ART CONSERVATION DEPARTMENT
BUFFALO STATE COLLEGE

DEVELOPMENT OF A PIGMENTED WAX/RESIN FILL FORMULATION FOR THE CONSERVATION OF PAINTINGS

CNS 695 SPECIALIZATION PROJECT

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I. ABSTRACT

Pigmented wax/resin fills are made and used by painting conservators to fill losses in oil paintings. It is an ideal material because textures, such as canvas weave, can be impressed into the fills to match the painted surface. The Buffalo State College Art Conservation program employs a successful pigmented wax/resin fill formula that uses beeswax, microcrystalline wax, resin, and pigments. One of the components, Laropal® K-80, a resin, is no longer manufactured. The purpose of this investigation was to research and find an alternative resin that would yield an equal or better wax fill formula. To gain more information, aged pigmented wax samples were examined from a report written by Frederick Wallace. In addition, a questionnaire was emailed to conservators to discover what, if any, wax fills they were using, and in what manner. When new formulations were made, different resins had different dissolution times. None of the mixtures were homogenous, most likely due to the titanium white pigment. Working properties of each pigmented wax/resin fill were evaluated by filling losses in a donated painting. Alternative waxes were also considered, and hardness tests were conducted, using a handmade apparatus with weights and a micro-needle probe. Cross-cut tests were performed on the original formula and a formula that used Laropal® A-81. A mock-up board with channels was made and filled with five pigmented wax/resin formulas, including the original. An identical board was made with additions of varnishes and inpainting media. It was concluded that Laropal® A-81 could replace Laropal® K-80 in the original formula, and achieve a similar, if not more improved pigmented wax/resin fill.

II. INTRODUCTION

The purpose of this investigation was to identify an alternative resin for a pigmented wax/resin fill formula (Table 1) used in the Buffalo State College Art Conservation program. The melted wax mixture is poured into a silicone mold, which produces thin sticks for ease of application. The formula yields a product with excellent physical and working properties. The resin component, Laropal® K-80[1], which gives more hardness and tack to the fill, was discontinued by the chemical company BASF in 2008. New formulations were created and comparison tests were conducted in an attempt to arrive at a similar, if not improved, pigmented wax/resin fill. An email questionnaire was sent to other art conservators, known to have used wax fills, in order to gain insight into common wax materials and practices being used elsewhere. To gather more information about the way wax fills might age, wax fill samples from a research project conducted by Fredric Wallace, were visually examined. He fabricated the fills 21 years ago at Buffalo State College as an art conservation graduate student. Another aspect of this study was to identify the advantages and limitations of pigmented wax fills in general. In seeking to develop a practical wax fill formulation and application process, a better system for filling losses in paintings may be achieved and hopefully a better understanding and appreciation of pigmented wax/resin mixtures will be gained.

Table 1. Pigmented Wax/Resin Fill Formula Most Commonly Used in the Buffalo State College Art Conservation Paintings Department.

Components	Parts (by mass)
Wax 1: Beeswax[2]	3
Wax 2: Be Square™ 195[3]	1
Resin: Laropal® K-80	1
Pigments	5
Total Parts	10

III. PROJECT PRESENTATION

3.1 Overview

When a painting suffers a loss of paint and/or ground layers, a conservator will often fill and then inpaint to compensate for the loss. To imitate the original paint as closely as possible, fills are leveled and can be textured to match the surrounding paint film. An ideal painting fill is chemically stable, has good adhesion, is compatible with varnishes, solvents, and painting materials, is easily reversible, and does not discolor, bloom, flow, or crack with age.

3.2 Background of Wax Fills Used in Art Conservation

Conservators commonly use gesso putty or commercial spackling compounds as fill materials. Two commonly used commercial gessoes are Modostuc® from Italy and Flugger® from Germany. Wax is also used as a fill material, however, its advantages may not be fully recognized or capitalized on, and therefore has found less use. It is important to note that wax properties can vary depending on the formulation and the way it is used. The most common waxes used in art conservation are beeswax, carnauba wax, and various microcrystalline waxes.

Waxes are organic compounds that can be derived both naturally and synthetically. They are thermoplastic materials that are solid at ambient temperature and become mobile liquids when melted (Waxes 2010). Waxes generally contain long-chain hydrocarbons, acids, alcohols, esters, or mixtures of these (Mills and White 1994). Two natural waxes, beeswax and carnauba (from the leaves of the Corypha cerifera palm in Brazil) (Appendix 3, Table 1), are composed of carbon, hydrogen and oxygen and are mainly fatty acid esters of monohydric alcohols of high molecular weight. They could have free fatty acids, alcohols, sterols or hydrocarbons (Bennet 2008). Mineral waxes procured by petroleum distillation fractions include microcrystalline waxes, which melt between 60° to 94° Celsius, and are primarily composed of branched saturated hydrocarbon chains (Abercauph 1998). Waxes feel smooth and sometimes tacky to the touch; they are most often opaque, have a slight sheen, and in their natural form, range in colors from a warm brown to white.

Waxes have thermoplastic and adhesive properties that make it an ideal fill material. It is also easily reversible by mechanical removal in conjunction with a solvent such as xylene. Waxes are nontoxic and theoretically, they have an indefinite shelf life if stored in a cool dry place. Another advantage is that they are water resistant and remarkably chemically stable. When pigments are added to melted wax, a fill similar in color to the surrounding paint can be achieved, which facilitates inpainting. In addition, pigmentation increases the density of wax; this causes it to be more stiff, bulkier, and less immediately soluble to some solvents. The main benefit of wax fills is that, unlike gesso fills, they can be easily sculpted and textured while warm and pliable to closely match subtle surface textures such as canvas weave, impasto, and brushstrokes. Molded Dow RTV 3110 silicone rubber[4] can be used to emboss customized textures into wax based fills. When filling with a wax, leveling can be achieved without overlapping the surrounding original paint film. Any excess wax can be easily cleaned using a wooden skewer that is shaped to an angle. Wax fills are well suited for paintings with dark colors and/or many cracks because they do not cause ghosting (residual chalk) the way gesso fills do.

One of the disadvantages of wax fills is that they are heat sensitive. At high ambient temperatures, wax fills may soften. They might also scratch easily and retain dust and dirt, which is particularly true for softer waxes. Over time, some wax fill formulas may crack or become susceptible to bloom. Although concerns exist that wax fills will solubilize in some solvents, the addition of pigments and resin to wax formulas decrease that likelihood.

Another consideration is that conservation paints are often rich in medium, and while gesso fills absorb a portion of the medium, wax fills are non-absorbent and the inpainting can become too glossy as a result. This characteristic can make pigmented wax/resin fills inappropriate for paintings that are unvarnished or have a matte varnish.

3.3 Results From Email Questionnaire

A questionnaire was emailed to various art conservators to ascertain which pigmented wax fill materials and methods of application are being used. Submitted wax fill formulas are listed in Appendix 1.

The survey asked what sorts of paintings were best suited for pigmented wax fills and why. Participants stated that they were excellent for paintings that are highly textural, or have high impasto. They are also ideal for panel paintings, wax-lined paintings, shallow losses, and fine cracks. Wax fills are especially appropriate for paintings that are sensitive to water. One conservator noted that they use pigmented wax fills over gesso fills for tear repairs, as they can be textured.

In response to what the beneficial aspects of using pigmented wax fills were, one conservator said that they are easy to prepare, texture, and residues can be easily lifted. A contradictory opinion stated they are messy and difficult to clean up when spread beyond the loss. One observed that wax fills were less likely to pop out of the loss the way gesso fills might if the painting were to flex.

Comments concerning negative characteristics of pigmented wax fills include the fact that a heat source is necessary and that there is not a lot of working time with wax since it cools quickly. Bloom can be a problem, and seems to be associated with beeswax. Another downside is that several solvents can dissolve wax, and therefore, there is concern about varnish application. One conservator mentioned that it takes practice to properly heat a silicone mold and successfully imprint texture into the wax fill. Some refuse to use wax fills because they are "too soft" and "difficult to use."

For one conservator, wax was their preferred fill material. Others stated that they often use the following: gelatin gesso putty made with whiting, spackle with pigments added, Flugger® putty, Modostuc® putty with 10% kaolin added, Beva with pigment (for heat imprinted fills), and gypsum and calcium carbonate mixed with 10% rabbit skin glue or 8% sturgeon glue (for panel paintings).

This questionnaire disclosed that conservators are using a variety of methods and materials for filling paintings, and when it comes to wax-based fills, the formulas vary considerably. Two concerns pertaining to wax fills often arise; one is that wax fills are too soft, and another that wax fills are soluble in commonly used solvents. These beliefs may be true or false depending on the wax fill formula. For example, a high ratio of pigments, along with a proper proportion of resin, can result in a relatively hard and less soluble fill.

