An Assessment of Some Practical Issues Related to Selective Chemical Paint Removal in Architectural Conservation

Ronald James Patrick Koenig

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AN ASSESSMENT OF
SOME PRACTICAL ISSUES
RELATED TO
SELECTIVE CHEMICAL PAINT REMOVAL
IN
ARCHITECTURAL CONSERVATION

Ronald James Patrick Koenig

A THESIS

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MASTERS OF SCIENCE

1999

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The following pages are dedicated to
David Evans, AIA,
1948—1998
who's great vision, humor, and gentle words
made of our architectural past a living thing.
May we be so wise.
Without the help and direction of a great number of people, this thesis would never have been completed. My wife Nichole Danova encouraged me always, and never fails to inspire me. Gail Caskey Winkler gave sage council when and where it was most needed, and her editing improved everything she touched. My friend and colleague Steve Seebohm gave me time, that most valuable commodity, in ways that allowed me to get this finished when the press of current projects was all around us. To all of these individuals I give my heartfelt thanks. Any wisdom found herein, I credit to those who have guided me. Any omissions and mistakes, are my sole responsibility.
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Introduction

The problems encountered in selective overpaint removal from original painted surfaces in historic buildings are multi-faceted. The potential variables in chemical paint removal processes are themselves complicated, as are the physical and chemical properties of historic finish stratigraphies. When considered within the context of architectural conservation projects, these issues are both physically and philosophically challenging. The effective execution of selective chemical exposures demands that the architectural conservator walk a delicate balance-beam between the practical parameters imposed by project restrictions, and the requirements for the highest possible conservation standards. Due to the broad number of variables, the methods for carrying out exposures of painted surfaces are best considered on a case-by-case basis. Many projects that contain these types of treatments, however, have common features that can be confronted using similar approaches. The following pages explore some of the issues in the selective chemical removal of paint from decorative architectural surfaces, and consider points for developing methodologies in such treatments. Although mechanical paint removal is a common method for removing overpaint from painted decoration, it is outside the scope of this work, and is therefore considered only peripherally. This paper also does not attempt a full examination of paint removal techniques in fine arts conservation, but, instead, will focus on problems commonly encountered in building conservation and restoration projects that include the exposure of decoratively painted finishes.

The first chapter examines how the exposure of decorative architectural finishes occupies a place apart from both general paint removal as well as fine arts conservation paint removal. Chapter two considers some of the specific circumstances that make the selective removal of overpaint from painted architectural decoration problematic. The third chapter looks at
chemical paint removers: what they are; what they do; how they work; as well as components commonly included in their formulation. Chapter Four examines the formulation, application and components of common historic paint types, how they are best removed, and how their physical properties can affect their removal or preservation. The fifth and final chapter explores the toxicology of chemical paint removers, as well as the associated potential toxicosis of removing lead-based paints.
Chapter 1
Selective Overpaint Removal in Architectural Conservation

Selective overpaint removal in architectural conservation is the exposure of decorative painting from beneath layers of overpaint through the removal of some layers and the retention of others. It is a procedure regularly executed by architectural conservators as a means of understanding finish histories. While it borrows materials and techniques used in the general painting trade, it also utilizes concepts established in fine arts conservation. Its goals and execution, however, are usually very different from the paint removal that occurs in either of these other fields.

Paint Removal in Architectural Conservation and General Painting

The criteria of the general house-painter in choosing paint removal materials and techniques are ordinarily based on improving the appearance and performance of paint adhesion, thereby increasing a building’s longevity. More specifically, the general painting trades remove paint for three reasons: to prepare surfaces for new finishes, to redefine the crispness of molding profiles, and to expose hardwoods that have subsequently been painted. The goal in general paint removal is to stabilize surfaces and usually entails removing all existing paint down to the substrate.

Although the technology of commercial chemical paint removers has evolved considerably through the past half-century, the general requirements for their performance have changed little. In 1948 Noël Heaton wrote:

The properties required in a paint remover are rapid penetration and solution of the defective paint, freedom from any injurious action on the surface or the hands of
the user, and complete but gradual evaporation, so that it does not dry off whilst the work is in progress.²

In 1968, Charles Martens added to these criteria: “the correct paint and varnish remover for a given application is the one which does its task satisfactorily at the lowest cost.”³ Martens also noted that proprietary paint removers are formulated so that a single product will “work on a variety of materials whose composition is unknown.”⁴ Further requirements for industrial removers include: “a lack of corrosiveness to substrates,” and the “ability to leave a readily recoatable surface.”⁵ General painters require paint removers that work quickly, are relatively safe, dwell on a surface long enough to penetrate paint layers, are inexpensive, will remove many types of paint, will not react with a substrate, and do not leave a residue.

In many cases the architectural conservator carries out selective paint removal for one of two reasons: to examine earlier overpainted decorative surfaces for documentation and replication, or to conserve earlier decorative paint schemes.⁶ While most conservators strive for the latter, often clients, architects and historians are interested in the selective removal of overpaint as a means of accessing and documenting earlier decorative schemes for replication. Although replication has its place in the conservation and preservation of historic buildings, the tenets of the American Institute for the Conservation of Historic and Artistic Works encourages conservators to “select methods and materials that, to the best of current knowledge, do not adversely affect cultural property or its future examination, scientific investigation, treatment, or function.”⁷ Although removal of a painted surface down to its substrate is normal practice in general painting, the eradication of a finish history is not acceptable in architectural conservation. Total paint removal destroys the information potentially contained within a stratigraphy.
Methodologically, the selective removal of overpaint from a decorative surface is a very different undertaking than general paint removal. While both endeavor to remove paint layers by chemical action, the ideal circumstance in general paint removal occurs when this break takes place between the lowest paint layer and the substrate. The architectural conservator, on the other hand, attempts to control the separation of paint layers at a given paint-to-paint interstice. The strata the conservator is aiming to interpret is referred to as the target layer. Once this target layer is uncovered, the chemical action of the paint remover must be arrested so that this layer is not affected.

**Speed and Dwell Time for Chemical Paint Removers**

The speed at which a chemical paint remover will remove finish layers is an important consideration for both architectural conservation and general paint removal. Its importance in each of these, however, is based on different objectives. Whereas in general paint removal the rate at which a chemical will remove paint is of concern primarily because of labor costs, in architectural conservation a paint remover’s speed must be understood and controlled so that its action can be checked once it has reached the target layer.

The amount of time a paint remover remains on a surface is referred to as its *dwell time*. Fast-acting paint removers require shorter dwell times than slow-acting ones. Due to the subtle timing required in selective paint removal, the architectural conservator requires a paint remover that will perform with minimal dwell-time. Slow-acting paint removers are more difficult to control because the point at which they reach a target layer is hard to determine. If, for example, a fast-acting methylene chloride-based paint remover is used, it can be repeatedly removed and reapplied every few minutes until the conservator determines the contact point at which he or she has reached the target layer. Removers such
as those based on dibasic esters (DBEs), on the other hand, are very slow-acting, making it difficult to ascertain when contact with the target layer has occurred. It may take dibasic ester paint removers up to 24 hours to reach a layer that can be uncovered by a methylene chloride remover in 20 minutes. The specific point in this 24 hour interval when the remover has contacted the target layer and its chemical action must be arrested is almost impossible to determine.

Safety

There are potential health risks inherent in all chemical paint removal. "All solvents have some toxicity," and exposure can occur through inhalation, ingestion, or absorption through the skin. When considering personal safety, there are no significant differences between architectural conservation and general paint removal. Some specific hazards of paint removal are more closely examined in Chapter 5.

Wide-Spectrum Paint Removers

Wide-spectrum paint removers soften and swell most types of paint, and both general painting and architectural conservation rely on them for the majority of their paint removal applications. General paint removal, however, is not encumbered by the retention of paint layers that is necessary in conservation, and can thus utilize a wider variety of paint removal products. Alkaline paint removers, for example, will remove many types of paint, but are too caustic to be useful for paint removal in conservation. "Rather than softening and swelling the paint film as methylene chloride does, caustic strippers saponify (decompose) the binder in the coating, much as lye or soda ash breaks down fat in old-time
soap-making." This caustic action leaves little of a finish history intact, and these materials often remain in the substrate. Caustic paint removers, however, are inexpensive and very effective in solubilizing most coatings, and can be used to good affect in many general paint removal operations.

**Non-reactivity with the Substrate and Re-coatability**

General paint removal requires paint removers that will not react with a substrate and will allow stripped surfaces to be recoated. Plaster substrates, for example, can be harmed by acidic removers, and aqueous removal systems can raise the grain on wood substrates. These issues, however, are of less consequence in architectural conservation. The goal in exposing historic paint is to stop the paint remover’s action at a given paint layer; the substrate should therefore not be affected during this process. Although replication of historic paint schemes through repainting often occurs following exposures, the removal materials ordinarily utilized by the architectural conservator are neutralized by the application of water, mineral spirits, or acidic neutralizers.

**Paint Removal in Architectural Conservation vs. Fine Arts Conservation**

Although architectural conservation and fine arts conservation both focus on conserving significant historic and artistic property, and are ultimately driven by respect for the cultural, aesthetic and physical integrity of their charges, there are significant differences that set them apart. The most important differences are those of scale and context. Fine arts conservation treatments have evolved within “laboratory conditions, carried on with small artifacts destined for the controlled climate of the museum.” Further,

Under such circumstances, diagnosis can be precise and therapy can be exactly practiced. The sheer size of buildings, and the fact that they stand in the
uncontrolled climate of the outdoors, precludes the mechanical application of art conservation to architecture.\textsuperscript{11} 

Historic buildings derive much of their significance from the site within which they have evolved. Separation from their site or major alterations to control their environment can severely undermine the cultural and aesthetic contextual integrity of historic architecture.\textsuperscript{12} In paintings and other movable artifacts, however, context is more intrinsic to the artifact itself, and is established through its history, provenance or artist. Movable objects are generally less reliant on their sites for significance than are buildings.

Due to innate differences, architectural and fine arts conservation approach the chemical removal of overpaint in dissimilar ways. Whereas “the fine arts paintings conservator most usually is called upon to remove a limited number of coatings” from relatively small areas,\textsuperscript{13} architectural conservators are often responsible for removing many layers of overpaint from vast expanses of decoration. Fine “paintings are usually of manageable size, and often of enormous value.”\textsuperscript{14} The value of even the finest painted architectural decoration is more difficult to quantify. These differences in scale and value necessitate developing very different methodologies for treatment within each discipline.

As a result of differences in scale and context, architectural conservation has developed paint removal performance criteria different from fine arts conservation. Fine arts conservation demands more material specificity from paint removal materials than does architectural conservation. Whereas fine paintings that require paint removal usually have a small amount of in-painting that must be removed, architectural settings can require the removal of many different coatings from a single stratigraphy. Unlike paint removal in architectural conservation, it is often expedient in fine arts conservation to develop specific paint removal regimens by matching the solubility parameters of coatings to solvents that will remove them. Richard Wolbers, for example, has developed “systems based on
organic solvents gelled in a water soluble, polyacrylic acid resin....These solvent-based systems may be engineered to remove specific coatings or to not react with a specific type of substrate.” 15 Although architectural conservators have utilized Wolbers’ gel systems for projects such as the removal of overpaint from the distemper decorative ceiling of Saint Francis Xavier Church in Parkersburg, West Virginia, they more often rely on commercial, proprietary removers to uncover historic decoration.

