 45X magnification with a binocular microscope and the best samples were selected for cross-section analysis. These samples were cast into polyester resin cubes for permanent mounting. The cubes were ground and polished for cross-section microscopy analysis and photography. The sample preparation methods and analytical procedures are described in the reference section of this report.

The cast samples were analyzed with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 5.1) for digital image capture and Adobe Photoshop CS for digital image management. Digital images of the best representative cross-sections are included in this report. Please note that the colors in the digital images are affected by the variability of image capture and color printing and do not accurately represent the actual colors.

Exterior Paint Analysis Results

The condition of the exterior paints is fragile and paints are actively flaking on many areas of the clapboards. The paints on the trim elements appear somewhat more intact than the clapboards, although there are accumulations of soot and grime, as well as blackish mold spores on many areas. The building has not been repainted for many years, but several neighbors observed to Stephen Foster that they had always known the house as being painted yellow.

One original clapboard, one sash and three different trim elements were sampled to search for the original 1760s paint on the rear elevation.

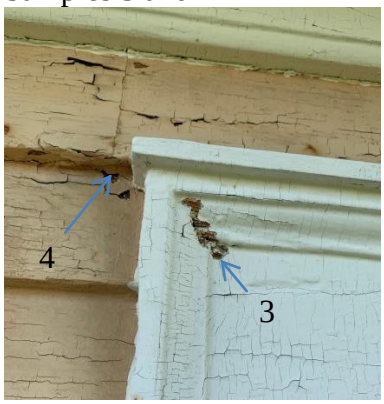
Exterior Paint Sample Locations
1. North elevation, arched window, backband molding, left side.
2. North elevation, arched window sash, upper portion of window, top left corner.
3. North elevation, window trim, top left corner of backband.
4. North elevation, clapboard above arched window.
5. North elevation, fascia of cornice.

Rear Elevation

Sample 1

Sample 2

Samples 3 and 4



Sample 5

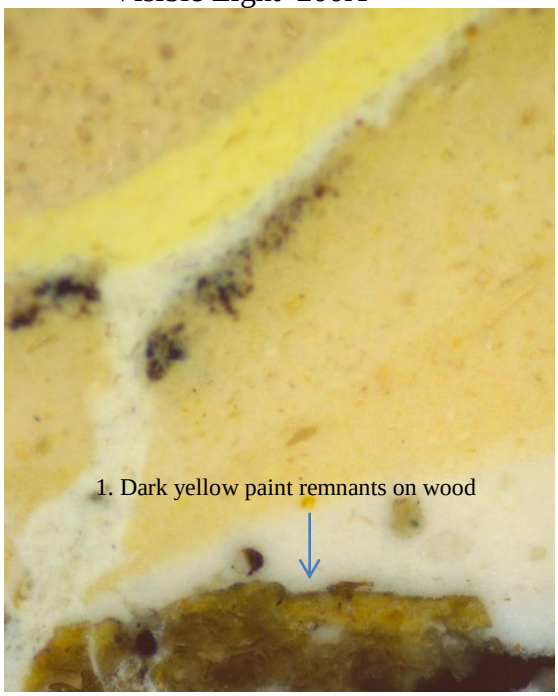
Cross-section sample 4 from the clapboard retains convincing evidence of the original coarsely ground, dark yellow paint on the clapboards. There are only isolated fragments of this dark yellow paint on the 1760s rear elevation, but it is directly on top of the wood, and is consistent in composition and weathering with an exterior paint of that period. This original paint could not be confidently separated out for pigment identification using plane polarized light microscopy, but in cross-section the coarse, irregular, dark yellow pigments are consistent with yellow ochre and raw sienna, in combination with white lead and calcium carbonate. Binding media analysis with biological fluorochrome stains confirms that all the paints contain oil components.

The paint layer stratigraphy is the clapboards are weathered and disrupted, but there are are still six generations of yellow paints which range in color from the original dark yellow, to pinkish-yellow, bright yellow and medium yellow. Most of the earliest paints are missing in this clapboard sample, likely from weathering and deliberate paint removal. So, the pinkish-yellow paint directly on top of the original paint was numbered as generation 8 because this same paint was found as generation 8 on the trim (see sample 1).