3.4 Experimental Procedure

Pigmented wax/resin sticks, previously made using the existing Buffalo State College Conservation Department formula (Table 1), were used to fill losses in an oil painting donated to the department. The formula proved to have good working properties. The wax/resin softened with mild heat and was easy to apply, level, and texture. The fills became hard upon cooling. Figure 1 shows some of the materials and tools used in the filling process.

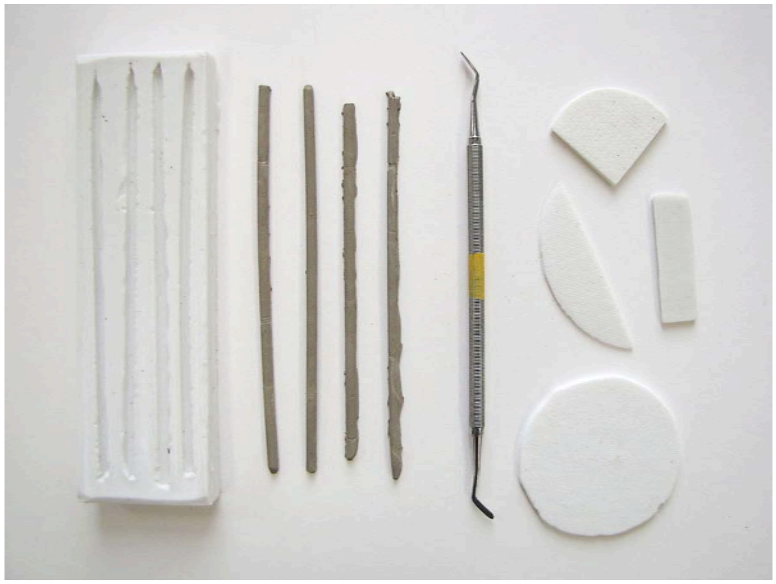


Figure 1. From left to right: silicone mold, four pigmented wax/resin sticks, dental tool, and pre-made Dow RTV 3110 silicone rubber molds with canvas texture impressions (cut to various sizes).

The losses in the oil painting were filled and textured in the following manner:

1. The painting (properly supported underneath) was set face up on a table.

2. A pre-made pigmented wax/resin stick was warmed* and formed to a point with fingers. The point of the stick was set into the edge of a loss.

3. A dental tool, with a flat end, was warmed* and used to compress and spread the pigmented wax/resin into the loss (Figure 2). Note: the wax should have a paste-like consistency unless it is intended to fill fine cracks, in which it can be warmed until liquefied, then run into the crack with a quick movement of the dental tool.

4. Excess wax was removed from surrounding original paint by gently rubbing it off with the tip of a wooden skewer that had its point sanded to an angle (Figure 3).

5. A pre-made Dow RTV 3110 silicone rubber mold, which had a canvas impression, was used to impart a texture into the pigmented wax/resin fill. It was first warmed on a hot plate then quickly placed over the wax fill. A piece of Plexiglas was set over the mold, followed by a wooden block; even pressure was applied by holding the block down with fingers for several minutes (Figure 4). Textured wax fills are shown in Figure 5.

** Warming can be achieved by using heat sources such as the flame of an oil lamp, a coffee warmer, or a hot air tool (on lowest heat setting).*

Figure 2. Compressing wax into loss with heated dental tool.

Figure 3. Cleaning edges of fill with wooden skewer.

Figure 4. Adding pressure to a warmed silicone mold to impart a canvas texture to the fill.

Figure 5. Textured wax fills in progress.

Frederick Wallace's research paper of 1990, which contained pigmented wax fill samples, was acquired at Buffalo State College Art Conservation Department's library. The samples (approximately 1/8 inch thick and 5/8 inch^2) were viewed under magnification and general conclusions were drawn based on the effects of age. The two main visible consequences of age were the formation of cracks and various degrees of bloom. Microphotographs[5] (Figures 6 to 14) were taken of representative aged wax fill samples from Wallace's research and visual observations are listed in Table 2. Evaluations are summarized in Appendix 4.

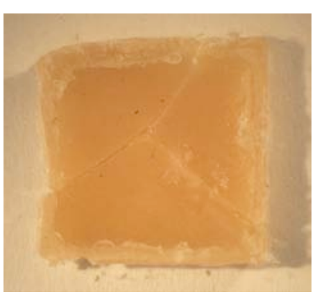


Figure 6. Unbleached beeswax

Figure 7. Unbleached beeswax
with titanium white;
38% pigment by weight

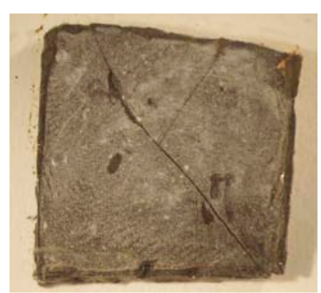


Figure 8. Unbleached beeswax
with raw umber;
30% pigment by weight

Figure 9. Unbleached beeswax and Elvax 150 (5:1)

Figure 10. Unbleached beeswax and Elvax 150 (5:1) with titanium white; 46% pigment by weight

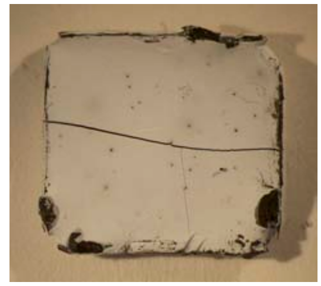


Figure 11. Unbleached beeswax and Elvax 150 (5:1) with raw umber; 32% pigment by weight

Figure 12. Multiwax® W-445[6]

Figure 13. Multiwax® W-445 with titanium white; 41% pigment by weight

Figure 14. Multiwax® W-445 with raw umber; 21% pigment by weight

Table 2. Observations of Aged Wax Fill Samples from Frederic Wallace's Research

Figure	Wax fill	Substantial Cracks	Efflorescent Bloom	Other
1	Unbleached beeswax	2	None	
2	Unbleached beeswax with titanium white; 38% pigment by weight	0	Possible white efflorescent bloom but difficult to tell on a white pigmented fill	
3	Unbleached beeswax with raw umber; 30% pigment by weight	2	Moderate degree of white efflorescent bloom	
4	Unbleached beeswax and Elvax 150 (5:1)	0	High degree of white efflorescent bloom	
5	Unbleached beeswax and Elvax 150 (5:1) with titanium white; 46% pigment by weight	0	Possible white efflorescent bloom but difficult to tell on a white pigmented fill	
6	Unbleached beeswax and Elvax 150 (5:1) with raw umber; 32% pigment by weight	1	High degree of white efflorescent bloom	
7	Multiwax® W-445	0	None	Sample has spread and deformed out of shape.
8	Multiwax® W-445 with titanium white; 41% pigment by weight	0	None	Two scratches present on surface.
9	Figure 9. Multiwax® W-445 with raw umber; 21% pigment by weight	0	None	

Roughly based on the existing formula, pigmented wax/resin fill formulations (Appendix 2) were made as follows:

1. Each component was measured on a top-loading balance.

2. In a double boiler, the main wax was melted first, followed by Be Square™ 195 microcrystalline wax. Resin (when used) was crushed to a powder and added slowly to the wax mixture while stirring and mulling with a bent microspatula. Resins varied in appearance (Figure 15). They also varied in the amount of time it took for dissolution. Raw umber and titanium white pigments[7] were added and mulled with the end grain of a ¼ inch by 1-inch wooden stock. Figure 16 shows the melted mixture. Note: it is important to regulate the heating temperature of a wax using a double boiler because if placed in a pan directly over heat, it will ignite if heated to its flash point or if it comes in contact with a flame.

Figure 15. Resins from left to right: Laropal® K-80, Paraloid™ B-72, Regalrez® 1094, and Laropal® A-81.

Figure 16. Formula A, melted in a double boiler.

3. Each mixture was poured into a silicone mold and leveled with a wooden tongue depressor (Figure 17). Once cooled, four sticks were removed from the mold (Figure 18). Note: silicone release Mylar[8] was placed under the mold so that excess wax mixture would not stick to it. The wax sticks (approximately 1/8″ wide x 5 1/2″ long) were bent and broken to empirically assess their hardness and brittleness.

Figure 17. Formula A in silicone mold after leveling with a tongue depressor.

Figure 18. Silicone mold with Formula A pigmented wax/resin sticks.

Formulation B (Appendix 2) was not completed because Paraloid™ B-72[9] was insoluble in the wax mixture (Figure 19). Therefore, other pigmented wax/resin fill formulations were considered, and since beeswax has a tendency to bloom, alternative waxes were researched.