Methodologies

Overpainting of architectural decoration usually occurs as a natural consequence of a building’s evolution and maintenance. While overpaint on fine arts paintings is sometimes the result of intentional alteration, it usually occurs through aesthetic reintegration and repair. As architectural conservator Brian Powell points out: “I know of no case where a Titian needed to be cleared of multiple layers of tenaciously bound house paint.” 16 Differences in scale, value, and motivation in treating movable and immovable paintings demand a separate approach and performance criteria from the two disciplines.

Conserving overpainted architectural finishes is a time-consuming and expensive process, and is usually considered prohibitive for all but those buildings deemed supremely significant. “In the study of lost architectural decoration, we often must design the most expeditious approach or a given job may not happen or may happen in too limited a fashion.” 17 It is difficult to quantify what the conservation of overpainted decorative schemes will cost, or how the final conserved finishes will appear. Furthermore, a project’s budgets, work schedules, and plans for decorative paint replication are often in place long before a conservator is brought on site. Convincing owners, architects, project
planners, and project managers that it might be possible to conserve rather than replicate significant historic painted designs is frequently a difficult proposition at best.

The financial resources which can be brought to bear on conserving paintings are rarely available to the architectural conservator, and this can have a profound influence when developing an architectural paint removal methodology. Scanning electron microscopy, emission spectroscopy, x-ray diffraction, and gas chromatography can all be utilized to precisely determine the components of a finish history and assist in planning a selective paint removal approach, but “these analytical procedures are costly and can be justified only for projects where the accurate identification of a paint’s pigment and media are required for the success of a restoration or conservation treatment.” While these types of testing are regularly utilized in the conservation of fine arts paintings, most architectural paint removal projects do not warrant this level of analysis.

Although in many cases architectural conservators selectively remove paint with the intent of conserving exposed decoration, exposures are also often executed solely to facilitate replication. In fine arts conservation painting, replication is not utilized in quite the same fashion. Whereas reinstatement of architectural decorative work is often appropriate, repainting of works of art under the care of the fine arts conservator may be ethically censurable. In the building arts painted decoration is only one facet of an interior scheme, and the significance of original painting must be balanced more liberally against the state of its aesthetic integrity than in fine arts conservation. In some instances replication is the only means of preserving the information contained in damaged or degraded architectural finishes; original materials may be lost in the process but their cultural meaning is preserved. If exposed painted decoration bears little resemblance to its artist’s intention, or how it appeared at any point in its history, it can detract from the integrity of an interior to the extent that replication becomes a sounder option than conservation.
Architectural conservation also differs from fine arts conservation in the autonomy each affords its conservators. Whereas fine arts conservators are often solely responsible for developing methodologies for treatment, most architectural conservation projects “involve architects, engineers, specification writers, general contractors, and tradesmen” in this process. Decisions as to whether architectural decorative painting will be exposed and conserved or exposed for replication are commonly handled within a team environment, with budget and time restrictions the primary consideration.

Fine arts conservation treatments ordinarily take place in a laboratory setting and are executed by interdisciplinary professionals adept at inorganic and organic chemistry, instrumental analysis, and their own very specialized branch of the material sciences. Fine arts conservation has two primary objectives: “Firstly the control of the environment to minimize the decay of artifacts and materials; and secondly, their treatment to arrest decay and to stabilize them against further deterioration.” To realize these objectives fine arts conservation treatments utilize a very tight focus on the objects and materials themselves. Due to their scale and site-specificity, immovable artifacts must be considered within a wider macro-focus; “architectural conservation has emerged today as a scientific discipline focused on the physical context of the present structure or site and its particular conditions of aging and survival.”

General Philosophical Considerations

Paint removal is by its very nature non-reversible. As a treatment, it must therefore be undertaken only with the greatest care. The architectural conservator must often make difficult decisions regarding the fate of intermediary layers, as decorative painting
campaigns later than those being target-dated are generally lost through the exposure process.

In executing exposures of decorative paint, painstaking photographic and written documentation are essential. The Code of Ethics for the American Institute for Conservation states that "The conservation professional shall document examination, scientific investigation, and treatment by creating permanent records and reports." This documentation is in many cases the only record that will survive of paint layers not targeted for conservation or replication. When possible, a representative section of unexposed surfaces should be left intact for future researchers.

The execution of exposures should, of course, occur only after all available data has been documented. At the least this should include a detailed inspection of the entire building, an examination of all existing maintenance records, and a search of all relevant archival materials. An understanding of regional historic paint colors and designs, as well as an idea of the target date which clients may have in mind for the surface(s) being considered, are also often necessary before exposures are attempted.
Paradoxically, while paints are specifically formulated to be robust and to adhere to almost any surface, the fragility of many historic surface coatings can make them particularly difficult to preserve. During the exposure process, the difficulties in managing these materials are combined with the variables inherent in selectively preserving some paint layers while removing others, and the technical complexities of such treatments can thus become intricate and difficult to control.

Of all the systems that make up a building, none play a more significant role in improving a building's appearance and longevity than its paint coatings. No system is more ephemeral, yet more enduring than the painted finish. While some surfaces fully give up their paint finish in a short time, others bond with their coatings to an astounding degree. Some finishes applied in relatively benign conditions will begin to chalk, peel, and crack after only months of exposure, while others, even in destructive environments, can remain well-bonded for decades. “Successful painting depends not only on the paint itself but also on how the surface is prepared, how the paint is applied, and the environmental conditions during drying.” With the application of multiple paint layers over time, the number of variables in a given situation—and thus the number of potential points for failure—can increase exponentially.

Historic paint systems may be very complicated. Caseins, for example, were often mixed with linseed oil and/or glue distemper, creating hard, intricately-bound amino acid-polymeric chains. With the exception of very specialized coating systems, all paints need to be applied in a semi-plastic state, yet dry in a reasonably short amount of time. Ideally, they should cure hard, yet remain flexible enough to allow for the expansion and
contraction of the substrates to which they are applied. Paints also have to have good film cohesion and adherence to the substrate, remain stable over time, accept pigmentation, and be compatible with a wide range of substrate materials. All of these physical properties are balanced in a film that may be only microns thick. Considering the large number of variables inherent in paints, it is remarkable that paint formulations perform so well. Precisely because we expect this high performance in architectural coatings, we also expect to remove them in a relatively simple manner.

Paint stripping in its simplest form is the action of breaking the bond between layers of paint, or paint and substrate. However, it is a "catastrophic" process in that it not only destroys paint layers, but usually simultaneously lifts and separates them as well, allowing them to be removed from a surface. The formulation of a paint stripper—like the development of any cleaning system—is something of an art. Paint removal requires experience, patience, and innovation, and is part technology and part informed intuition. Architectural conservators "have incrementally built a repertoire of approaches, but have not yet come so far that an element of invention is not often necessary."

"Knowing what to use when, and how, to effectively remove paint is really more an art than a true science." Most often an experienced architectural conservator deductively assesses the appropriate paint removal materials and techniques that will work to uncover lost decoration. As Andrea Gilmore has noted: "Identifying the correct solvent requires testing and is time consuming." In an early description of the exposure process, Esther Stevens Brazer described selective paint removal:

When old designs have been obliterated by successive layers of paint, we have before us a chance to indulge in an exciting archeological adventure. Undoubtedly we will meet with varying degrees of success ranging from the perfect revelation of a beautiful design to the disappointing discovery that some decorator before us had scraped away all original paint... The uncovering procedure is largely experimental, due to the widely varying make-up of paints used in the past one hundred or two hundred years. What will dissolve the outer paints in one case will not work at all in many other attempts.
Although Esther Brazer was writing in the early 1940s, prior to the widespread introduction of the primary solvents used in paint exposure today, little has changed in the general methodology for uncovering overpainted decoration.

To date, no comprehensive primer has been written on the subject of chemical paint removers, and the chemical mechanisms that we utilize to remove paint are not well understood. In addition, “variations in coatings, substrates, and surface contaminants make it impossible to provide firm guidelines identifying the most effective methods” for paint removal. Different materials and techniques are needed to remove paint in different sorts of circumstances.

Although deductively matching specific custom-formulated solvent mixtures to paints should be the most effective way to selectively remove overpaint from decoration, such an approach does not ordinarily work. “At best, this view is oversimplistic,” because paint removers usually require a wide range of chemical mechanisms to do their work. Though paint removers in conservation are usually chosen because of their specific solubility parameters, it is difficult to deduce precisely how they will perform. Often formulations use methylene chloride as a primary solvent, and are then balanced with a few co-solvents to locate the mixture in its ideal position on the Teas diagram. The solvent selection process, however, is generally more arbitrary than the use of the Teas diagram would suggest. “Subjectively, it is appreciated that ‘like dissolves like’ but this aphorism is insufficient to predict the effect of a solvent on a polymer.”

The Teas system of diagramming the solubility parameters of solvents was developed by Charles M. Hansen in 1967 as a means of establishing in a graphical model the three types of molecular bonding forces believed responsible for the action of individual solvents on
polymers. By plotting the dispersion forces, dipole forces, and hydrogen forces of a given solvent, he believed one could predict its performance with specific materials. Using Hansen’s system, however, is difficult, because “the three solubility parameters are not that accurate....[and] compressing the parameters onto a triangular diagram makes matters worse.” 15 Further, using Teas diagrams for the aromatic and aliphatic hydrocarbons—the solvents generally utilized in paint removal—is fruitless, because Hansen’s formulae for creating Teas diagrams simply does not work for these particular solvents. 16

While it may seem methodologically sound to execute selective paint removal through matching the solubility parameters of solvents to finish materials, in practice it is rarely successful. Understanding that casein paints are soluble in ammonia but less soluble in methylene chloride, for example, can be helpful in removing or retaining them. Plotting the solubility parameters of all the finishes in a complex, overpainted stratigraphy, however, is fraught with difficulties.

It is rare that a complex paint stratigraphy can be removed down to a specific strata simply through planning and executing a quantifiable methodology that matches a remover with finishes it is known to remove. Even after careful analysis to match a paint to a solvent, “chemical combinations that theoretically should work, often do not.” 17 Experimentation through informed trial and error in conjunction with stratigraphic and chemical analysis is often the most useful means for determining which paint removal system will be successful. As is the case in establishing an appropriate level of "clean," establishing a consistent and appropriate end product for an exposed surface is often the most difficult of the conservator's tasks.
Determining Colors In Exposures

The wide range of circumstances the conservator will encounter when selectively removing overpaint makes it difficult, if not impossible, to outline precisely how one should approach color analysis for all exposed surfaces. Every project will have components peculiar to its geography, building, space, surfaces, budget, and available documentation. The determination of most historic finish colors, however, can usually follow a fairly predictable methodology.