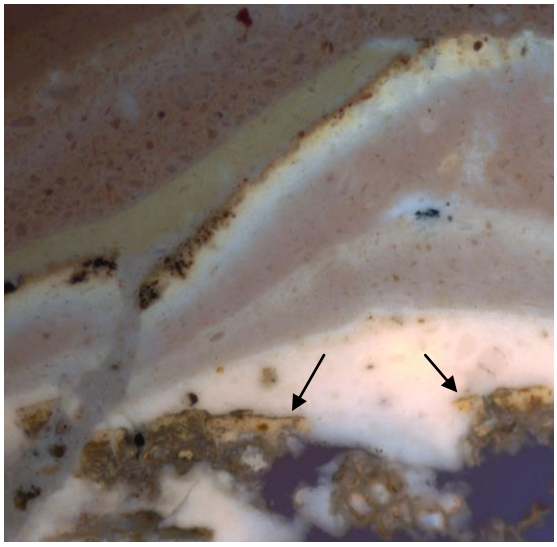
4. North elevation, clapboard above arched window.

Visible Light 100X

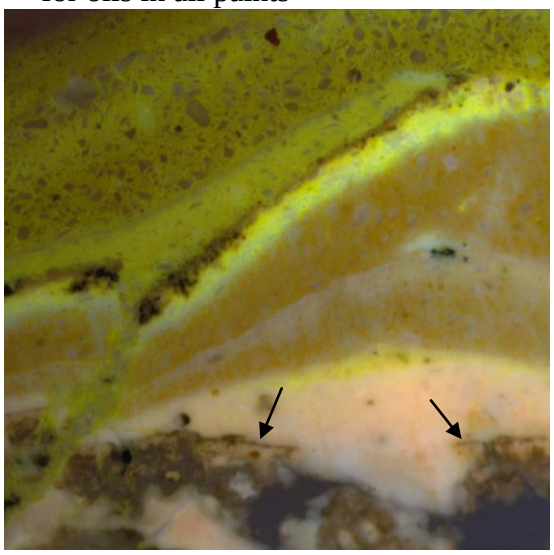
Visible Light 200X



Ultraviolet Light 100X



UV Light & DCF for oils 100X
+ for oils in all paints

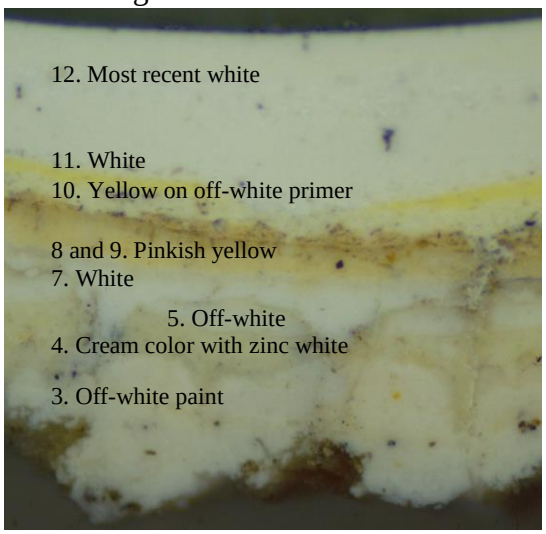


Samples 2, 3 and 5 contain remnants of the original off-white paint on top of the wood substrate. This paint is also dirty and fragmentary, but it is trapped in the wood fibers (see sample 5 from the cornice), confirming that it was the first paint applied to the trim elements. The pigments could not be confidently separated out because the original off-white paint is compromised by penetration of later coatings, but the pale pinkish- yellow autofluorescence of the earliest off-white paint is typical of a white lead-based paint in a linseed oil binder. The presence of oil in all the paints was confirmed with the fluorochrome DCF (see sample 5).