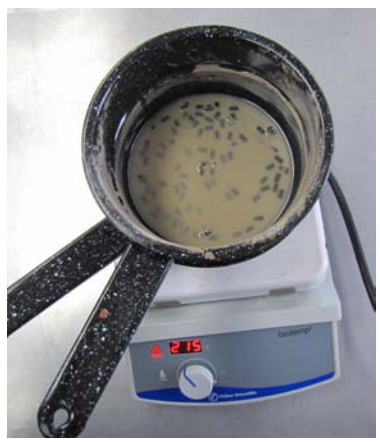


Figure 19. Insoluble resin floating in waxes of formula B

It was decided that for the revised formula, Regalrez® 1094 would replace Paraloid™ B-72, and either Multiwax® W-445 or Cosmolloid 80H[10] (Table 1, Appendix III) would replace beeswax.

While making formulation B_1 (Appendix 2), which contained Multiwax® W-445, 13 grams of pigment was considered to yield the proper consistency instead of 50 grams as used in the original formula. While mixing, some of the pigment, especially titanium white, did not wet up but rather fell out of suspension. In addition, the resulting mixture thickened significantly while mulling and stuck to the stirring stick in one large clump (Figure 20). Wax/resin sticks were impossible to make. Therefore, proportions were changed in order to arrive at a more workable mixture.

Figure 20. Thickened formula B_1 stuck to the piece of wood used for mulling.

For formula B_2 (Appendix 2), the amount of Be Square™ 195 was increased, with the other components remaining in essentially the same ratios. However, even with this modification, the results were very similar to the mixture discussed previously. The mixture was not as thick as the previous attempt, but thick enough to have difficulty pouring into the mold, and the resulting sticks were soft.

Cosmolloid 80H was tried as formula B_3 (Appendix 2). Note that for this formula, the portion of Be Square™ 195 was returned to the value used in the original formula (formulation A). As in the previous two attempts with Multiwax® W-445, some of the pigment, especially titanium white, crashed out of solution, and when poured, the material became thick. However, unlike formula B_2, the resulting sticks were hard. Therefore, formulation B_3 was chosen as a replacement for formula B.

Pigmented wax/resin sticks, made from each formula (A, B_3, C, D, and E), were used to fill losses in a painting donated to the department and their working properties were evaluated.

Waxes vary in hardness depending on their low molecular weight constituents. Wax hardness can be tested with a needle penetrometer in accordance with the American Society of Testing and Materials (ASTM). The standard test method for needle penetration of petroleum waxes is ASTM D1321. Higher needle penetration values indicate a softer wax. Since the equipment and specific wax hardness literature information was not easily obtainable, a simple wax hardness test apparatus was built to measure and relatively compare the hardness of each wax used in this experiment (Figure 21). A metal cylinder was affixed to a board that was clamped to a table. The cylinder was oriented in the vertical dimension and its diameter was wide enough for a micro-needle probe to freely pass through it. A micro-needle probe was modified by drilling a hole into a piece of wood (~2″W x 2″H x ¼″ D) and fitting the base of the probe into it. This created a platform for the weights to be placed. Wax hardness was tested by first placing each wax under the probe suspended in the cylinder. Calibration weights were set on the platform, and for each penetration, yellow acrylic paint was painted on the needle just above the surface of the wax. The area below the paint to the tip of the needle was measured in millimeters with a ruler (Figure 22). After each penetration, the needle was moved to another location on the wax surface.

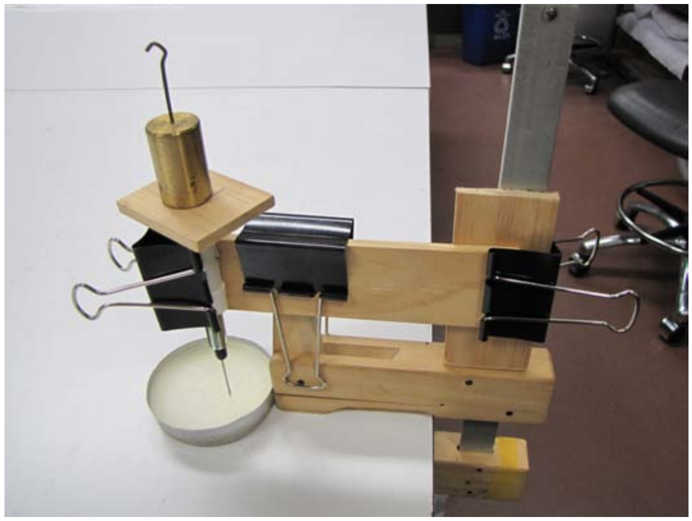


Figure 21. Apparatus for testing the hardness of waxes.

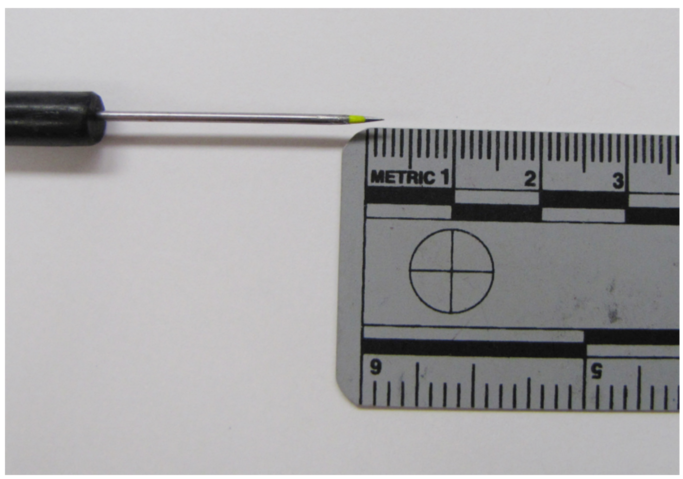


Figure 22. Measuring needle penetration depth in millimeters.

Based on the results (Table 3), Be Square 195 was the hardest and Multiwax® W-445 was the softest of the waxes listed. In this experiment, Be Square™ 195 was used in all of the pigmented wax/resin formulas. Cosmolloid 80H tested softer than Be Square™ 195 and was slightly harder than beeswax; Multiwax® W-445 was relatively much softer than all of the other waxes. These results are congruent with empirical observations, as the pigmented wax/resin sticks made with Cosmolloid 80H were hard and the sticks made with Multiwax® W-445 were soft.

Table 3. Relative/Simple Test for Wax Hardness Using a Handmade Apparatus With Micro-needle Probe

Weight Applied (g)	Needle Penetration Depth into Be Square™ 195 (mm)	Needle Penetration Depth into Cosmolloid 80H (mm)	Needle Penetration Depth into Beeswax (mm)	Needle Penetration Depth into Multiwax® W-445 (mm)
10	0	0	0	<< 1
20	0	0	0	< 1
50	0	0	0	1
100	<< 1	< 1	1	3
200	<< 1	1	1	4
500	1	2	4	10
1000	2	5	5	25

Two mock-up boards for the five pigmented wax/resin fills were prepared in the following method:

1. A plywood board (5/16 inch thick) was cut to 12 x 14 inches.
2. A pre-primed canvas[11] was adhered to the board with Beva gel[12] and set under weights until dry.
3. Five strips of 3/4″ Scotch Blue Painter's tape were applied in eight layers to the canvas/board support.
4. Two alkyd paints[13] (combinations of titanium white and raw sienna or titanium white and raw umber) were mixed together in about a 1:1 ratio, then 12 coats of paint were painted onto the primed canvas (Figure 23).
5. The blue tape was peeled up, leaving shallow channels (< 1mm deep) for filling (Figure 24).
6. The channels were primed with two coats of different varnishes using a brush.
7. Each channel was filled with different pigmented wax/resin fills (Figure 25).

For the second board, further steps were carried out:

8. Different varnishes were sprayed across the fills in horizontal bands.
9. Different inpainting media were painted over the pigmented wax/resin fills (Figure 26).
10. Different varnishes were sprayed over the inpainting media in horizontal bands.

Note: The arrangement of the components is illustrated in Figures 28 and 29.

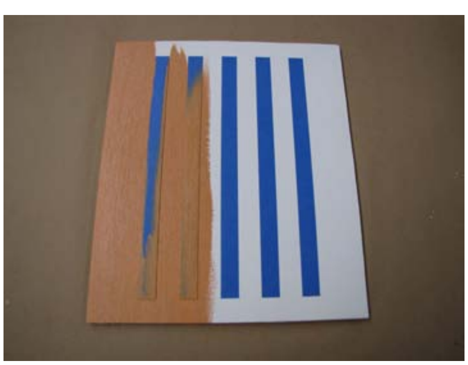


Figure 23. Mock-up board painting in progress.


Figure 24. Mock-up board after tape removal.

Figure 25. Mock-up board 1 after filling with pigmented wax/resin.