A typical project involves a client asking a conservator to match the original overpainted decorative finishes in a particular room. Often this person has no sense of the finish history of this space—just a suspicion that some sort of decorative motif(s) are likely present. The methodology for approaching this task requires at least five steps: archival research; an initial examination; sampling and microscopic analysis; test exposures; and the compilation of a documentary report with recommendations. Additional steps may include: pigment and binder analysis, in situ cratering, full exposures of painted decoration, the generation of blue-lines for the decorative painting contractor, analysis for LBP (lead-based paint), testing for stabilization of plaster and/or damaged paint, testing the feasibility of exposing decorative surfaces so they can be conserved, and cost estimates for the trade components of the project. Part of the conservator’s responsibility is to act as an advocate for the building, ensuring that the project specifications for the skilled-trades are such that the longevity of the historic and restoration materials are not compromised.

Documentation

The most important task of the conservator carrying out exposures is the gathering of archival documentation. Uncovering the amounts and kinds of materials billed at the time of
construction, architect’s or builder’s specifications, the elapsed time between the dates materials were purchased (thus suggesting the general amount of time phases of construction required), and payment records, can be extremely useful to the conservation professional. In many cases, however, very little or no archival documentation survives for decorative finishes and it is often necessary to chart the evolution of a building’s decorative history exclusively through the physical evidence that has survived beneath surfaces. In the Michigan State Capitol, for example, over 750 pages of decorative painting blue-line drawings were generated in order to replicate the original overpainted complex wall and ceiling decoration, but only two photographs detailing decorative work in the building were ever found. Following exposure and documentation of the decorated plaster walls and ceilings, the majority of plaster surfaces were demolished and reinstated with new work; thus effectively destroying all of their historic physical evidence. It was therefore the critical responsibility of the technicians carrying out selective paint removal to conscientiously document the exposed overpainted decoration, as this was the only evidence that would survive of these alterations.

The Alteration of Color Through the Exposure Process

Although it is possible to expose period decoration mechanically and chemically in ways that leave colors more or less intact, these process are all potentially damaging, and will often change the visual properties of finishes. The process of paint color identification can thus become very complex. The exposure process can alter colors in myriad different ways; chipping and scratching a finish can mar it beyond recognition, chemicals can blanche and discolor decorative films, and failure to remove the most diaphanous of overpaint residues can dramatically obfuscate decoration. It is the conservator’s challenge to ferret out the least
invasive method of paint removal, that will in turn leave the colors of an exposure with the highest degree of visual integrity.

Chemical paint removers rely on their capacity to alter the physical properties of paint materials. This process is not only physically invasive, but chemically invasive as well, altering and destroying not only the intra-layer bond in paint stratigraphies, but also the chemical and molecular structure of the materials in these individual layers. The colors and complex effects of decorative finishes are often dependent upon ephemeral physical properties that are easily impaired by the solvent action of paint strippers; even slight changes to their physical properties can dramatically impact how they appear. The accidental removal of a diaphanous glaze, for example, can change a robust grained panel into a pink one, and the loss of the final plate of a multi-layered stencil can make a pattern unrecognizable.

More subtle alterations, however, can be equally problematic. Chemical exposures rely on a paint remover swelling and softening overpaint so that it can gently be extracted, but the chemical’s solvent action must be stopped before it can dissolve intended target layers. If the solvent action of the paint remover does travel beyond the overpaint and soften the layers one is attempting to preserve, these finishes are visually spoiled. During selective paint removal in the Senate President’s Office of the Massachusetts State House (the Coolidge Room), “solvents that removed the overpaint penetrated the layer below, leaving it muddied.”18 This tendency of methylene chloride removers to create a murky haze across the surface of a finish is due to the solvents penetrating the face of the layer and beginning the swelling process before their action is arrested. 19

Oil paints are particularly sensitive to chemical paint removers, with blanching being one of the most common problems. “Blanching fades the apparent color of a paint not by
photochemical change, but by degrading the oil, thus reducing the paint’s glossiness and causing diffuse reflections of incident white light."\textsuperscript{20} While most oil paint surfaces suffer some blanching through their normal aging process, paint removers exacerbate this condition. The chemical exposure process often severely degrades the oil in revealed finishes, giving them a “chalky” appearance. Although the application of a varnish can consolidate these fine surface particles and thus improve this condition, it is rarely fully reversible.

Problems can also arise when pigments are sensitive to the solvents in paint remover formulas. Most commercial paint removers contain a number of different solvents to increase the types of coatings they can remove.\textsuperscript{21} In addition to the primary solvent methylene chloride in most commercial retail strippers, many removers also contain solvents such as methanol, toluene, trichloroethylene, and ethylene dichloride.\textsuperscript{22} These solvents can all react with various historic pigments to alter their visual characteristics; this is particularly the case with alkaline sensitive pigments such as Prussian blue, gamboge,\textsuperscript{23} and most reds.

Pigments are often sensitive to changes in pH from paint strippers. While caustic alkaline strippers are not ordinarily used to carry out exposures, even methylene chloride strippers are ordinarily formulated towards either the alkaline or the acidic end of the pH spectrum. The most common “methylene chloride-type removers are unique in their ability to accept co-solvents and activators that allow the solution to be neutral, alkaline, or acidic.”\textsuperscript{24} Paint remover manufacturers formulate their materials so that they cover the widest solubility parameters possible, and this usually means making their products particularly basic or acidic to attack binders sensitive to these extremes.\textsuperscript{25} “Carbonates, ultramarine, and some oxides and sulfides...are readily decomposed by acids.”\textsuperscript{26} “Even the weakest acids will...diminish the rich blue of lapis lazuli and ultramarine...[and] even the weak basic
detergents which may be present in cleaning fluid encourage yellowing, if small amounts of residue are left on most pigmented surfaces. 

Pigments that should be reactive in these strong solvents are sometimes not much affected by them. This lack of reactivity appears to particularly be the case "when the pigments are used in oil medium, because the oil encloses each particle in an envelope that protects it."  

Overpainted varnish and glazes can act as protective coatings when solvents are applied. In complex decorative schemes, however, the upper paint applications in a design may have been applied over these transparent or translucent materials and will quickly be affected by the exposure process, while lower protected components of the design will be left untouched.

Colors—particularly highly saturated ones—may react unpredictably in the presence of chemical paint removers because of solvent action, because of their variable pH levels, or for unknown reasons. Decoratorative painters practice a very specialized craft that is positioned somewhere between house painting and fine painting; the materials used in their work are often a mixture of the conventional and exotic. Fine examples of painted architectural decoration—such as that executed in the 19th century by the German-trained artist George Herzog in Philadelphia's Masonic Temple and The Union League of Philadelphia—are ordinarily an amalgam of gilding, glazing, stenciling, and free-hand work, carried out in oils, distempers, and glazes. Such complex finishes will react in unexpected ways when exposed to chemical paint removers.
Sampling, Microscopic Analysis and Exposures

Examination of paint samples under the microscope reveals a paint history vertically, using the archaeological model which posits that the lower strata—those closer to the substrate—were laid down earlier in the sample’s history, and those closer to the surface represent layers of more modern execution. Whereas the exposure of decorative work provides a window to how historic painted schemes appeared in their horizontal orientation, cross sections show this history as a sequence of painting campaigns.

Sampling and microscopic analysis are carried out in concert with exposures to yield different types of information. Whereas the exposure of a painting campaign segregates it from a stratigraphy and allows it to be viewed in isolation, the microscopic analysis of paint cross-sections permits the conservator to examine the relationship between stratigraphic layers, one on top of another. Each procedure imparts different kinds of information and has its own limitations. While exposing decorative schemes can reveal in a general way how they once appeared, the physical integrity of exposed surfaces has usually been dramatically altered through overpainting, time, and the exposure process itself.

While microscopic analysis can reveal important information about color, surface treatments, building histories and the condition of individual painting campaigns, it is only capable of revealing a very thin two-dimensional profile of a paint stratigraphy, and is therefore ultimately limited by its very narrow field of view. This profile is also limited by the location from which sampling has occurred. Electron microscopist Sidney Polton uses the following analogy to describe this phenomenon:

Let us say you cut an automobile in half down the middle. In that case, you could guess the complete, ‘whole,’ structure. But if you cut a very thin slice from the automobile, and if you cut it on a strange angle, it could be more difficult. In your slice, you might have only a bit of bumper, and rubber tire, and glass. From such a slice, it would be hard to guess the shape and function of the full structure.  

22
While microscopic cross-sections are useful in understanding particular, minute aspects of a stratigraphy, they are less useful for imparting macro-information about overpainted complex decoration in-plane.

If undertaken prior to exposure, the microscopic analysis of cross-sections may reveal the presence of decorative painting and the types of decorative finishes that will be encountered (particularly metallic leaf and glazes), as well as the number and physical properties of layers of overpaint. Such information can be exceedingly useful, as it allows the conservator to anticipate what will likely be encountered during the exposure process. If a sample is not taken directly over decoration, however, the existence of decorative treatments can be missed. Further, if a sample is taken through, for example, the field band behind a stencil, this color may erroneously be interpreted as a flat-painted painting campaign.

If carried out after exposures have been executed, samples can be utilized to determine information vital to replication, including colors, grounds, and types of size for metal leaf. It is ordinarily only after decoration has been exposed that color locations of its various elements can be determined. Without prior exposures the conservator is blind to subsurface decoration; it is thus rarely possible to determine the existence or nature of overpainted decorative painting without first executing exposures.

While simple initial examination of a paint chromachronology under the microscope gives little indication of how finishes may react to exposure methods, it can show the condition of particular strata and help to determine if conservation rather than replication might be possible. Until the conservator actually begins the exposure process, however, such conservation treatments are rarely predictable.
To accurately determine colors of exposed overpainted decoration under the microscope it is essential that sampling be carried out in a way that keeps samples from being compromised by the paint removal process. Ordinarily, samples for color matching are not taken directly from areas of decoration that have been chemically exposed, because the pigments in these have been altered by contact with the chemical remover and may not read true under the microscope. This creates a dilemma: how does one gauge precisely where a particular colored element will be situated, so a representative sample can be taken? In repetitive stenciled decoration this is fairly simple—once a repeat has been uncovered, it is easy to anticipate where the different colors of the next repeat will fall and take samples from these areas. More complex decorative schemes are customarily arranged with bilateral symmetry so that all 4 quadrants of a room contain the same basic decorative information; this allows one to carry out exposures on one side of a room, and take samples from corresponding areas on the another side. If work is figurative, scenic, or otherwise non-symmetrical, postulating precisely where similar overpainted decoration will occur in a space is difficult.

Samples can be mounted for examination in a variety of ways: they can be set in resinous media, sliced with a microsaw or microtome, and finely polished so that a perfectly planar surface can be viewed in high magnification; or they can be broken cleanly, mounted on wax or clay, and examined under lower magnification. The first of these procedures is usually necessary when chemical analysis for binders or pigments is performed. The second method is generally utilized when the technician’s primary goal is a simple visual inventory of the sample’s stratigraphy.  