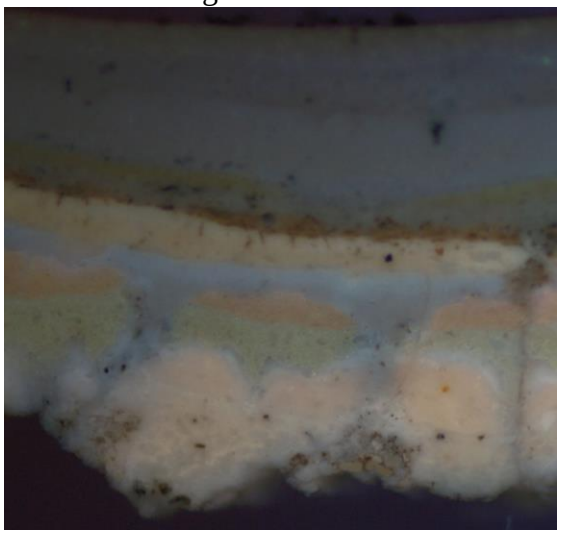
The comparative paint evidence suggests that the trim matched the clapboards in generations 8, 9 and 10 as the same yellows were found in samples 1, 3 and 5. Cross-section 2 from the sash shows that it was generally painted off-white and cream-colored like the trim, however, the sashes were black in generation 5 when the trim was off-white, and cream-colored in generation 10 when the trim was yellow. Generation 4 in this trim paint chronology contains the pigment zinc white (identified based on its characteristic sparkly autofluorescence), which dates this layer to after about 1845 when zinc white became commercially available.