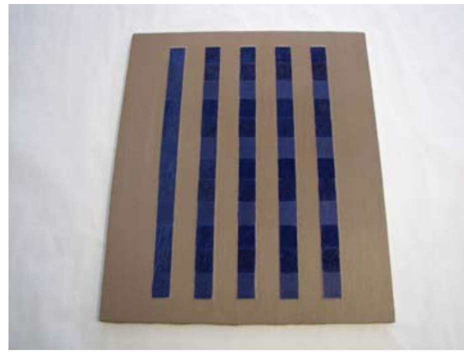
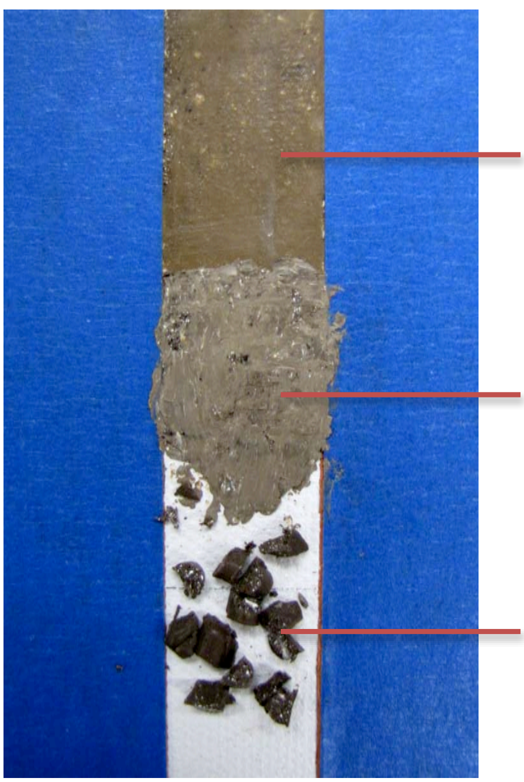


Figure 26. Mock-up board 2 after inpainting media was applied.

The following describes how the channels were filled: The pigmented wax/resin sticks were cut into small chips. Then heat was applied to a dental tool, which was used to soften the wax chips into a paste, and compact it into the channel. A sheet of silicone release paper[14] was laid over the fill and ironed smooth with a tacking iron. Further smoothing and leveling was accomplished using fine sandpaper and scraps of linen. Finally, the wax fill was buffed by wrapping a cork in nylon stocking and rubbing the surface in circular motions. Figure 27 illustrates the progression.



After being smoothed and leveled with a tacking iron, fine sandpaper, linen, and a cork wrapped in nylon stocking.

After being softened and compressed with a heated dental tool.

Chips of pigmented wax/resin.

Figure 27. Stages of pigmented wax/resin filling.

Figures 28 and 29 are schematic diagrams illustrating the mock-up boards with dimensions and regions of material applications. A key (below) lists the components. Note: For the first board (Figure 28), varnish layers were brushed on before the fills were applied. For the second board (Figure29), varnish layers were brushed on before the fills were applied, and spray-applied after the fills were applied. Then, varnishes were spray-applied over the inpainting media.

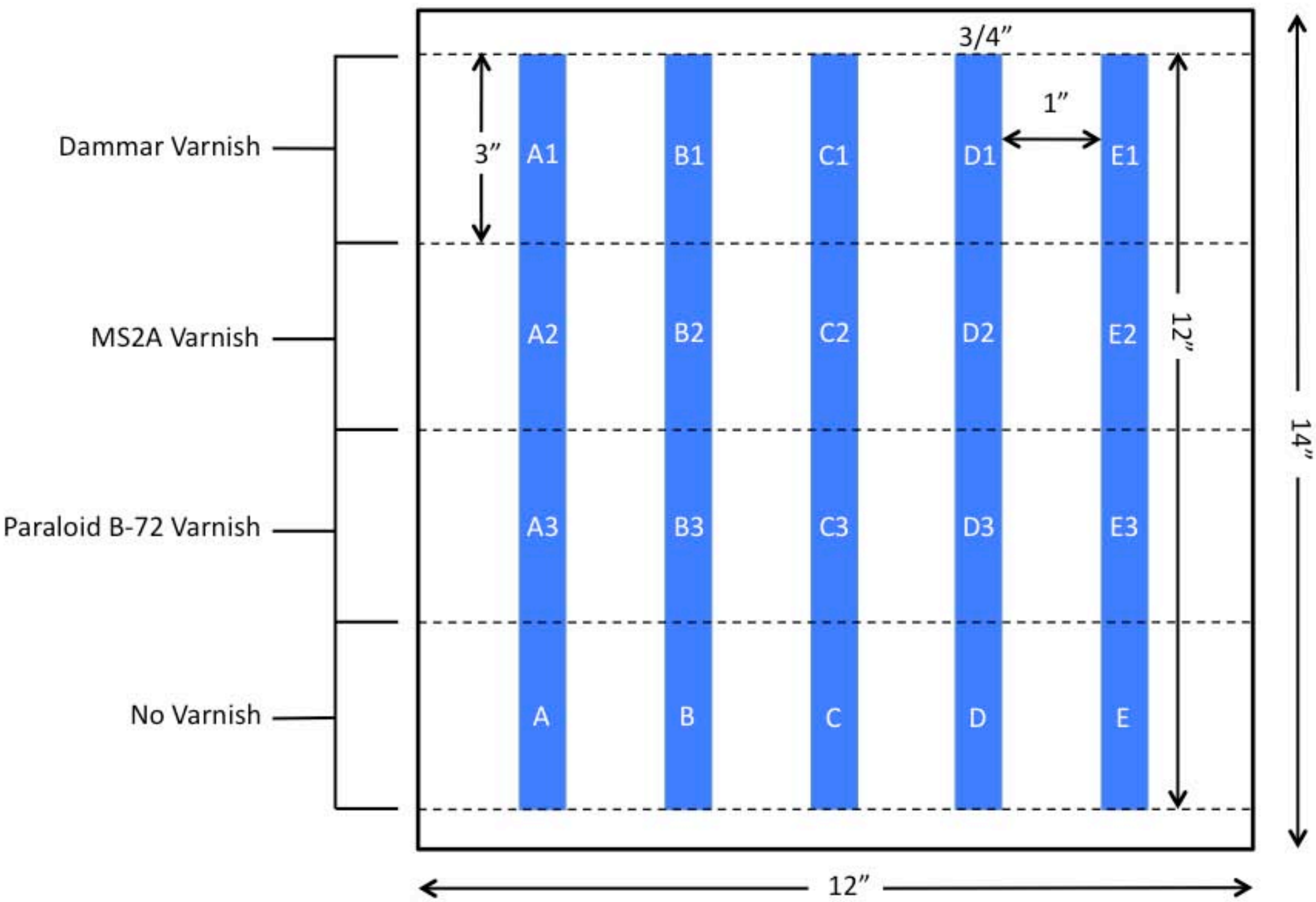


Figure 28. Pigmented Wax/Resin Fill Mock-Up Board 1 of 2

KEY	
A	Pigmented wax/resin fill formulation A
B	Pigmented wax/resin fill formulation B_3
C	Pigmented wax/resin fill formulation C
D	Pigmented wax/resin fill formulation D
E	Pigmented wax/resin fill formulation E
1	Dammar varnish (12g dammar and 0.12 g tinuvin; 100 mL of 3:2 xylene to Shellsol TS28)
2	MS2A varnish (15.2% MS2A and 1% tinuvin; 100mL of Shellsol 340HT)
3	Paraloid® B-72 varnish (7.5% B-72; 8:4:1 xylene to toluene to A100)