When matching paint samples for color under the microscope, it is important that the conservator take into consideration changes in paint manufacture and application. Until the introduction of widely available commercial painting materials around 1875, “oil paints
were usually dispersed by hand, and most unevenly, so that each pigment exists in the paint in many different degrees of dispersion.” Modern commercial paints demonstrate more finely-divided, homogeneous mixtures. When a historic paint mix is a blend of several different large-granule pigments, at the macro-level the eye will see one color—red and yellow microscopic particles, for instance, can be perceived by the naked eye as orange. High magnification can separate these larger pieces of pigment and cause them to be perceived and erroneously interpreted as discreet, individual colors.

Paint chronologies may be interrupted by disturbances during their history, such as cracking and peeling of a paint layer. This complicates analysis, but often allows conjecture as to the state of a surface’s finishes at a particular time in its history; for example, failing paint in a strata may indicate poorer maintenance than other years when repainting took place on a regular schedule. Cross sections can also help determine structural changes. In the Old State House in Boston, different color woods were used in a renovation and thus woodwork that was not original could clearly be determined. At the Allen County Courthouse, in Fort Wayne, Indiana, chemical exposure and later micro-examination of samples from ceiling panels in the West Courtroom uncovered an earlier complex decorative scheme that had been executed in only one coffer, and led to the conclusion that this represented a sample carried out by the decorators in 1919, and subsequently rejected.
Chapter 3
Chemical Paint Removers

Prior to the development of chemical paint removers, paint removal was accomplished through simple scraping or open-flame burning with a torch. In 1910, Fred Maire wrote: “most of old paint removed from overpainted surfaces is chiefly taken off by the aid of the paint burners which heats it and softens it into heat blisters.”¹ He added that the gasoline torch was “an indispensable tool to have and should have a place in every well regulated paint shop, as it will save money over any other method that can be used in removing old paint over large surfaces.”² Although using open flame to remove paint created a great risk of fire, it was the only practical means which painters had to remove hardened accretions of paint.

The earliest chemical paint removers used in America were alkaline and were made from processed wood ash (lye). Patents on commercial removers based on acetone and alcohols were first taken out in 1920s. In the 1930s and 1940s, removers utilizing 2-nitropropane, dimethyl sulfoxide, and 1,1,2-trimethoxyethane appeared on the market, but were generally too costly for everyday use.³ Following World War II, paint removal formulations using methylene chloride began to be used widely on architectural projects of limited scope. Improvements in coatings technology has led to “today’s high performance formulations for the removal of epoxies, urethanes, and silicones.”⁴

Chemical paint removers are regularly categorized by six characteristics: their primary ingredient; application method; alkalinity; method of removal; general viscosity; or hazardous classification.⁵ These categories tend to be user-specific; for example, while those manufacturing paint removers are likely to group them by primary ingredient, the Environmental Protection Agency groups them by their hazardous classification.⁶ For the
architectural conservator carrying out the selective removal of overpaint, each of these classifications should be utilized for different circumstances encountered during evaluation and treatment.

Primary Ingredients

Although different situations call for finish removers with different ingredients, the primary ingredient in most formulae used by architectural conservators for chemical exposures is methylene chloride. "Hardware store strippers are the most common solvent used in exposures." Methylen chloride is a unique solvent in the way in which it penetrates, softens, swells and lifts paint from a surface. While many other solvents and chemicals are used as the primary ingredient in paint remover formulas and can be used in creating exposure windows, no other medium works as quickly, nor as evenly, as methylene chloride in this particular application.

Application

While removers can be applied in a wide variety of ways, including trowelling, soaking, spraying, brushing, or rolling, it is these last three application techniques that are used by most architectural conservators for exposing decorated surfaces. In exposing decorative surfaces, "it is imperative to apply the material evenly over workable area to allow an equal dwell time." These three application methods distribute the material in the most uniform manner, allowing the target strata to be evenly uncovered.
Alkalinity

The pH of a paint stripper can play a significant roll in determining performance on specific finish materials and is also often a limiting factor when sensitive substrate must be accounted for. Alkaline plaster, for instance, can react poorly to acidic strippers, particularly if their isolating layers of paint have been breached by cracking, peeling, or alligating. Paint removers used for carrying out exposures can be neutral, basic, or acidic, and slight variations in pH can dramatically alter how a paint stripper performs. During the exposure of a decoratively painted ceiling fragment from the Union League of Philadelphia, for example, it was discovered that a slight change in the pH of some common solvents would allow the successful solution of paint layers that would not soften with the same solvents at a different pH. In carrying out exposures on the northeast hallways in The New York State Capitol, Brian Powell found that raising the pH of an ammonium bicarbonate solution allowed the softening and removal of overpaint from a particularly rough-surfaced plaster.11

Method of Removal

All chemical paint removal involves a mechanical component as a part of the process, for stripper and overpaint residue have to be physically separated from the target layer when it has been reached. The manner in which removal is accomplished will often be the most important aspect of a treatment. A careful method of removal can be accomplished in several ways depending on how the surfaces respond to the stripping medium. Sometimes methylene chloride will in a very short time swell the layers of overpaint away from the target strata sufficiently that they can simply be lifted away with a thin-bladed putty-knife. While the dwell time must be monitored to insure that the stripper does not "burn through"
the target layer as well the overpaint, the dwell-time window can be relatively long (10-30 minutes) in which the lower decorative work is not unduly harmed. This is particularly the case when exposures are being executed with the primary goal of simply documenting designs and placement of overpainted decoration, and an aesthetically perfect original treatment is not necessary.

In other situations the dwell-time of the paint stripper has to be very carefully controlled, with the layers of overpaint being removed with different materials of different textures. During the restoration of The Michigan State Capitol, House of Representatives Offices, technicians used large amounts of expensive medical gauze to rub away softened oil overpaint and finding an economical substitute was important. As carpeting was in the process of being removed from the suites, a large supply of yellow foam-rubber carpet padding was readily available. The foam rubber proved a perfect substitute as it was absorbent enough to hold the softened paint, had sufficient “tooth” to pull the paint from the surface, and yet was soft enough it did not scratch the target layers below. In the Treasury Department in Washington, DC, a selective removal process was developed that also used a padding material. To remove the bulk of the overpaint, scrapers and commercial strippers were used; as the target layer was reached, applications of denatured alcohol and 5F5 (a methylene chloride-based stripper produced by Sterling, Clark, Lurton, of Medford, Massachusetts) were alternately wiped on with rags to a point where the ghost of the target decoration was just discernible. The 5F5 was then applied for only a few seconds, and, as Brian Powell reports: “When the overpaint was thoroughly weakened, but before the target layer was attacked, we vigorously rubbed the chemical and paint residue off with rough pieces of burlap.” 12 Again, as was the case with the foam rubber, the burlap worked as both a gentle abrasive, and also as an absorbent wipe.
General Viscosity

The viscosity of a chemical paint remover plays an important role in determining its performance. In paint removers "the viscosity can vary from water thin, to a thick spray-on, to a paste trowel-on remover." Most selective paint removal is carried out using thixotropic gelled formulas that remain in place when applied. If a less viscous formula is used, the conservator must be careful that the outer perimeter of the area being exposed is carefully controlled, to insure that a continuous planer surface is produced. "When clearing paints from a large area, especially when those paints may remain exposed, it is important to control the edges of each block of work area." If the areas between exposure windows are not feathered in properly, the resulting lines will break up the work, giving it an uneven appearance.

Most gelled strippers are applied with a brush or roller in small areas that they can be carefully controlled by one person. Selective paint removal over too large an area makes it difficult to remove the entire surface at the same moment in the dwell-time sequence; some areas can thus retain too much of the material from the upper layers of overpaint, while other parts can be compromised by the paint remover. While this is less an issue when decorative work is being exposed only for replication—as designs will be recoated—it is not acceptable when an attempt is being made to expose and then conserve overpainted work.

Although gel formulas are used for most exposures, in some situations thinner formulas are used because of the wider range of application methods they allow. In exposing modular decoration in the Wisconsin State Capital, for example, sharply delineated areas were masked off and a water-thin methylene chloride based paint remover was sprayed across surfaces with a pump sprayer. The low viscosity of this material allowed it to be applied in
very thin coats. In this instance, it was found that the method of application (spraying) determined the viscosity of the material used. Gelled formulas can also be sprayed, but they tend to go on in a thicker, spattered pattern, which will often not allow paint to be removed as uniformly. As it is “imperative to remove each layer or group of layers in the most even manner possible,” careful consideration and testing must be undertaken to determine the appropriate viscosity of the formula for a given application.

Hazardous Classification

The health issues surrounding the exposure of historic surfaces are examined in greater detail in Chapter 5, “The Health Hazards of Paint Removal.” A product’s hazardous classification relates not only to its toxicological hazards but also to its corrosiveness and flammability. These classifications are designated by the US Department of Transportation as a way of monitoring and regulating the shipping and storage of these materials. All paint removal methods contain some degree of risk, and it is the conservator’s responsibility to balance the efficacy of paint removal systems with the dangers imposed by them. While the health risks of these chemicals to individuals are certainly a part of why they are classified, the primary focus of the Department of Transportation is the safety of the public at large.

Solubility Parameters

Chemical paint removers rely on the solubility of coatings for their removal performance. In essence, paint removers seek to reverse the process by which a paint goes from a liquid state to a solid state, as well as to break the adhesive bonds that hold a coating to its
Although a number of different types of removers are commercially available, only a relatively small number of these are regularly used by Architectural Conservators. Circumstances, however, do arise where other paint removers are required. If the upper layer of a paint stratigraphy, for example, is composed of epoxy, with the lower target strata being a well-bonded oil paint, the conservator might attempt to remove the epoxy with an acid-based stripper, neutralizing its action before the stripper could solubilize the target layers. Success would depend on factors such as the thickness of the epoxy, the strength of the stripper, the bond between other strata, and the experience and luck of the conservator.

"In the chemical exposure of decorative paints there is a range of possible solvents and possible results." This range is spread out between the most difficult circumstances—separating paints whose chemical and physical properties are very much alike—to very simple situations in which the layers of overpaint can easily be solvated with chemicals that do not affect the lower target strata. In using solvent-based strippers to perform exposures, "The challenge is to find one or to use one in such a fashion that it does not go on to dissolve the target decorative layer". The ideal situation is where a more easily soluble paint such as an acrylic emulsion can quickly be swelled and removed with a stripper, yet leave solidly bonded decorative layers beneath untouched.