1. North elevation, arched window, backband molding, left side.

Visible Light 100X



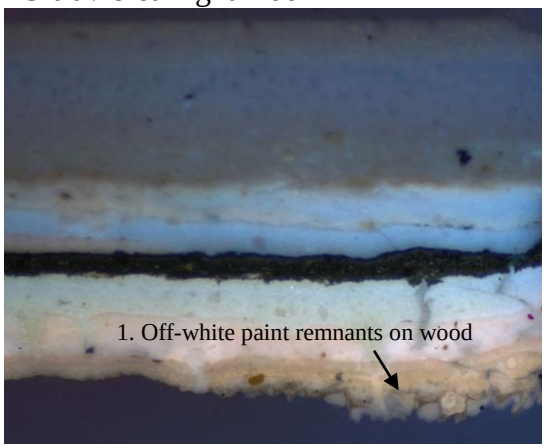
Ultraviolet Light 100X



2. North elevation, arched window sash, upper portion of window, top left corner.

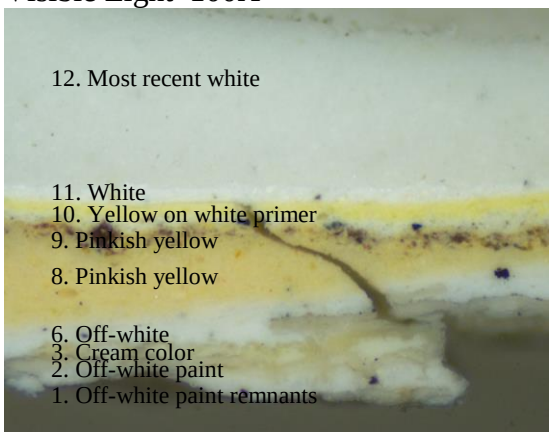
Visible Light 100X Paint flake

Ultraviolet Light 100X

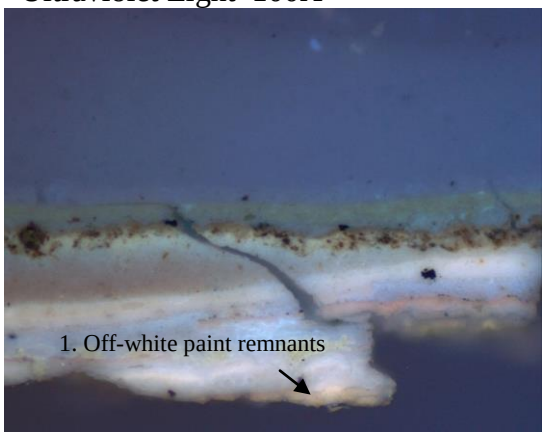


3. North elevation, window trim, top left corner of backband.

Visible Light 100X



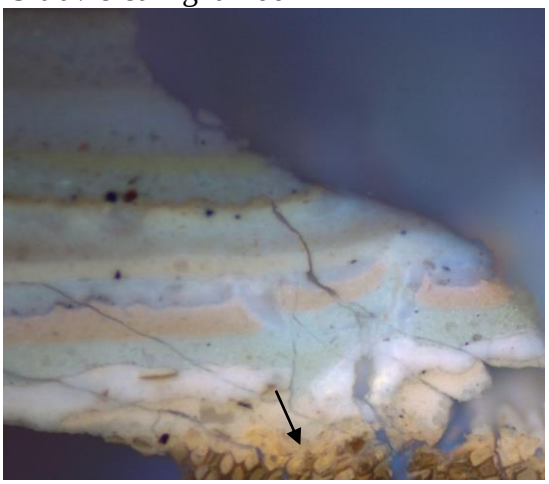
Ultraviolet Light 100X



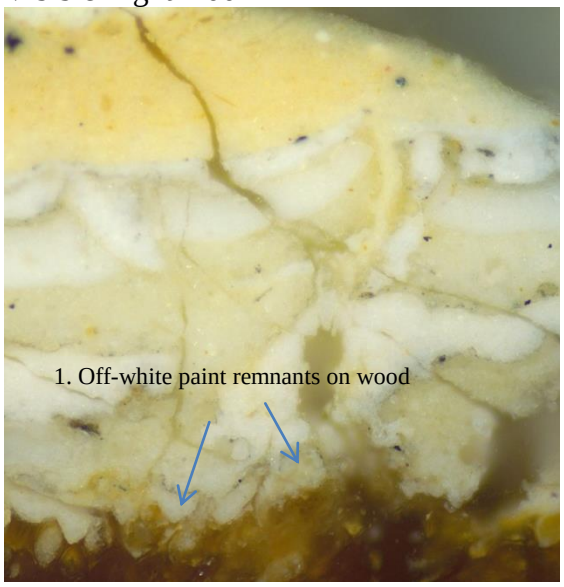
5. North elevation, fascia of cornice.

Visible Light 100X

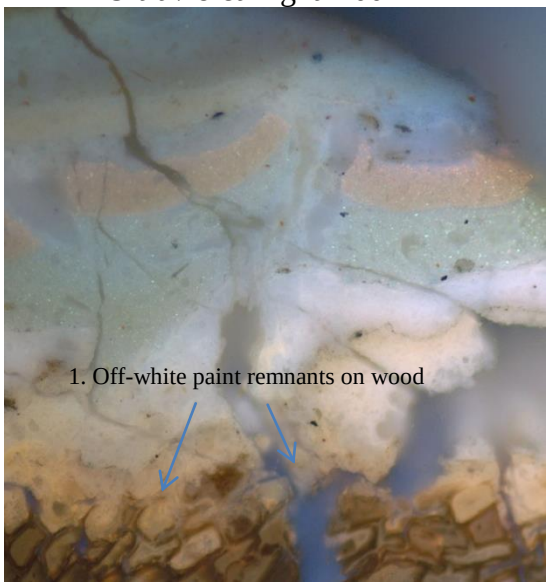
Ultraviolet Light 100X



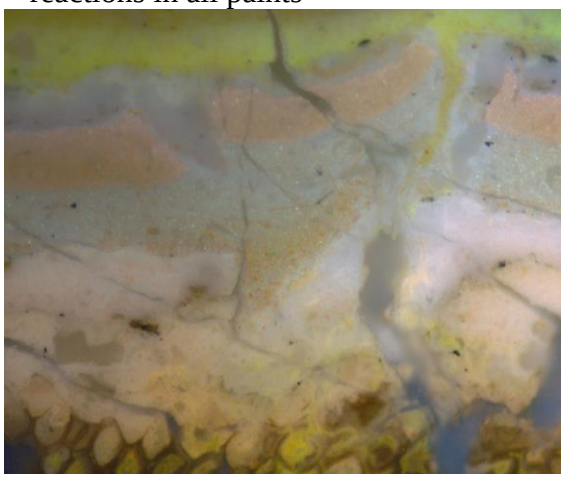
Visible Light 200X



Ultraviolet Light 200X



UV Light & DCF for oils 200X
+ reactions in all paints



Conclusion:

Despite the degraded nature of the exterior paints on all elevations of the building, it was gratifying to find evidence of the earliest clapboard and trim paints on protected areas of the 1760s clapboards, arched window, and cornice on the north elevation. There are only remnants of the original coarsely ground, oil-bound, dark yellow paint remaining in sample 4. But these remnants are directly on the wood, and also penetrated into the wood substrate, confirming the dark yellow paint as the first coating on the clapboard. This dark yellow paint has a thick film of dirt on its surface, and it is cracked and fragmentary, suggesting it was left exposed for many decades before being painted over.

The earliest paint on the trim was found to be off-white. It was found in three of the four trim samples, and the evidence suggests that the trim was repainted off-white or cream-colored from generation 1 through 7. In generation 8 through 10 all the trim elements were painted in different shades of yellow to match the clapboards. The comparative evidence on the 1760s sash shows that it was off-white or cream-colored to match the trim until generation 5 when the sash was black while the trim was off-white. After generation 5 the sashes were generally the same color as the trim up to the most recent white.

The color measurement and matching process shows that the original dark yellow paint is significantly darker and browner in tone than the current medium yellow, while the original trim paint is slightly creamier in color than the current white paint.

COLOR MATCHING PROCEDURES

Uncast portions of the most intact samples taken from the dark yellow paint on the clapboards and the off-white paint on the trim were used for matching with the Minolta Chroma Meter CR-241, a tristimulus color analyzer/microscope with color measurement area of 0.3mm. This instrument has an internal, 360-degree pulsed xenon arc lamp and provides an accurate color measurement in a choice of five different three-coordinate color systems.

The first layer of dark yellow paint on the clapboards and the original off-white trim paint was exposed with a scalpel at 30X magnification to provide clean areas for color matching. The exposed layers were measured three times in three different areas of the exposed target layers to establish the color coordinates. The measurements were first generated in the Munsell color system (a color standard used in the Architectural Preservation field), and after the measurements were taken the closest Munsell color swatches from a standard Munsell Book of Color (gloss paint standards) was compared under 30X magnification to the actual samples. The measurements were also generated in the CIE L*a*b* color space system, which is currently one of the most widely accepted industry color space measuring systems.

However, when the Munsell matches generated through color measurement were compared to the actual samples it became obvious that the paints were too darkened and degraded to allow accurate color measurement. So, a second round of color matching was done by eye comparing the Munsell swatches to the samples under 30-45X magnifications and a color-corrected light source. The best visual matches for the Munsell swatches were then used to generate close commercial paint matches.

The best commercial swatches are provided for reference.

Generation 1. Original dark yellow paint on the 1760s clapboards

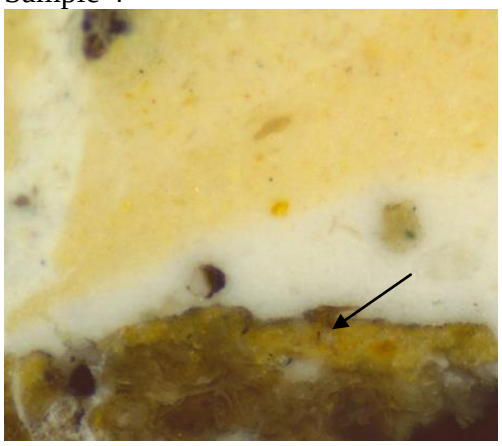
Sample 4

Color-matched August 26, 2019

Benjamin Moore #HC-41 "Richmond Gold"

Color System*		Coordinates	
Munsell	Hue	Value	Chroma
	9.6YR	6.0	4.8
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L60.65	a+6.88	b+30.23

Sample 4



The degraded dark yellow layer was matched by eye at 30X magnification under a color-corrected light source to the Munsell Book of standards and it was measured with a Minolta CR 241 colorimeter/microscope. The swatch for HC-41 is an excellent visual match to the best surviving areas of this original dark yellow exterior clapboard paint. The evidence in the cross-section and the uncast samples suggest this paint was originally moderately glossy and could be reproduced in a semi-gloss level coating.