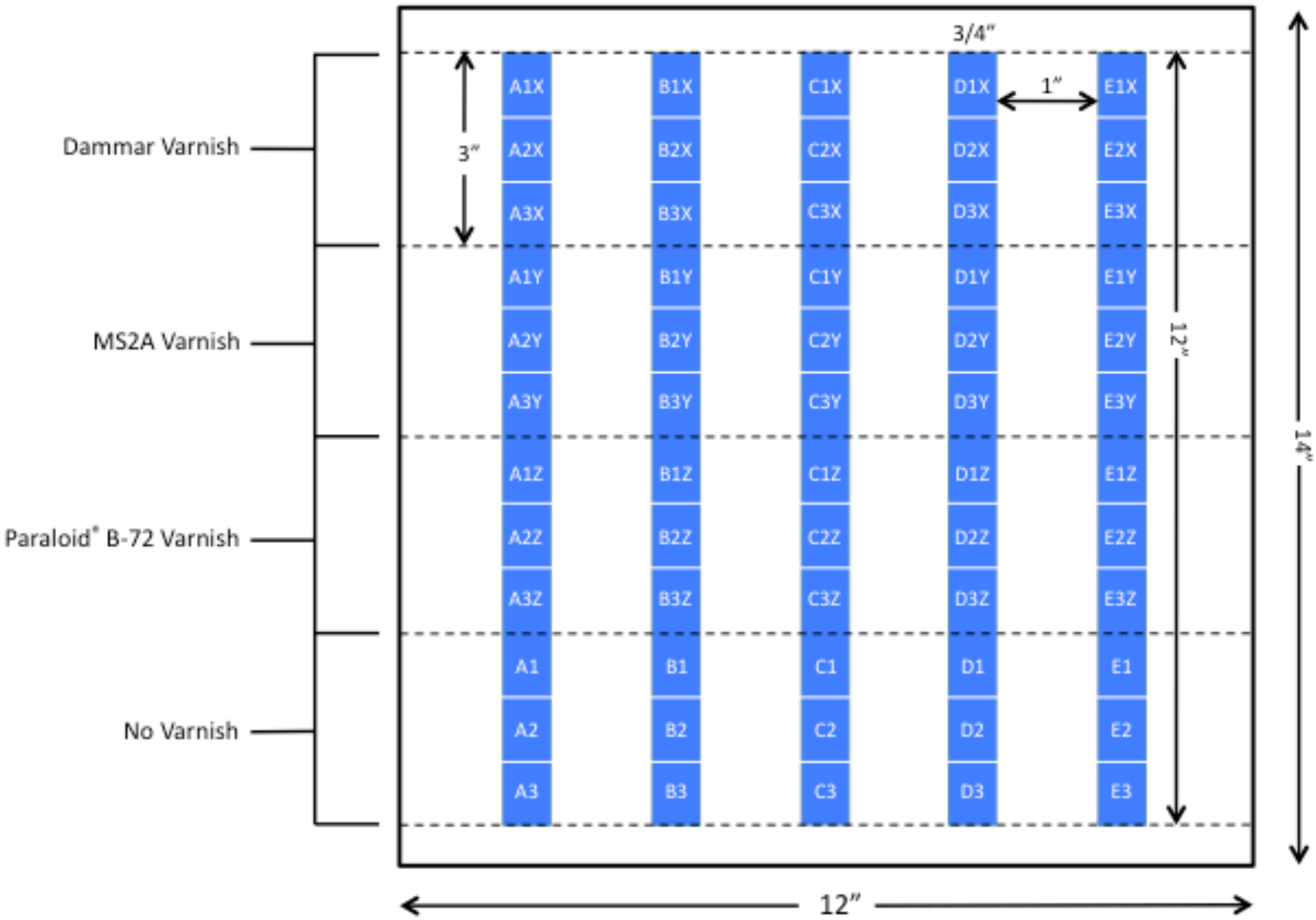


Figure 29. Pigmented Wax/Resin Fill Mock-Up Board 2 of 2

KEY	
A	Pigmented wax/resin fill formulation A
B	Pigmented wax/resin fill formulation B3
C	Pigmented wax/resin fill formulation C
D	Pigmented wax/resin fill formulation D
E	Pigmented wax/resin fill formulation E
1	GOLDEN Poly(vinyl acetate),[15] pigments dispersed in a proprietary blend of two PVA resins (probably AYAA & AYAC). Diluent was 4:1 ethanol to diacetone alcohol
2	Gamblin Conservation Colors,[16] pigments plus Laropal® A81. Diluent was isopropanol
3	GOLDEN MSA[17], pigments dispersed in n-butylmethacrylate resin in mineral spirits. Diluent was xylene
X	Dammar varnish (12g dammar plus 0.12 g tinuvin; 100 mL of 3:2 xylene to Shellsol TS28)
Y	MS2A varnish (15.2% MS2A and 1% tinuvin; 100mL of Shellsol 340HT)
Z	Paraloid® B-72 varnish (7.5% B-72; 8:4:1 xylene to toluene to A100)

To assess the adhesive properties, a cross-cut test (ASTM D3359) was conducted on formulation A (the original formula) and on the most promising replacement candidate formula. The waxes were filled into two channels of a third mock-up board, then leveled and polished. An "X," at approximately 45 degrees, was cut into each wax fill using a scalpel with a fresh #15 blade. The following tapes were adhered over each "X" then pulled off slowly from left to right: 3M Scotch Blue Painter's tape #2090, 3M Scotch Heavy Duty Shipping Packing tape, and 3M Scotch Duct tape. Four trials were performed.

IV. RESULTS AND DISCUSSION

In most cases, when the pigmented wax/resin fill formulas were made, the waxes melted quickly and smoothly. Subsequently, solid resin was added slowly, and with stirring and mulling, dissolved into the clear, colorless liquid mixture. Different resins took different amounts of time to fully dissolve (Table 4). Paraloid® B-72 was insoluble in the wax mixture. After 2.5 hours, the resin was slightly softened but was not dissolving. This could be due to its relatively high molecular weight: 105,000 grams per mole compared to the other three resins, which have relatively low molecular weights. For example, Laropal® K-80 has an average molecular weight of 531 grams per mole (Table 2, Appendix 3).

When pigments were added, all of the liquid mixtures became opaque, taupe-colored, and slightly more viscous. Not all of the titanium white combined homogenously with raw umber; even after mulling, there were swirls of white in the mixture. Formulas B_1, B_2, and B_3 contained Regalrez® 1094, which took about 20 minutes to dissolve into the wax. For these formulas, much of the titanium white pigment crashed out of solution and stuck to the bottom of the pot.

All of the wax sticks had small white specs of pigment throughout. The wax sticks were stressed by bending with fingers until they broke to assess how hard and brittle they were. Hardness is a measure of how much energy is needed to deform something, so if the wax stick bent under stress, it was soft; if it resisted bending, it was considered hard. Brittleness is a measure of how easily something breaks when it is under stress. If the stick snapped or crumbled under stress, it was considered brittle. Table 5 shows the results. Wax formulation E, without resin, made very brittle sticks that crumbled into pieces. This confirmed that resin was a necessary component in the wax fill formula. On different ends of the continuum, formula B_2 made soft, pliable sticks, while formula C made very hard, brittle sticks.

The working properties of the pigmented wax/resin fills were tested by filling losses in a painting donated to the Buffalo State College Art Conservation Program. Table 6 shows those results.

Without resin, wax formula E crumbled and seemed to have poor adhesion. Formula B_3, with Cosmolloid 80H wax, produced a nonhomogenous fill – it was brown with white specks throughout. Formula C, with Regalrez® 1094, produced a very hard wax that was difficult to level and texture. There were no observable differences between the original formula A that used Laropal® K-80 and formula D that used Laropal® A-81. Therefore, Laropal® A-81 could be used as a replacement of Laropal® K-80.

Table 4. Time Required for Resin Dissolution in a Wax Mixture (~100ºC)

Formulation	A	B_1	B_2	B_3	C	D	E
Resin	Laropal® K-80	Paraloid® B-72	Regalrez® 1094	Regalrez® 1094	Regalrez® 1094	Laropal® A-81	None
Wax mixture	Beeswax/ Be Square 195	Beeswax/ Be Square 195	Multiwax® W-445/ Be Square 195	Cosmolloid 80H Be Square 195	Beeswax/ Be Square 195	Beeswax/ Be Square 195	Beeswax/ Be Square 195
Time (min.)	~ 10	insoluble	~ 20	~ 20	~ 20	~ 180	N/A

Table 5. Relative/Simple Tests for Hardness and Brittleness of Pigmented Wax/Resin Sticks

Formulation	A	B_1	B_2	B_3	C	D	E
Hardness	hard	no sticks made	soft	hard	very hard	hard	hard
Brittleness	brittle	no sticks made	pliable	brittle	brittle	brittle	very brittle

Table 6. Relative/Simple Tests to Assess Working Properties of Pigmented Wax/Resin Sticks

Pigmented Wax/Resin Fill	General Working Properties/ Observations
A	Semi-hard; Good consistency; Leveled well; Good adhesion; Textured well
B_3	Hard; Nonhomogenous, speckled fills; Fair consistency; Fair adhesion; Textured very well (deep impression)
C	Very hard; Good consistency; Difficult to level; Good adhesion; Did not texture well (shallow)
D	Semi-hard; Good consistency; Leveled well; Good adhesion; Textured well
E	Semi-hard; Brittle and crumbled; Leveled well; Poor adhesion; Did not texture well (shallow)

All of the varnish layers applied to the mock-up board (Figure 29) were found to be mostly compatible with the substrate, pigmented wax/resin fills, and inpainting media. While inpainting, the first application of paint, over varnished pigmented wax/resin fills, tended to be streaky, which indicated poor wetting of the surface. In contrast, formulation D appeared to be more compatible, as inpainting media exhibited less streaking. Figure 30 shows two examples of streaky paint. The second layer of inpainting coated more smoothly, with Golden® MSA as the exception. The second layer of this paint dissolved the first coat in some areas. This observation may not be associated with the wax fill and/or varnish combination, but rather the property of the paint and diluent mixture. Note: Golden® MSA had a matte finish, while the PVA and Gamblin Conservation Colors had a glossy finish.