The most difficult paint removal occurs where the paints that make up the target layer have physical properties very similar to those of the overpaint, and the layers are well-bonded. "In the uncovering of architectural decoration, we may need to remove very similar layers one from another, and, while surveying to find work that might be hiding in a number of different layers." When this situation arises, there is not a clear delineation between when the layer above the target strata has been breached, and the solvation and swelling of the target layers have begun. This situation is exacerbated if these paint strata are similar in
color. Most of the signals that warn the conservator that he or she has reached the target layer are visual. If the chroma, texture, and hue of the overpaint and the target layer are difficult to distinguish, the very subtle point when the chemical reaction must be halted can be almost impossible to determine. In a first floor office reception room on the East Corridor of the Michigan State Capitol, it required three days to uncover a simple Greek key frieze pattern. While its overpaint was readily removed, the colors of the two-plate stencil were so close to their field colors and overpaint that its outline constantly slipped-by during exposure. The problem was aggravated by the original plaster and decoration being extant in only three small areas; exposures were only successful on the final fragment.

The reality of selective paint removal is that exposures are often only moderately successful, and the surfaces left behind are usually less brilliant, sharp, or intact than when they were first executed. Often areas of loss can be in-painted, or, as in the case of the Pennsylvania State Capitol, plexiglas placed over exposures to highlight the archaeological method used to uncover replicated designs. In 1997, during Preservation Week in Lansing, Michigan, plaster wall fragments with an exposed complex trellis design from a Michigan State Capitol office were exhibited along with photographs of the same surfaces after the wall pattern was replicated. This illustrated for the public how the exposure of decorative surfaces was used in the restoration of an important public building. In buildings in Rome, Italy, areas of exterior exposed painted decoration is sometimes left in place on a facade; here they give a poignant glimpse of how these streets must have looked in a lost painted past.

While the selective removal of overpaint from historic painted surfaces can occur with varying degrees of success—that is, the target strata are uncovered more intact or less intact—with creativity, their conservation and presentation can in most cases communicate how these surfaces once appeared. Though the popular American aesthetic stresses bright,
unsullied perfection in decoration, with some education clients can ordinarily be convinced by the conservator of the strength and beauty of often imperfect exposed historic decoration.

The Components of Commercial Chemical Paint Strippers

Most paint removal compounds have been formulated for an industry that is interested in removing all traces of paint from surfaces prior to refinishing. Proprietary paint removers are therefore usually a complex amalgam of ingredients that, in a wide-spectrum approach, are intended to remove paint as efficiently as possible. The paint remover industry has increased the complexity of their formulae, adding a wide array of ingredients that assist each step of the paint removal process. Most modern formulations include principle solvents; co-solvents; activators; thickeners; emulsifiers and surfactants; evaporation retarders; and corrosion inhibitors. Each additive contributes specific physical properties to a formulation. These ingredients, however, are not added with the needs of the conservation professional in mind and can each assist or hinder the selective paint removal process.

Co-solvents

The addition of co-solvents to paint remover formulae improve performance by “attacking coatings that resist the primary solvent.”20 “Co-solvents are solvents that may not be a significant remover by themselves, but when added to a major-ingredient solvent increase the stripping efficiency of the mixture.”21 These secondary solvents can be a wide variety of different materials, and are normally added at a concentration of 5-10%.22
Activators

Activators increase the efficacy of remover formulae by aiding the penetration of solvents into a paint film. Rather than acting in the secondary manner of co-solvents, they have a synergistic effect on the primary solvents and co-solvents. The addition of 1% water to a methylene chloride remover formula, for example, can improve the efficiency of its penetration and film swelling capabilities up to 90%. The inclusion of acidic or alkaline activators can also improve the performance of solvents. Phenol, phosphoric acid, acetic acid, and formic acid “are used to increase the cutting ability on epoxide-type paints and other modern finishes.” Adding sodium hydroxide, trisodium phosphate or potassium hydroxide can improve a product’s “stripability on enamel and latex paints.”

Thickeners

Thickening agents are polymers added to increase adhesion of paint removers to vertical surfaces and overhangs. A four-part criteria for the selection of a thickener has been offered by Charles Martens. Thickeners must 1) impart high viscosity at low concentrations; 2) be compatible with a formula; 3) retain constant viscosity during storage; and 4) produce a film upon drying that is soft and does not adhere to surfaces. Thickeners are dispersed in most paint remover formulae and then swelled through the presence of a reactive solvent or by adjusting alkalinity. “When the polymer swells, it causes the viscosity of the mixture to increase.” As noted, paint removers are available in a wide range of viscosities, from water thin to extremely thick trowel-on varieties.
Emulsifiers and Surfactants

Surfactants and/or emulsifiers are included in most paint removers to assist in clearing surfaces after paint films have been solubilized and swelled. In removers that utilize non-water-soluble organic solvents, emulsifiers are added to allow these materials to be suspended and washed from surfaces. “For water rinse removers, a detergent that is compatible with the remover formula must be selected.” Surfactants also “assist solvents by wetting or penetrating the surface of the paint films.” Surfactants are materials containing two components of extremely different polarity. One portion of the surfactant is capable of attaching to non-polar materials and the other to very polar materials, thus producing linkages between substances of very different molecular make-up. “The soaps, for example, have an ionizing salt ‘head’ to the molecule and a long non-polar hydrocarbon ‘tail.’” Soaps are thus able to bridge the incompatability between oils and water through emulsification.

Evaporation Retarders

Evaporation retarders in paint removers increase the dwell-time of surface-active ingredients. “Small molecule solvents that make up the most effective paint removers also have a high vapor pressure and evaporate easily, sometimes before the remover has time to penetrate the finish.” Most “evaporation retarders in paint and varnish removers are waxes of petroleum origin.” “When evaporation occurs the solvent is chilled and the wax is shocked-out, forming a film on the surface of the remover that acts as a barrier to evaporation.” Although alkaline-based paint removers have low volatility, they are often slow-acting and cease to work if allowed to dry out. Evaporation retarders such as fumed
silica\textsuperscript{35} are added to alkaline removers to slow the evaporation of their aqueous components.

**Corrosion Inhibitors**

The inclusion of corrosion inhibitors in paint remover formulae protect metal containers during shipping and storage. Inhibitors are also added if a remover is acidic and will be used on nonferrous metal substrates.\textsuperscript{36}

**Methylene Chloride**

Methylene chloride-based paint removers came into general use at the close of World War II,\textsuperscript{37} when their popularity quickly surpassed all other available formulations. Although there is no such thing as a “magic bullet” in paint removal, removers based on methylene chloride are the closest thing we have to a perfect paint stripper. Their ease of application, availability, inflammability, power and speed in removing finishes and reasonable cost make them the first choice for most paint removal treatments.\textsuperscript{38}

When first applied to a painted finish, methylene chloride removers change the color of the uppermost, exposed, layers of paint; dark colors become lighter and light colors darker. After five to fifteen minutes, most paint materials begin to ripple and bubble, lifting in clear, wrinkled patterns away from the surface. Once the majority of the surface has lifted, a flat-bladed putty knife scraped across this surface will remove the lion's share of the softened and separated paint. Small amounts of highly solubilized paint often remain on the
surface—particularly around the edges of the stripped area—and are usually re-wet with the stripper or another solvent to be wiped off.

Chemical paint removal is a "catastrophic process." The power and speed with which the bonds between paint and paint—or paint and substrate—are broken by methylene chloride is nothing short of remarkable. It is through understanding and controlling the nuances of these mechanisms that the selective removal of overpaint is accomplished.

**Methylene Chloride Removal Mechanisms**

The specific mechanisms by which most paint strippers work are not fully known. Further, although many books have been published on the formulation, curing properties, and application of paint, very little research has been dedicated to the way in which these same paints may be removed. The mechanisms behind methylene chloride are not fully understood, but chemists believe that methylene chloride's small molecular size is in some way responsible for its efficacy. Two explanations are given to explain the way in which it works. One scenario involves the pressure created when paint swells, and the other the penetration, solublizing of lower strata of paint, and evaporative action of the material. It seems likely, however, that both of these mechanisms are responsible for how methylene chloride functions.

It is primarily the superiority of this swelling that sets methylene chloride above other removers; particularly the speed with which it occurs. Other solvents are generally of a larger molecular dimension, and "cannot cause this lifting action." It is believed that "the low molecular volume of methylene chloride allows it to penetrate the finish by entering the microvoids of the finish." The methylene chloride "type of paint remover relies on the action of small organic molecules which can penetrate the film, swell it, and also reach the
film/substrate interface and there reduce the strength of the adhesive bond." As this bond is released, the paint film itself begins simultaneously to swell, growing up "to 10 times its original volume." This swelling causes a dramatic increase in the internal pressures within and around the paint film that cannot be released along the surface plane, and can only be discharged through forcing the paint away from the surface. These swelling mechanisms, paradoxically, rely on high intrinsic strength in paint films. The swelling, buckling, and pulling-away from the surface requires a volumetric accumulation of paint heavy enough that the swelling of the mass can create the pressure necessary to break the intralayer paint bonds. A thinner overburden of paint will often not have sufficient mass to break these interstitial bonds and will simply "melt" on the surface.

Where a strata exists in a paint chronology that is less permeable for the solvent, methylene chloride-induced swelling can also take place away from the less permeable strata, rather than away from the substrate. When this occurs, layers of overpaint can often easily be removed down to this layer. These harder, less sensitive, strata are often exploited as stopping points to allow the conservator to control the selective removal of paint. The common historic practice of varnishing painted decoration can be a boon for exposing period finishes, as it can create the ideal stopping place in a paint chronology. While most types of varnish are soluble in methylene chloride, they often resist its action long enough for separation to occur between the varnish layer and the overpaint.

Figure 1
Paint Swelling Occurring at Substrate

Figure 2
Paint Swelling Occurring at Varnish Layer
One of methylene chloride's unique physical properties is its acceptance of many different co-solvents and activators that occupy different points on the pH scale; formulations can thus be alkaline, acidic or neutral. "This ability greatly expands the number of coatings that can be removed with methylene chloride removers." In many instances, methylene chloride will not remove a specific coating at one pH, but will be very effective at a different alkalinity. Even solvent-resistant caseins can be solubilized if a methylene chloride formulation has a high alkalinity. "The stripability on catalyzed urethane and epoxy resin can be increased by adding formic acid, acetic acid, and phenol."

Methylene chloride has a high vapor pressure. To extend its dwell time long enough to allow penetration, it is therefore necessary that formulations be contained with a vapor barrier to retard evaporation. Most water-rinsible formulations use paraffin wax to create this barrier. The wax is fully soluble in the methylene chloride but "when evaporation occurs the solvent is chilled and the wax is shocked-out forming a film on the surface of the remover that acts as a barrier to evaporation." When applying methylene chloride removers it is important to not continuously brush them out—in the manner paint is applied—but, rather, to gently "lay" them on in one direction. "Brushing back and forth disrupts this skin and causes the solvents to evaporate."