Generation 1. Original off-white paint on the 1760s trim

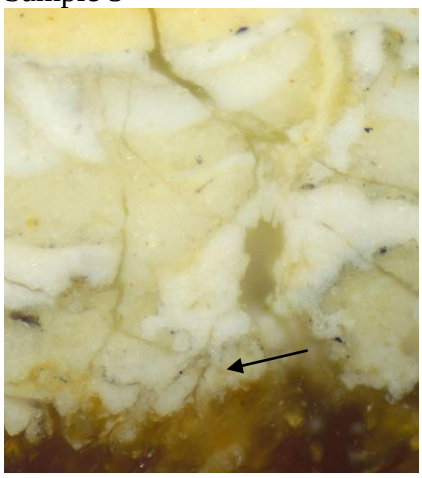
Samples 2, 3, 5

Color-matched August 26, 2019

Benjamin Moore #OC-10 "White Sand"

Color System*			Coordinates
Munsell	Hue	Value	Chroma
	2.9Y	8.3	1.4
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L84.05	a-0.36	b+9.95

Sample 5



The degraded off-white paint layer was matched by eye at 30X magnification under a color-corrected light source to the Munsell Book of standards and it was measured with a Minolta CR 241 colorimeter/microscope. The swatch for OC-10 is an excellent visual match to the best surviving areas of this original off-white exterior trim paint. The evidence in the cross-section and the uncast samples suggest this paint was originally moderately glossy and could be reproduced in a semi-gloss level coating.

*** COLOR SYSTEMS** Derived from the Minolta CR-241 Instruction Manual and Minolta Precise Color Communication

Chroma Meter CR-241 offers five different color systems for measuring absolute chromaticity: CIE Yxy (1931), L*a*b* (1976), and L*C*H* (1976) colorimetric densities DxDyDz; Munsell notation and four systems for measuring color differences.

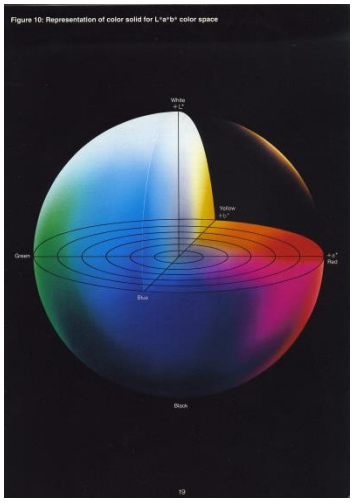
For two colors to match, three quantities defining color must be identical. These three quantities are called tristimulus values X, Y, and Z as determined by CIE (Commission Internationale de l=Eclairage) in 1931.

Color as perceived has three dimensions: hue, chroma and lightness. Chromaticity includes hue and chroma (saturation), specified by two chromaticity coordinates. Since these two coordinates cannot describe a color completely, a lightness factor must also be included to identify a specimen color precisely.

Munsell Color System: The Munsell color system consists of a series of color charts which are intended to be used for visual comparison with the specimen. Colors are defined in terms of the Munsell Hues (H; indicates hue), Munsell Value (V; indicates lightness), and Munsell Chroma (C; indicates saturation) and written as H V/C.

CIE Yxy (CIE 1931): In the Yxy (CIE 1931) color system, Y is a lightness factor expressed as a percentage based on a perfect reflectance of 100%, x and y are the chromaticity coordinates of the CIE x, y Chromaticity Diagram.

CIE L*a*b*: Equal distances in the CIE x,y Chromaticity Diagram do not represent equal differences in color as perceived. The CIE L*a*b* color system, however, more closely represents human sensitivity to color. Equal distances in this system approximately equal perceived color differences. L* is the lightness variable; a* and b* are the chromaticity coordinates.



ΔE: ΔE (Delta E) is the industry measure used to determine how closely two colors match in the CIE L*a*b*. The symbol Δ means "the change in". It is based on calculating the sum of the differences between each measure. The calculation is: $\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$, or, the color difference equals the square root of the squared sums of the differences between each of the three L* a* b* tristimulus values. Industry color standards indicate a ΔE of 1 is barely perceptible to the human eye, and ΔE of 6 to 7 is acceptable for color matches in the printing industry.