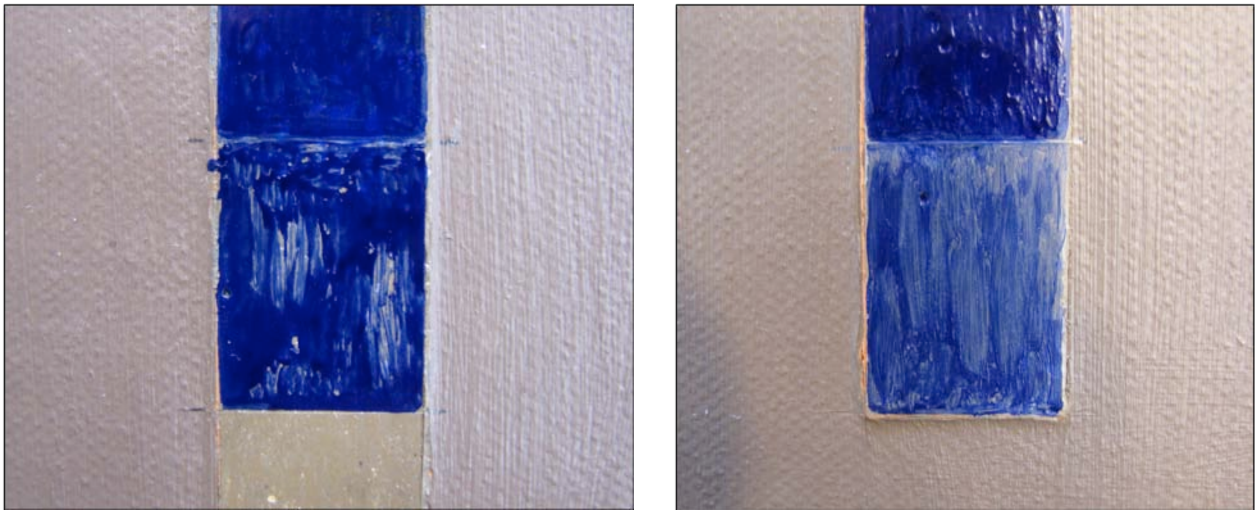


Figure 30. Two examples of streaky inpainting.

Formulation D was the most comparable to formulation A, and was therefore chosen for a Cross-cut test to compare their adhesive properties (Table 7). When “X’s” were cut into both wax fill formulas, there were cracking noises and the waxes seemed to become loosened from their substrates. For both formulas, no affect occurred after the Blue Painter’s tape was peeled up and after the Packaging tape was peeled up. Both formulas did, however, loose adhesion in small areas when Duct tape was peeled up (Figure 31). Formulation A experienced three small wax losses out of four trial runs, while formulation D only had one small loss out of four trials. All wax losses occurred on the side the Duct tape was peeled up from, which was from the left. Since more of the pigmented wax/resin of formulation A lifted away onto the tape, the assumption can be made that formulation D has slightly better adhesion to the substrate than formulation A (the original formula). This is a beneficial property for wax fills.

Table 7. Cross-Cut Test to Assess Adhesive Properties of Two Pigmented Wax/Resin Fills

	Trial	Blue Painter’s tape	Packaging tape	Duct tape
Formula A	1	No affect	No affect	Pulled up about 1/10 of area within “X” (on left side)
	2			Pulled up about 1/10 of area within “X” (on left side)
	3			No affect
	4			Pulled up about 1/10 of area within “X” (on left side)
Formula D	1	No affect	No affect	Pulled up about 1/10 of area within “X” (on left side)
	2			No affect
	3			No affect
	4			No affect

Note: Trial runs were performed from the bottom of the wax fill to the top.

Figure 31. Four trials of a Cross-cut test performed on formula "A" (left channel) and formula "D" (right channel).

Based on the results of Tables 5, 6, and 7, formulation D, which contained Laropal® A-81, could replace formulation A, which contained Laropal® K-80, and by doing so, similar pigmented wax/resin sticks could be produced that have ideal properties for filling losses in oil paintings. The new resin (Laropal® A-81) could be mixed with the same components and in the same proportions as the original pigmented wax/resin formula (formulation A). As long as Laropal® A-81 continues to be manufactured and sold in small quantities, painting conservators could purchase the resin for pigmented wax/resin fills. One disadvantage to formulation D, is that while making the wax mixture, Laropal® A-81 took much longer to dissolve into the wax than Laropal® K-80 did (about three hours compared to only ten minutes, respectively). Perhaps dissolving the resin first, before adding the waxes could shorten the dissolution time of Laropal® A-81. It is uncertain how formulation D will age and how it will be affected over time by factors such as temperature and relative humidity, light, pollution, dust, and oxidation. The pigmented wax/resin fills on the two boards should be monitored and compared to each other as they age.

V. CONCLUSION

The goal of this study was to develop a new wax fill formula to replace one that was using a resin (Laropal® K-80) that is no longer manufactured. In addition, the objective was to learn more about pigmented wax fills, their limitations, as well as their positive and negative properties.

Formulation B_3, which used Cosmolloid 80H wax and Regalrez® 1094 resin, had good working properties but making sticks was difficult because it did not pour easily and the white pigment did not stay suspended in the mixture. The resulting wax/resin fills were mottled with brown and white specs. More experimentation with the formula would be necessary to make this a more workable pigmented wax/resin fill.

Formulation C, which used Regalrez® 1094 resin, made hard and brittle sticks, but the resulting wax fill may have been too hard, as leveling and texturing were somewhat difficult to achieve.

Formulation E, which did not use resin, made very brittle sticks that broke and crumbled easily. In addition, the wax fill did not seem to have adequate adhesion while applying into losses.

Formulation D, which used Laropal® A-81 resin, made sticks similar in hardness and brittleness to formulation A (the original formula that used Laropal® K-80 resin). Formulation D had working properties similar to and perhaps even better than formulation A. Compared to the other wax/resin fills, formulation D was the most compatible with inpainting media and varnishes on the mock-up board. In a Cross-cut test, formulation D displayed better adhesion to the substrate than formulation A. These properties make formulation D a viable substitute for formulation A. One adverse aspect is that it took three hours to dissolve the Laropal® A-81 resin into the wax. There may be a better way to mix the components, such as melting the resin first; this should be investigated further.

The mock-up boards used in this study will be retained and allowed to age naturally. Studying how time affects the pigmented wax/resin fills (both with and without inpainting media and varnishes) could prove to have interesting results. In addition, ambient environments could significantly affect the fills as they respond to shifts of temperature and relative humidity. Expected problems include cracking, deformation, bloom, or delaminating. Bloom on pigmented wax/resin fills could be a worthwhile future study.

VI. ACKNOWLEDGEMENTS

The author would like to thank James Hamm, my paintings professor and supervisor, for guiding me every step of the way with this study; his knowledge and input, as well as his assistance with editing was invaluable.

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VIII. APPENDICES

Appendix 1: Pigmented Wax Fill Formulas Submitted by Questionnaire Participants.
(Numbered to retain confidentiality).

Pigmented Wax Fill #1

- Multiwax® 500
- Powdered pigment

or for a harder fill:

Pigmented Wax/Resin Fill #2

- 1 part Regalrez® 1094
- 1 part Cosmolloid 80H wax
- Powdered pigment

A heated silicone mold is used to imprint texture into the wax fill. Poly(vinyl acetate) in ethanol is used to seal the fill, then additional inpainting can be done with Gamblin Conservation Colors, as an example.

Pigmented Wax Fill #3

- Microcrystalline wax
- Pigments (in high ratio so that the fill is hard at room temperature)

Raw umber works well because it mixes smoothly into the wax and produces a deep, brown-black fill. Surprisingly, the dark fill can be inpainted with all colors including lighter ones. The wax pigment mixture is made up and allowed to cool. The loss is varnished before filling. When ready to be used, the wax is warmed and shaped with fingers, then applied to loss using a dental tool. It is leveled then polished with a piece of silk. Inpainting is applied quickly to avoid softening the fill.

Pigmented Wax Fill #4

- 1 part chalk
- 1 part Cosmoloid® 80H wax (beeswax had been used but was substituted because it flows at melting point)
- 1 part pigment

The loss is isolated with a thick Regalrez solution so excess can be cleaned up by undercutting with mineral spirits. The fill is locally coated with Paraloid® B-72 mixed with ethanol or isopropanol, and inpainting is done with Gamblin and isopropanol as the diluent.

Pigmented Wax Fill #5

- Victory wax
- Some paraffin (to stiffen)
- Pigments

A customized pen is used to apply the wax fill. The pen is made from an old ruling pen, which is heated by a craft wood-burning tool. Inpainting is done directly over the wax fills using PVA-AYAB or dry pigments in ethanol.

Pigmented Wax Fill #6

- A mixture of microcrystalline waxes (mostly Multiwax® 145-X, with some Multiwax® W-445)
- At times with the addition of carnauba wax.

The mixture is bulked and toned with dry pigments and the fill material is kept warm on a hot plate or coffee warmer. The fills are usually coated with PVA resin prior to inpainting with Golden® PVA Colors, Golden® MSA Conservation Paints, etc.