A typical formula for a methylene chloride paint remover can be found in Table 1.
Table 1: Typical Methylene Chloride Paint Remover Formula\textsuperscript{51}

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight %</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Chloride</td>
<td>80.1</td>
<td>Primary solvent. Softens/swells paint</td>
</tr>
<tr>
<td>Water</td>
<td>1.0</td>
<td>Activator. Improves primary solvent action</td>
</tr>
<tr>
<td>Paraffin Wax</td>
<td>1.6</td>
<td>Evaporation retarder. Increases dwell-time</td>
</tr>
<tr>
<td>Toluene</td>
<td>2.1</td>
<td>Co-solvent. Keeps wax in solution</td>
</tr>
<tr>
<td>Methylcellulose</td>
<td>1.2</td>
<td>Thickener. Holds formula to vertical surfaces</td>
</tr>
<tr>
<td>Methanol</td>
<td>7.8</td>
<td>Co-solvent. Keeps thickener in solution</td>
</tr>
<tr>
<td>Mineral Spirits</td>
<td>6.2</td>
<td>Activator. Prevents redeposition</td>
</tr>
</tbody>
</table>

Petroleum-Based and Oxygenate Paint Removers

The primary solvents in petroleum-based removers are toluene, monochlorotoluene,\textsuperscript{52} and xylene. Oxygenate removers utilize solvents such as acetone and methyl ethyl ketone as their primary ingredient.\textsuperscript{53} Unlike methylene chloride, petroleum-based and oxygenate removers do not operate through intensively wrinkling and swelling paint layers but, rather, through forcing the paint into solution with the solvent.\textsuperscript{54} “The removal mechanism is one of dissolving the coating, then washing the surface or wiping away the finish.”\textsuperscript{55}

Prior to the introduction of proprietary methylene chloride paint removers, acetone was the preferred primary solvent in commercial formulations. In 1908 Alvah Sabin wrote that superior patented paint removers were “usually made of acetone, benzole, and similar liquids, and the best contain some waxy substance which prevents the film from drying up again rapidly.”\textsuperscript{56} In 1945, F.N. Vanderwalker wrote that “the higher priced removers and the most effective have a larger percentage of acetone in them while the cheaper and less
effective removers have little or no acetone but rather depend upon wood alcohol as the solvent.”\textsuperscript{57} Acetone is fully miscible in oils, water, and many solvents, and was “an important ingredient of neutral paint removers because of its action on resins and on linoxyn (oxidized linseed oil).”\textsuperscript{58}

The blending of petroleum-based and oxygenate solvents and the addition of surfactants significantly improve their performance. By combining the solvent strength of these solvents and improving their rinsability, paint can be solubilized and separated from a substrate before it can congeal. A typical oxygenate and petroleum paint remover formula can be found in Table 2.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight %</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>21</td>
<td>Primary Solvent. Solubilizes film</td>
</tr>
<tr>
<td>Acetone</td>
<td>19</td>
<td>Co-solvent. Increases capability</td>
</tr>
<tr>
<td>Alkyl acetate</td>
<td>31</td>
<td>Emulsifier. Surfactant</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>19</td>
<td>Co-solvent.</td>
</tr>
<tr>
<td>Butyl alcohol</td>
<td>10</td>
<td>Co-solvent.</td>
</tr>
</tbody>
</table>

It is difficult to expose decoration with heavy accretions of overpaint using petroleum-based or oxygenate removers. The control of exposures relies on separating paint layers quickly to avoid contaminating target decoration with overpaint residue. Simple film dissolution on heavy overpaint produces large quantities of residue, and makes clearing a surface problematic. When overpaint is simply put into solution, the conservator can end up simply smearing unintelligible solvent and paint residue across an exposure surface.
Although methylene chloride formulations are superior to other solvents in their ability to penetrate and swell paint films, “in certain instances it is desirable to reject chlorinated hydrocarbons in favor of solvent blends that are designed to dissolve the paint film.” The use of “single solvents or blends of petroleum solvents and oxygenates” can be used successfully to remove many older finishes, if only a small number of coats have been applied. While “pure dissolution of the paint film generally is not viewed as desirable because dissolution leads to redeposition and clearance problems,” these solvents can be used successfully to remove overpainting in instances where only small amounts of paint residue will be produced. In situations where only one or two layers of overpaint cover target decoration, swelling of paint layers by methylene chloride may not be of sufficient strength to separate upper strata from lower strata. If methylene chloride is used and separation fails to occur, solvents can continue their penetration into target layers, damaging them. Petroleum and oxygenate solvents and solvent blends can soften overpaint to the extent it can be scraped or wiped from decorative target layers.

Alkaline Paint Removers

Alkaline paint removers are one of the least expensive, as well as “the oldest and simplest formulas for removing paints and varnishes.” A 1913 recipe for a home-made alkaline paint remover called for “eight parts slaked lime and one part pearl ash; mix and add water until the mass is about the consistency of oil paint.” The mixture was applied with an old brush and left on for 16 hours, after which the paint was softened enough to be scraped off.
Caustic paint removers work by degrading the binder component in finishes through saponification. “In many types of coatings (e.g. oils or alkyds), materials such as alkali saponify or break down the ester linkage, thereby aiding removal.” The primary active ingredients in alkaline paint removers are sodium hydroxide (caustic soda) or potassium hydroxide. Calcium hydroxide is also used in some formulations. These removers are slow and difficult to control. Due to their erosion of most paint materials, alkaline removers rarely leave overpainted surfaces in a condition suitable for conservation. Clearly reading overpainted decoration through saponified paint and alkaline residue is also difficult.

The most popular alkaline systems “use a paper or fabric covering to allow the remover-finish mixture to be peeled away.” The fabric also acts as a poultice, slowing evaporation and increasing dwell-time. This system, however, is cumbersome, and is not generally applicable to the selective removal of overpaint. Even with careful testing the point when the target layer is reached is almost impossible to determine. Using Peel-Away-1® (manufactured by Dumond Chemicals, Inc. New York, N.Y.) on the exterior of the Henry Ford Birthplace, in Greenfield Village, Dearborn, Michigan, the time required to remove a specific number of paint layers changed dramatically from one elevation to another (this, despite identical finish histories). While it is also sometimes difficult to ascertain when a methylene chloride remover has reached a target layer, its action of physically lifting paint greatly assists in making this determination. Caustic removers do not appreciably swell paint films, but instead simply saponify and degrade them. Following degradation, overpaint must be wiped or scraped from a stratigraphy that has lost the boundaries between its layers. This makes them extremely messy to use.
Alternative Paint Removers

As a result of health and environmental concerns “the paint and coatings industry in general is moving away from traditional solvent-based products” and relying instead on materials “which use neither methylene chloride nor caustics as their active agent.”68 The primary solvents in the most popular of these substitute formulations are organic dibasic esters (DBE) and N-methylpyrrolidinone (NMP). These materials remove paints by softening them so they can be scraped, wiped or washed from the surface. Their removal mechanism also relies on surfactants which assist the wetting of paint residue and remover so they can be washed from a surface. “Alkyl aryl sulfonates, toyl fatty acids, and varieties of nonionic surfactants are used in water rinse formulas.”69 N-methylpyrrolidinone and dibasic ester-based removers are less volatile than traditional formulations and thus leave a soapy residue after wiping and rinsing that must be cleared from a surface with either a second water rinse, or through wiping with solvents such as acetone.

These solvents “have been used for some time in printing inks, automotive finishes, and other industrial applications.”70 N-methylpyrrolidinone is widely used for degreasing engine parts. The two dibasic esters utilized in paint remover formulas are dimethyl glutarate and dimethyl adipate. N-methylpyrrolidinone and dibasic esters are often utilized as co-solvents when the other is used as the primary solvent. D-limonene, the primary ingredient of “citrus” industrial hand cleaners, is sometimes used as an activator in these alternative paint removers. Limonene is a powerful citrus-based solvent that effectively breaks down synthetic and organic oils and is used extensively as the active ingredient in industrial cleaning products. In recent years it has begun to take the place of 1,1,1 Trichloroethane (TCE) in the dry cleaning industry.
Epoxy and catalyzed finishes are not effected by either N-methylpyrrolidinone nor dibasic esters. They will, however, “remove single-component finishes but work more slowly than methylene chloride, petroleum and oxygenate group removers.” They are quite effective in removing varnishes, and this is where they can be utilized to their greatest advantage. Their lack of speed in removing finishes makes them only moderately useful as a component of paint exposure systems. In addition to being marketed as a healthier alternative to traditional chemical removers, these products “are non-flammable [and] biodegradable.”

Single Solvents, Solvent Mixtures and Custom Formulations

In some circumstances single solvents, solvent mixtures, or modified proprietary paint removers can work well to remove overpaint from decorative surfaces. Where only a single layer of paint has been applied over decoration, the application of a solvent such as ammonia, acetone or toluene can soften oil or emulsion paint enough that it can be rubbed from a surface, leaving lower strata intact. In the St. Johns County Courthouse, in Centreville, Michigan, the walls behind the rostrum in the Assembly Chamber had been covered with a single layer of acrylic emulsion paint, which was softened with non-sudsing household ammonia and rubbed with terry cloth until the metallic decoration beneath was sufficiently uncovered for documentation and replication. In the Hawkin’s House in Ann Arbor, Michigan, paper-hangers in the 1950s painted the ceiling, door and window trim prior to wallpapering, and extended their painting onto the decorative frieze patterns and panel-borders, which were to be papered over. When the wallpaper was removed, the owners of the house chose to conserve the original decorative painting. Conservation included removal of overpaint from the edges of the patterns. The overpaint proved to be a well-bound white lead and linseed oil. Removal of the overpaint was accomplished through
the application of lacquer thinner—a mixture of toluene, xylene, methyl ethyl ketone, methanol and ethyl acetate—which was allowed to dwell on the surface for 2-3 minutes, and vigorously rubbed off with cotton cloth. Lacquer thinner’s extreme toxicity and flammability preclude its use in many circumstances. With good ventilation and personal protective equipment—respirator, goggles and gloves—however, it is sometimes the appropriate choice.

The performance required of paint removal systems on decorative surfaces that will be retained and conserved can require specialized custom formulations which will work within very narrow performance parameters. Overpainted water gilding, for example, is sensitive to alternative water-borne paint removers, but can remain relatively stable if exposed through the use of oxygenate or petroleum-based removers.

Alternative paint removers can also be modified to perform in very specific ways through the addition of different solvents. In 1998, during the conservation of the Detroit Athletic Club (1916), in Detroit, Michigan, a proprietary gelled N-methylpyrrolidinone paint remover was modified for use in cleaning the main foyer ceiling coffers. The original decorative treatment consisted of painted and gilded raised plaster that was covered with a light scumble oil glaze and varnish. The varnish and oil glaze had oxidized to an opaque dark brown, and areas had been overpainted with bronze powder and, later, with brown oil paint. Testing with an N-methyl-2-pyrrolidinone and d-limonene paint remover (Citristrip, manufactured by Specialty Environmental Technologies, Inc., Auburn Hills, Michigan) showed the product to be too harsh, removing overpaint, varnish, glaze, and gilding down to the plaster substrate. A mixture of Citristrip, acetone and benzole alcohol in a 3:1:1 ratio, however, reduced the stripping action of the formulation and allowed the removal of the overpaint, varnish, and oxidized glaze, leaving most of the original paint intact. The
acetone and benzole alcohol had the added benefit of sequestering the water in the Citristrip, lessening its impact on the gilding.