REFERENCES

Cross-section Preparation Procedures:

The samples were cast into mini-cubes of polyester resin (Excel Technologies, Inc., Enfield, CT). The resin was allowed to cure for 24 hours at room temperature and under ambient light. The cubes were then ground to expose the cross-sections, and dry polished with 400 and 600 grit wet-dry papers and Micro-Mesh polishing cloths, with grits from 1500 to 12,000.

Cross-section microscopy analysis was conducted with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 4.6) for digital image capture and Adobe Photoshop CS for digital image management. Photographs and digital images of the best representative cross-sections are included in this report. UV photographs were taken with the UV-2A filter in place (330-380 nanometers excitation with a 400 nm dichroic mirror and a 420 nm. barrier filter). Please note that the colors in the printed photomicrographs may not accurately reflect the actual color of the samples because the colors in the digital images are affected by the variability of color printing.

The following fluorescent stains were used for examination of the samples:

Triphenyl tetrazolium chloride (TTC) 4.0% in ethanol to identify the presence of carbohydrates (starches, gums, sugars). Positive reaction color is dark red or brown.

Alexafluor 488 (ALEXA) 0.02% in water, pH 9.0, 0,05M borate and 5% DMF. Positive reaction for proteins is bright yellow-green.

Eosin isothiocyanate (EITC) 0.2% in anhydrous acetone to identify the presence of proteins. A yellow or yellowish-green colors indicates a positive reaction.

2, 7 Dichlorofluorescein (DCF) 0.2% in ethanol to identify the presence of saturated and unsaturated lipids (oils). Positive reaction for saturated lipids is pink and unsaturated lipids is yellow.

Rhodamine B (RHOB) 0.06% in ethanol to identify the presence of oils. Positive reaction color is bright orange.

N-(6-methoxy-8-quinolyl)-p-toluenesulfonamide (TSQ) 0.2% in ethanol to mark the presence of Zn in the cast cross-section. Positive reaction color is bright blue-white.

The best cross-section images for each area are included in this report. Photographs were taken at 40X, 100X, 200X and 400X magnifications.

Information Provided by Ultraviolet Light Microscopy:

When viewed under visible light, cross-sections which contain ground, paint and varnish may often be difficult to interpret, particularly because clear finish layers look uniformly brown or tan. It may be impossible using only visible light to distinguish between multiple varnish layers. Illumination with ultraviolet light provides considerably more information about the layers present in a sample because different organic, and some inorganic, materials autofluoresce (or glow) with characteristic colors.

There are certain fluorescence colors which indicate the presence of specific types of materials. For example: shellac fluoresces orange (or yellow-orange) when exposed to ultraviolet light, while plant resin varnishes (typically amber, copal, sandarac and mastic) fluoresce bright white. Wax does not usually fluoresce; in fact, in the ultraviolet it tends to appear almost the same color as the polyester casting resin. In visible light wax appears as a somewhat translucent white layer. Paints and glaze layers which contain resins as part of the binding medium will also fluoresce under ultraviolet light at high magnifications. Other materials such as lead white, titanium white and hide glue also have a whitish autofluorescence.

There are other indicators which show that a surface has aged, such as cracks which extend through finish layers, accumulations of dirt between layers, and sometimes diminished fluorescence intensity, especially along the top edge of a surface which has been exposed to light and air for a long period of time.

Pigment Preparation:

Dispersed pigments from specific early layers were crushed onto microscope slides and permanently mounted under cover slips with Cargille MeltMount with a refractive index of 1.66. The pigments were viewed under plane polarized light and under crossed polars, and were compared to a standard set of reference pigments.

Tobias Lear House, Portsmouth, New Hampshire
Paint Sample Locations
Paint Samples removed August 5 and 6, 2019 by Susan L. Buck

Exterior
1. North elevation, arched window, backband molding, left side.
2. North elevation, arched window sash, upper portion of window, top left corner.
3. North elevation, window trim, top left corner of backband.
4. North elevation, clapboard above arched window.
5. North elevation, fascia of cornice.