Appendix 2: Pigmented Wax/Resin Fill Formulations (Parts by Mass)

FORMULATION	**A**	**B**	**B_1**	**B_2**	**B_3**	**C**	**D**	E
RESIN	Laropal® K-80 1 part	Paraloid® B-72 1 part	Regalrez® 1094 1 part	Regalrez® 1094 1 part	Regalrez® 1094 1 part	Regalrez® 1094 1 part	Laropal® A-81 1 part	None
WAXES								
Beeswax	3 parts	3 parts				3 parts	3 parts	3 parts
Be Square™ 195	1 part	1 part	1 part	2 parts	1 part	1 part	1 part	1 part
Multiwax® W-445			3 parts	3 parts				
Cosmolloid 80H					3 parts			
PIGMENTS								
Raw umber and titanium white (1:1)	5 parts	5 parts	1.3 parts	1.6 parts	2.5 parts	5 parts	5 parts	5 parts
TOTAL	10 parts	10 parts	6.3 parts	7.6 parts	7.5 parts	10 parts	10 parts	9 parts

Appendix 3: Properties of Components in Pigmented Wax/Resin Fill Formulations

Table 1. Properties of Waxes

Wax Fill Component	Description	Melting Point or Range (ºF/ºC)	Flash Point (ºF/ºC)
Beeswax	Beeswax is a natural wax secreted from the epidermal glands of female worker honeybees and is used to form hexagonal cells for honeycomb. Pure beeswax is composed of carbon, hydrogen, and oxygen. When it is harvested from the hive it contains impurities.[a] Beeswax is generally composed of myricyl palmitate, cerotic and homologous acids with small amounts of hydrocarbons, cholesterol esters and ceryl alcohols, pollen and resins (Bennet 88). It is moderately hard and brittle, with good adhesive properties. Sold in the following grades: crude, refined, and bleached. Crude virgin beeswax is amber-colored and bleached beeswax is colorless and opaque. Crude wax is refined by re-melting and filtering with subsequent solvent extraction or bleaching with chemicals or sunlight. Manufacturers often adulterate beeswax with mineral matter. These may include tallow, stearic acid, Japan wax, carnauba wax, rosin, and paraffin wax (Bennet 87). It is compatible with other waxes, fats, oils, and resins.	143.6-149/ 62-65[b]	399/ 204[b]
Be Square™ 195 Microcrystalline	A natural mineral wax derived from petroleum distillation fractions. Chemically composed of complex mixtures of paraffinic, isoparaffinic, and naphthenic hydrocarbons.[c] Tough but with a high degree of plasticity. Microcrystalline waxes are flexible and have good adhesive properties. They are highly compatible with other mineral waxes and to various degrees with animal waxes and synthetics (Wallace 1990).	197.6/ 92[d]	500/ 260[d]
Cosmolloid® 80H	A petroleum-based, microcrystaline wax, with saturated branched and cyclic aliphatic hydrocarbon chains.[e]	165.2-176/ 74- 80[f]	500/ 260[g]
Multiwax® W-445	Same as Cosmolloid 80H	170/ 76.7[h]	410/ 210[h]

Note: Natural waxes will show variations in properties because of different sources of origin, age, exposure to the elements, and impurities.

[a] http://www.rfpaints.com/index.php?option=com_wordpress&Itemid=89&p=2007
[b] http://www.prochemical.com/MaterialSafety/Waxes/Beeswax.pdf
[c] http://www.innovadex.com/Inks/Detail/1748/116841/BE-SQUARE-195-WAX
[d] http://www.bakerhughes.com/assets/media/technicaldatasheets/4c97bbd2fa7e1c177c000013/file/28736_microcrystalline-waxes-sheet-2-5-10.pdf.pdf&fs=249715
[e] http://www.specialchem4adhesives.com/tds/multiwax-w-445/chemtura-crompton-witco-/5858/index.aspx
[f] Talas Catalog, http://apps.webcreate.com/ecom/catalog/product_specific.cfm?ClientID=15&ProductID=23426
[g] The Paintings Specialty Group of the American Institute for Conservation (AIC). Collaborative Knowledge base. Painting Conservation Catalog. Vol. 1. *Varnishes and Surface Coatings*. 1998. "Wax as a Surface Coating". 201-211.
[h] MSDS, Sonneborn, Inc., http://www.sonneborn.com/products/pdf/MultiwaxML445-MSDS.pdf

Table 2. Properties of Resins

Substitute Resin	Description	Melting Range (ºF/ºC)
Laropal® A-81	A low molecular weight aldehyde resin that is manufactured by BASF. It works particularly well in combination with resins such as Regalrez® 1094 when used as a varnish. It is It is soluble in Shell Sol 340 HT, Shell Sol 100, isopropanol, Shell M/S 145, xylene, 1-methoxy-2-propamol, benzine, and toluene.[a]	176-203/ 80-95[b]
Laropal® K-80	A synthetic polycyclohexanone condensation resin manufactured by BASF in 1979.[c] It was discontinued in 2008. Polycyclohexanones, or ketone resins, form a clear, colorless coating. They form a film that is harder with less wrinkling, yellowing, and blooming than natural resins. Ketone resins have a relatively low molecular weight for a polymer (average being 531 grams per mole) and a high refractive index (1.529).[c] They autooxidize with age and become more brittle and less soluble. Laropal K-80 has a low viscosity and has good pigment wetting properties. It can be used to improve body, gloss, hardness, strength, and elasticity (BASF Laropal K-80 Technical Information). It is soluble in white spirits, petroleum benzine, xylenes, toluene, isopropynol, ethanol, Shell sol 340H, and turpentine.[c]	167-185/ 75- 85[d]
Paraloid® B-72	An Ethyl methacrylate copolymer that has excellent flexibility and produces stable, durable, non-yellowing coatings. Its average molecular weight is 105,000 g/mol.[e] Its refractive index is 1.479-1.489.[f] Soluble in toluene, xylene, and methanol. The alcohol dispersions may become slightly cloudy.[g]	158-167/ 70-75[h]
Regalrez® 1094	A highly stable, nonpolar, hydrocarbon resin that has low molecular weight. It is a hydrogenated oligomer of styrene and alpha-methyl styrene. Its average molecular weight is 850 g/mol.[i] It has a refractive index of 1.519.[j] Regalrez® 1094 is soluble in mineral spirits, petroleum benzine, turpentine, xylenes, and toluene.[k]	206.6/ 97 (softening point)[l]

[a] http://www.conservationsupportsystems.com/product/show/laropal-a-81/synthetic-resins
[b] BASF Safety Data Sheet
http://worldaccount.basf.com/wa/NAFTA~en_US/Catalog/Pigments/doc4/BASF/PRD/30041405/.pdf?title=&asset_type=msds/pdf&language=EN&validArea=US&urn=urn:documentum:ProductBase_EU:09007af88008fb8b.pdf
[c] The Paintings Specialty Group of the American Institute for Conservation (AIC). Collaborative Knowledge base.
Painting Conservation Catalog. Vol. 1. *Varnishes and Surface Coatings*. 1998. "Ketone Resin Varnishes". 75-80.
[d] http://ge-iic.com/files/fichas%20productos/laropal_K80.pdf
[e] http://www.dow.com/products/product_detail.page?product=1121670&application=1120631
[f] http://cameo.mfa.org/materials/record.asp?key=2170&subkey=6848&Search=Search&MaterialName=paraloid+b72
[g] http://apps.webcreate.com/ecom/catalog/product_specific.cfm?ClientID=15&ProductID=17018
[h] http://cameo.mfa.org
[i] http://talasonline.com/photos/instructions/Regalrez_1094_data_sheet.pdf
[j] http://cool.conservation-us.org/waac/wn/wn17/wn17-1/wn17-104.html
[k] http:/www.conservationwiki.com/index.php?title=Chapter_IV_low_molecular_weight_varnishes#C_ketone_resin_varnishes
[l] http://kremer-pigmente.de/shopint/PublishedFiles/67260MSDS.pdf

Table 3. Properties of Varnishes

Varnish	Description
Dammar[18]	Dammar is a natural resin made of triterpenoid compounds. It is extracted from the Dipterocarpaceae tree family from Malaysia and Indonesia.[a] It is used as a painting medium and when mixed with ShellSol TS28 and D38 (2:1), as a high gloss picture varnish. It is made up of alpha- and beta-resene fractions of Damarolic acid with terpenic essential oils. Dammar has a weight average molecular weight of 424 to 506 g/mol.[a] Its refractive index of 1.539.[b] It is soluble in white spirits, turpentine, petroleum benzine, xylenes, and toluene.[a]
MS2A®[19]	A chemically reduced cyclic ketone resin.[a] When mixed with the solvent Shellsol D38 plus TS28 (9:1), MS2A is a low viscosity, highly stable varnish that is fast drying and non-yellowing. It is the product of condensation reactions involving Methyl Cyclohexanone and formaldehyde derived in-situ from Methanol and Caustic Soda. It is compatible with a wide range of solvents, plasticisers and resins. MS2A has optical properties similar to natural resins. MS2A has an average molecular weight of 1176 g/mol and a refractive index of 1.505.[c] It is soluble in low polarity solvents such as mineral spirits, petroleum benzine, turpentine, xylenes, toluene, and isopropanol.[a]
Paraloid® B-72	For a picture varnish, it can be mixed with xylene or with xylene plus Shellsol™ A100 (2:1). (See Table 2 for resin technical information)

[a] http:/www.conservation-wiki.com/index.php?title=Chapter_IV_-_Low_Molecular_Weight_Varnishes#C._Ketone_resin_varnishes
[b] http://cool.conservation-us.org/waac/wn/wn17/wn17-1/wn17-104.html
[c] http:/www.lindenchemicals

Appendix 4: Evaluations Based on Frederick Wallace's Research, Conducted in 1990.