The components of the five most common paint remover types can be found in Table 3 on the following page.
<table>
<thead>
<tr>
<th>Table 3: Typical Paint Remover Components</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Solvent(s)</strong></td>
</tr>
<tr>
<td>Methylene Chloride-Based</td>
</tr>
<tr>
<td>• methylene chloride</td>
</tr>
<tr>
<td>Oxgenate &amp; Petroleum-Based</td>
</tr>
<tr>
<td>• acetone</td>
</tr>
<tr>
<td>• methyl ethyl ketone</td>
</tr>
<tr>
<td>• toluene</td>
</tr>
<tr>
<td>Alkaline (Paste)</td>
</tr>
<tr>
<td>• sodium hydroxide</td>
</tr>
<tr>
<td>• potassium hydroxide</td>
</tr>
<tr>
<td>N-methylpyrrolidinone</td>
</tr>
<tr>
<td>• n-methylpyrrolidinone</td>
</tr>
<tr>
<td>Dibasic Esters</td>
</tr>
<tr>
<td>• dimethyl glutarate</td>
</tr>
<tr>
<td>• dimethyl adipate</td>
</tr>
<tr>
<td>Other Names</td>
</tr>
<tr>
<td>• dichloromethane</td>
</tr>
<tr>
<td>• acetone-propylene</td>
</tr>
<tr>
<td>• MEK-Butan-2-one</td>
</tr>
<tr>
<td>• ethyl methyl ketone</td>
</tr>
<tr>
<td>• toluene-methyl benzene</td>
</tr>
<tr>
<td>• caustic</td>
</tr>
<tr>
<td>• dye</td>
</tr>
<tr>
<td>• N-methyl-2-pyrrolidinone</td>
</tr>
<tr>
<td>• NMP</td>
</tr>
<tr>
<td>• M-Pyro™</td>
</tr>
<tr>
<td>• N-methyl-2-pyrrolidinone</td>
</tr>
<tr>
<td>Formula of Primary Solvent(s)</td>
</tr>
<tr>
<td>CCl₂H₂</td>
</tr>
<tr>
<td>• acetone-CH₃COCH₃</td>
</tr>
<tr>
<td>• MEK-CH₃COCl₆</td>
</tr>
<tr>
<td>• toluene-(CH₃)₂CCH₃</td>
</tr>
<tr>
<td>• NaOH</td>
</tr>
<tr>
<td>• KOH</td>
</tr>
<tr>
<td>• CH₂OOC(CH₂)ₙ-COOCH₃</td>
</tr>
<tr>
<td>Removal Mechanism</td>
</tr>
<tr>
<td>• film dissolution &amp; swelling</td>
</tr>
<tr>
<td>• film dissolution</td>
</tr>
<tr>
<td>• film degradation/saponification</td>
</tr>
<tr>
<td>Flammability</td>
</tr>
<tr>
<td>None @ &gt;78%</td>
</tr>
<tr>
<td>Very High</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Finishes Effective on:</td>
</tr>
<tr>
<td>oils; emulsions;</td>
</tr>
<tr>
<td>epoxies (acidic);</td>
</tr>
<tr>
<td>lacquers; varnish</td>
</tr>
<tr>
<td>oils; emulsions;</td>
</tr>
<tr>
<td>lacquers; varnish</td>
</tr>
<tr>
<td>oils; emulsions;</td>
</tr>
<tr>
<td>epoxies; lacquer;</td>
</tr>
<tr>
<td>varnish</td>
</tr>
<tr>
<td>Co-solvents</td>
</tr>
<tr>
<td>• methanol</td>
</tr>
<tr>
<td>• isopropyl alcohol</td>
</tr>
<tr>
<td>• ethanol</td>
</tr>
<tr>
<td>• toluene</td>
</tr>
<tr>
<td>• methanol</td>
</tr>
<tr>
<td>• n-butanol</td>
</tr>
<tr>
<td>• sec-butyl alcohol</td>
</tr>
<tr>
<td>• xylene</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>• diacetone</td>
</tr>
<tr>
<td>• alcohol</td>
</tr>
<tr>
<td>• γ-butrolactone</td>
</tr>
<tr>
<td>• ethyl 3-ethoxypropionate</td>
</tr>
<tr>
<td>• dibasic esters</td>
</tr>
<tr>
<td>Activators</td>
</tr>
<tr>
<td>• H₂O</td>
</tr>
<tr>
<td>• formic acid</td>
</tr>
<tr>
<td>• acetic acid</td>
</tr>
<tr>
<td>• hydroxides</td>
</tr>
<tr>
<td>• trisodium phosphate</td>
</tr>
<tr>
<td>• sodium hydroxide</td>
</tr>
<tr>
<td>• gluconic acid</td>
</tr>
<tr>
<td>• alkali metal gluconate</td>
</tr>
<tr>
<td>• phenol</td>
</tr>
<tr>
<td>• monoethanolo mine</td>
</tr>
<tr>
<td>• citric acid</td>
</tr>
<tr>
<td>• acetic acid</td>
</tr>
<tr>
<td>• formic acid</td>
</tr>
<tr>
<td>• D-limonene</td>
</tr>
<tr>
<td>• monoethanolo mine</td>
</tr>
<tr>
<td>• citric acid</td>
</tr>
<tr>
<td>• acetic acid</td>
</tr>
<tr>
<td>• formic acid</td>
</tr>
<tr>
<td>• D-limonene</td>
</tr>
<tr>
<td>Thickeners</td>
</tr>
<tr>
<td>• hydroxypropyl methylcellulose</td>
</tr>
<tr>
<td>• hydroxyethyl cellulose</td>
</tr>
<tr>
<td>• polymer type</td>
</tr>
<tr>
<td>• fumed silica</td>
</tr>
<tr>
<td>• hydroxypropylcellulose</td>
</tr>
<tr>
<td>• poly(acrylic) acid</td>
</tr>
<tr>
<td>Emulsifiers/Surfactants</td>
</tr>
<tr>
<td>• ethylene glycol monobutyl ether</td>
</tr>
<tr>
<td>• various ionic &amp; nonionic detergents</td>
</tr>
<tr>
<td>• alkyl aryl sulfonates</td>
</tr>
<tr>
<td>• amines</td>
</tr>
<tr>
<td>• Petroleum sulfonates</td>
</tr>
<tr>
<td>• petroleum sulfonates</td>
</tr>
<tr>
<td>• alkyl aryl sulfonates</td>
</tr>
<tr>
<td>• total fatty acids</td>
</tr>
<tr>
<td>• other non-ionic surfactants</td>
</tr>
<tr>
<td>• alkyl aryl sulfonates</td>
</tr>
<tr>
<td>• total fatty acids</td>
</tr>
<tr>
<td>• other non-ionic surfactants</td>
</tr>
<tr>
<td>Evaporation Retarders</td>
</tr>
<tr>
<td>• paraffin wax</td>
</tr>
<tr>
<td>• paraffin wax</td>
</tr>
<tr>
<td>• some utilize fabric poultice</td>
</tr>
<tr>
<td>• hydroxypropyl methylcellulose</td>
</tr>
<tr>
<td>• hydroxypropyl methylcellulose</td>
</tr>
<tr>
<td>Corrosion Inhibitors</td>
</tr>
<tr>
<td>• propylene oxide</td>
</tr>
<tr>
<td>• sodium benzoate</td>
</tr>
<tr>
<td>• butylene oxide</td>
</tr>
<tr>
<td>• triethylammonium phosphates</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>various</td>
</tr>
<tr>
<td>various</td>
</tr>
</tbody>
</table>
Chapter 4

Traditional Paints and Paint Exposures

Most paints can be broken down into at least two discreet components: colorant and medium. While colorants lend color, sheen, and opacity to paint, media give a finish its cohesion, adhesion, durability, viscosity, and elasticity.¹ Paint media (also known as “vehicles”) are most commonly made up of two constituent components—a binder and a solvent. The binder, or film-former is the actual film that remains upon cure; it functions “to bind together the pigment particles and hold them on to the surface.”² The binder in oil paint, for example, is linseed oil, and in whitewash it is lime. A medium's solvent or “carrier” is the volatile component of a paint system, and lowers the viscosity of the mix allowing it to penetrate a surface and be easily applied. Common solvents are turpentine (for oil-based paints) and water (for water-based emulsions). Most paint types are characterized by either their primary medium or their solvent; oil and alkyds, for example, are referred to as “oil” paints, and acrylic emulsions and distempers are referred to as “water-borne” paints.³

In the selective removal of overpaint, it is primarily the physical and chemical properties of the binder in the paint or paints that are being removed, as well those paints that are retained, that determine the efficacy of a chosen process. It is therefore necessary to understand the particular properties of individual paint binders if they are to be removed in a manner that does not disturb previous painting campaigns. While an understanding of traditional coatings does not by any means lend full control to their selective removal or conservation, it can assist in answering difficult questions when they are encountered.

Prior to the introduction of mechanically mass-produced paints—an industry created in large part through the invention of the re-sealable paint can in the 1860s⁴—paints were
hand-crafted, with a small number of ingredients used. Modern paints, however, are generally more complex. "Whereas old paints may have had five or six ingredients, modern paints may number from twenty-five to thirty." Many modern paints contain ingredients such as levelers, extenders and fillers, or fungicides and mildewcides, as well as other synthetic additives blended-in to improve shelf-life and aid in how a paint film flows on, penetrates, evens out, and dries.

The relative simplicity of historic paint recipes, however, does not make them simple to remove. Some are inherently tough. Casein, a milk-based paint, for example, can prove exceedingly tough, and breaking its intralayer bond, or its bond to a substrate may be difficult. David White, president of the Paint Removers Manufacturer’s Association believes that the Belgian paint “scureuse,” formulated from lanolin, white lead, and earthen pigments, is the most difficult finish he has ever tried to remove, resisting everything from methylene chloride to strong acids. Depending on the specific properties of the individual strata as well as which layers the conservator wishes to remove or retain, the sensitivity or resistance of historic binders to stripping mediums or techniques can be a blessing or a curse.

Historic paints may also be difficult to remove because of the complexity of paint types one on top of another. While most modern paint stratigraphies commonly contain alkyd oil or acrylic emulsions historic paint stratigraphies can contain combinations of different kinds of now obsolete paint materials such as distempers, caseins, and linseed oil. A historic stratigraphy might, for instance, contain oil paint over casein, which was painted over traces of distemper, along with layers of varnish or oil glaze. Diverse materials are prevalent in decorative schemes, as decorative painters often utilized a much wider range of materials to create their complex effects. Selectively removing paint from decorative surfaces is therefore a more complex affair than stripping simple flat-painted surfaces.
Traditional Historic Paint Mediums

Although painters of the past used a wide variety of materials in their craft, a list of historic paint binders most commonly encountered is relatively short. The most common painting materials encountered on historic American buildings are linseed oil, alkyds, calcimine (also spelled "kalsomine"), distemper, whitewash, casein, and emulsion paints. The physical and chemical properties of these materials will cause each to react to paint removal systems in very different ways.