Listed below are some of Frederick Wallace's conclusions based on his pigmented wax fill experiment conducted in 1990.

- Mixtures that contained carnauba wax and those containing cellulosics became colored readily.
- For any wax mixture, the addition of pigment to wax with a 1:1 ratio is sufficient for toning.
- Microcrystalline waxes were the most adhesive.
- All of the mixtures had sufficient tack but mixtures with carnauba had less.
- The harder and more brittle the wax, the less adhesive strength it had.
- Most waxes exhibited low surface tension. In general, harder waxes have a higher surface tension than the softer waxes.
- The Elvax containing mixtures could be textured but not to the same sharpness or degree as other samples.
- Microcrystalline waxes are too soft to be used as a fill material alone.
- Unbleached beeswax and carnauba wax (2:1) was hard and brittle but did not have enough adhesion. A 3:1 ratio might be better.
- Mixtures of wax and cellulosic materials had good physical properties and the tack was sufficient. They also accepted pigments well and showed sharp, clear texturing.
- The most successful mixture contained beeswax and Elvax 150 (9:1). The wax mixture was hard and tough but flexible. It had good adhesive properties and could be easily sculpted and textured. It was soluble in xylenes.

Listed below are conclusions drawn from examining Frederick Wallace's pigmented wax fill samples. Note: The samples, aged 21 years, are approximately ½ inch squared by 1/8″ depth. None of the pigmented waxes contained resin.

• From Wallace's report, it was unclear what experimental methods were conducted on the waxes in order to make determinations about hardness, adhesion, flexibility, surface tension, solubility, and ease of texturing and toning.

• Out of 20 samples, 10 were made with unbleached beeswax, and out of those, eight had a whitish haze (assumably fatty acid bloom). None of the pigmented wax fill formulations without beeswax exhibited bloom. As noted above, Wallace found that the wax mixture of beeswax and Elvax 150 had ideal working properties. However, these samples exhibited the greatest degree of bloom, and would therefore not be recommended; the colorless, opaque bloom layer was most visible on the raw umber sample (Figure 11).

• Out of 20 samples, 10 samples had cracking in various degrees. In general, the mixtures that used unbleached beeswax and a cellulosic had the greatest degree of cracking. Unbleached beeswax with pigments also displayed cracks. In addition, waxes pigmented with raw umber had, on the average, more cracks than waxes pigmented with titanium white. Wax samples without cracks included formulations containing unbleached beeswax with chalk (4:1), Multiwax® W-445, and Multiwax® W-885.

• Although wax samples using Multiwax® W-445 did not exhibit cracking, the sample without pigment had flattened to some degree and deformed out of shape (Figure 12). This suggested it was a softer wax. This is in agreement with Frederic Wallace's conclusion that alone, microcrystalline waxes are too soft to be used as a fill material.

IX. FOOTNOTES

[1] LAROPAL® K-80 (no longer manufactured) (polycyclohexanone resin) manufactured by Badische Aniline und Soda Fabrik [BASF], supplied by Conservator's Emporium, division of Museum Services Corporation, 385 Bridgepoint Drive, South St. Paul, MN 55075; (651) 554-8954.

[2] BEESWAX (bleached) Will Corporation and subsidiaries (no longer in business), Catalog No. 87188. Can be purchased through many suppliers globally.

[3] BE SQUARE™ 195 (microcrystalline wax) melting point 92ºC, needle penetration 6.5mm., Conservation Materials Ltd. (no longer in business), Catalog No. 3925-050.
Can be purchased from supplier:
Conservator's Emporium, division of Museum Services Corporation, 385 Bridgepoint Drive, South St. Paul, MN 55075; (651) 554-8954. [Manufactured by Bareco division of Petrolite Corp., P.O. Box 384, Wayne, PA 19087].

[4] RTV 3110 Silicone Rubber base, catalyst no. 4; Dow Corning, Midland, MI. available from**:** Conservator's Emporium, division of Museum Services Corporation, 385 Bridgepoint Drive, South St. Paul, MN 55075; (651) 554-8954.

[5] MICROPHOTOGRAPHS were taken with a Wild Heerbrugg M650 surgical microscope at 2.6X magnification.

[6] MULTIWAX® W-445 (a petroleum-based, microcrystaline wax); Sonneborn, Inc. 575 Corporate Drive, Suite 415, Mahwah, NJ 07430; (877) 948-2688.

[7] PIGMENTS (Used in pigmented wax/resin fill formulas at a 1:1 ratio)
1. Cyprus umber pigment, Kremer 4061 2000, http://kremerpigments.com.
2. a) Titanium white pigment (Formula A): Sinopia, PW6, Rutile Opaque Artist's Grade, K46200/75.
b) Titanium white pigment (Formulations B-E): Kremer 46200 2000, http://kremerpigments.com.

[8] SILICONE coated polyester film 0.015" thick; (Mylar with silicone coating on both sides) University Products, Inc., 517 Main Street, P.O. Box 101, Holyoke, MA 01041-0101. (800) 628-1912 or Talas 20 West 20th Street, 5th floor, New York, NY 10011. (212) 219-0770; OR: Archivart, Division of Nielsen Bainbridge, LLC, 40 Eisenhower Drive, Paramus, NJ 07652; (800) 804-8428.

[9] PARALOID® B-72 (a copolymer of ethylmethacrylate and methyl acrylate); Rohm & Haas, Philadelphia, PA.

[10] COSMOLLOID 80H (microcrystalline wax) melting point 74-80º C, Kremer Pigmente GmbH & Co. KG Hauptstrasse 41-47, D-88317 Aichstetten; Tel: +49 7565 91120. Available from Talas 330 Morgan Avenue, Brooklyn, NY 11211. (212) 219-0770.

[11] ARTIST CANVAS, pre-primed and unbleached, 7 oz, triple primed 100% cotton duck, titanium acrylic gesso, www.Art-Alternatives.com

[12] BEVA GEL (An aqueous dispersion of acrylic and EVA resins); Conservator's Products Company (CPC), P.O. Box 601 Flanders, NJ 07836; (973) 927-4555.

[13] ALKYD PAINTS (titanium white, burnt sienna) (fast drying oil colour) Winsor & Newton, Griffin Alkyd, Series1, permanence AA.

[14] SILICONE release paper roll [48" x 100 yds OR 68" x 100 yds.] Talas 20 West 20th Street, 5th floor, New York, NY 10011. (212) 219-0770.

[15] PVA AYAC, and/or AYAA (polyvinyl acetate resins); manufactured by Union Carbide; available from: Talas 20 West 20th Street, 5th floor, New York, NY 10011; (212) 219-0770.

[16] GAMBLIN CONSERVATION COLORS (Laropal A81 + pigments); Gamblin Artists Colors Co., PO Box 15009 Portland, OR 97293; (503) 235-1945.

[17] GOLDEN® MSA (pigments dispersed in n-butylmethacrylate resin in mineral spirits); Golden Artist Colors, Inc., 188 Bell Road, New Berlin, NY 13411-9527; (607) 847-6154.

[18] DAMMAR (hand selected Sumatra natural resin); Kremer Pigments, 247 West 29th Street New York, NY 10001; (212) 219-2394.
OR:
DAMMAR (Singapore #1 natural resin) Conservation Support Systems, P.O. Box 91746, Santa Barbara, CA 93190; (805) 682-9843.

[19] MS2A® (a chemically reduced cyclic ketone resin); Linden Nazareht, Hendre Wen, Nazareth, Caenardon, Gwynedd LL54 6DU. Wales, U.K.; Tel: 01286 882162.

GOLDEN® MSA (pigments dispersed in n-butylmethacrylate resin in mineral spirits); Golden Artist Colors, Inc., 188 Bell Road, New Berlin, NY 13411-9527; (607) 847-6154.