Linseed Oil-Based Paint

Historically, linseed oil-based "paints have been the most important class of paints in American architecture." A. Ashmun Kelly, in his 1913 book The Expert House Painter, wrote: "The chief value of linseed oil as a paint is in its power of drying in a comparatively short time to a hard, tough, elastic and durable film when exposed to air." Linseed oil is an extract from the seed of the flax plant and is a member of the class of drying oils known as "fixed" oils. Drying oil-based paints cure through oxidative cross-linking upon contact with air, they take up oxygen and harden. Though some other oils such as walnut oil, poppy seed oil, menhaden (fish) oil, hempseed oil, and China wood (tung) oil, also cure through this reactive process, their higher cost and lower performance generally prohibited their use in architectural paints, except occasionally in decorative schemes or for special applications. An 1868 painting manual stated that: "Although many vegetable oils have been introduced to the consideration of the painter, yet linseed oil still holds the preëminence for general painting."
Driers

Linseed oil has ordinarily been mixed with driers to improve its rate of cure. "A drier is a metal soap with an acid portion that confers solubility in the oil medium."14 "Many compounds have been used as driers, among them are...lead compounds...white copperas' (zinc sulfate), and salts of various multivalent metals."15 Also referred to as "Japan driers," the most commonly utilized of these metal soaps were cobalt, manganese, and lead naphthenates. Both white lead and red lead pigments also have a drying effect, with the latter being the more effective of the two.16 Acting as a catalyst, driers accelerate linseed oil's uptake of oxygen and thus speed its cure—mixed with driers, linseed oil will absorb about 12% of its own weight in oxygen. With the assistance of driers, linseed oil will dry in about 2.75 hours; without driers it could require some 120 hours to cure.17 While relatively small amounts of these metallic soaps—about 1%—will immensely improve the performance of linseed oil,18 in slightly higher concentrations they "will set up stresses and strains in the paint film that can result in wrinkling."19

Raw and Boiled Linseed Oil

While two types of linseed oil were used in paint production—raw linseed oil and boiled linseed oil—it was raw linseed oil that was "recommended for the painting of exteriors of buildings or even the interiors."20 Boiled linseed oil was generally considered an inferior painting material and a common adulterant of raw linseed oil. Boiled linseed oil is prepared by heating linseed oil to 150-160° C, which "induces the start of oxidation and polymerization." The resulting product is "more viscous and dries more quickly."21 Boiling lessens the elasticity of the oil so that "it cannot contract and expand itself to accommodate
the nature of the surface it covers...with the result that it cracks to accommodate it.”\textsuperscript{22} Fred Maire, in his 1918 \textit{Modern Painter's Cyclopedia}, writes of linseed oil that: “in its raw state it is elastic, which permits it to expand and contract along with any kind of surfaces it is spread over, be they wood, brick, metal or stone.”\textsuperscript{23}

The Production of Raw Linseed Oil

Raw linseed oil was manufactured through pressing or percolation. Pressed linseed oil was produced much the same as cold pressed apple cider, with flax seed simply being placed under pressure between rollers or stones. Later, production methods were improved to extract a greater yield through heating the flax seed with steam prior to pressing, thereby breaking down the cellular lignin and allowing more oil to be released.\textsuperscript{24}

The percolation method used benzene to draw oil from seed. Flax seed was ground and packed into metal percolators occupying several stories in a tall building. Benzene was poured through the flax meal and percolated down, dissolving the oil contained in the mix. At the base of the percolator, the benzene/oil flowed into heated pipes, where it was separated, the oil collected, and the benzene driven off to be reused again and again.\textsuperscript{25}

Cold pressed oil was thought superior to “tempered” oil, because it had a smaller percentage of “foots” or mucilaginous particulates suspended in the oil.\textsuperscript{26} All raw linseed oil, however, was filtered and then stored in settling tanks to clarify the material.\textsuperscript{27} The highest quality raw linseed oil was thought to come from “Calcutta seed,” flax grown in India, while domestic flax was believed to be of lower quality. Indian flax seed was harvested by hand, producing a seed that was allowed to fully ripen and thus acquire a higher oil content. The harvesting machinery used in collecting American flax seed required
harvesting of the seed cases before they were fully matured, for in their mature state “much of it would shell out and be scattered over the field and be wasted from the violent shaking it receives when struck by the harvesting machine.”

Domestic flax seed was therefore lower in oil content, and produced a linseed oil higher in feet. Although modern harvesting and extraction equipment is technologically superior to that used in the nineteenth and early twentieth centuries, the principal processes utilized have not changed fundamentally.

White Lead and Linseed Oil

The combination of white lead and raw linseed oil created an affordable paint with superior workability, adhesion, longevity, and hiding power, and was the paint of choice through most of the history of architectural painting in America. White lead, the basic carbonate of lead, is particularly miscible in linseed oil. White lead was typically made up of a compound that was 75% lead carbonate and 25% lead hydrate. The lead hydrate component in white lead partially saponifies linseed oil, forming a homogenous lead soap. It is believed this is “why white lead in oil forms such a homogeneous, durable, hard, and non-porous paint film.” Due to the general toxicity of lead, lead and linseed oil-based paint films also proved resistant to most insects and other forms of biodeterioration.

Deterioration Mechanisms of Linseed Oil Paint

The deterioration of white lead and oil-based paints is primarily due to the decay in their linseed oil binder. “Unfortunately, oil paints embrittle with age through oxidative processes
that continue beyond the point of optimum properties.”^33 Historically, in exterior applications of lead and linseed oil paints, paint films naturally degraded with a chalking effect, gradually leaving an excellent surface for repainting.^34 The advent of modern paints with superior internal adhesion, however, have produced conditions in which thick paint build-up is not only common but the norm. Rather than naturally weathering away, much thicker stratigraphies of paint are now applied to building exteriors. The internal stresses created by this build-up can often cause checking, allegatoring, and cracking, as these layers, each with different coefficients of thermal expansion, move under changing conditions or temperature and humidity and as the materials lose their elasticity.\(^35\) While building interiors ordinarily experience less dramatic shifts, they too are subject to thick paint deposition.

Another paint decay mechanism in linseed oil-based paints is their tendency to naturally yellow in the absence of light, “especially in the darkness created by later layers of paint.”^36 Overpainted interior paints may be drastically altered with, for example, light blues becoming green and reds becoming orange. Exposure to bright light may partially reverse this yellowing.\(^37\) This phenomenon “might be explained by the oil’s producing, in the dark, mostly coloured, conjugated, unsaturated ketones that are unstable to light.”^38 When historic oil-painted decorative surfaces are cleared of overpaint color correction is needed during analysis, or, if possible, the surfaces should be bleached in bright light if they are to be left exposed.

Often, decorative painting was varnished after execution, to homogenize and protect its surfaces. This is often a boon when carrying out the exposure of these finishes as the hard varnish can act as an isolating coat and may allow a natural stopping place for chemical and mechanical paint removal.\(^39\) “Oil or varnish glazes over older paints become brittle with age, and can make removal of later paints” easier.\(^40\) Although these varnishes can assist the
exposure process, they are also susceptible to yellowing, and can further obfuscate painted finishes already altered by age, overpainting, and the exposure process. Not only linseed oil materials, but also organic resinous coatings such as copal, and sandarac, oxidize and darken over time.

Linseed Oil and Chemical Paint Removers

Oil finishes are one of the easiest types of paint to remove as well as to conserve. They are hard, with a texture resistant to stripping media that permits time to stop the removal process and preserve the oil decoration buried beneath overpaint. It thereby becomes the conservator’s job to find a paint removal process that will be powerful enough to remove the overpaint, yet leave the decorative layers underneath undissolved by these materials; “solvents must be identified that will remove overpainting without damaging the decorative paint finish.” Fortunately, oil paints are sensitive to a number of solvents, and many formulae, techniques, and methodologies have been established for their removal.

Methylene chloride paint removers work quickly on linseed oil due to their unique tendency to rapidly soften and swell the material. Other solvents can also be utilized for removing linseed oil, but most simply solvate the paint enough that it can be scraped, rubbed, or brushed from a surface. Lacquer thinner (a mixture of toluene, xylene, and methanol), acetone, and methyl ethyl ketone, will also soften oil paint in this way. Further, linseed oil-based paint is slightly soluble in ammonia, which will occasionally soften it enough that it can be mechanically removed. Ammonium bicarbonate has also been successfully used to remove thin films of linseed oil.
Alkyds

After the Second World War most oil-based paints used in architectural applications were based on alkyd formulations. Alkyds are synthetic drying oils developed to incorporate the gloss, hardness, and endurance of traditional enamel (linseed oil cooked with a natural resin such as copal) with the flexibility and ease of use of linseed oil-based paints. The first practical use of synthetic polymeric finishes was during the early 1920s, when nitrocellulose lacquers were introduced for painting automobiles. In the 1940s, 50s and 60s, the development of alkyd-based materials evolved so quickly, and with such startling results that "many authorities writing on the subject call[ed] it the Alkyd Revolution." Though a form of alkyd was widely available in the 1930s, the modern form of these paints was largely developed "after 1940 as a substitute for linseed oil." These types of paint are "the ‘oil’ paints in use today."

The term ‘alkyd’ is derived from the two primary ingredients used in manufacture: alcohols and acids. They are a mixture of the fatty acids of drying oils with different alcohols and acids. The drying oils generally used in alkyd paints are tall, castor, linseed, soya, and safflower oils. As with linseed oil paints, alkyds dry through cross-linking. Most alkyds dry more quickly than simple linseed oil paints, are harder and more durable, and have better color and gloss retention. One of the drawbacks of alkyd paints, like linseed oil paints, is that they yellow with age. The extent to which alkyds yellow is primarily determined by the drying oil utilized in their formulation. Safflower oils resist this tendency best, while linseed oil yellows the worst. Once the curing process of these materials has begun, hardening can continue well past the point where this physical property is a benefit; "all alkyds tend to embrittle through their service lifetime, more so when high levels of drier have been used."

58
Removing Alkyd Overpaint

Although much historic decoration has been carried out in alkyds, due to their relatively recent invention, they are most often encountered during the exposure process as the overpaint one is attempting to remove. The brittleness of aged alkyd paints makes them good candidates for removal through mechanical means. Mechanical exposure relies on the tendency of older paints to fracture in plane across their surfaces. Exploiting the brittleness in an older finish is often the best way to uncover decorative layers, leaving them intact. Alkyds are also soluble in most strong solvents, including, MEK, toluene, xylene, and, of course, methylene chloride.

Distemper & Calcimine

The terms "distemper" and "calcimine" are confusing, because painters and authors of period books use the terms imprecisely, as well as interchangeably. Calcimine is also often spelled "kalsomine." In the United States distempers were historically understood to refer to glue-bound paints, while in England the term could denote a variety of water-borne paints, including those bound with casein.61 "In architectural applications, glue distempers have often been called 'calsimines.'"62 Under the heading "CALCIMINING," Fred Maire in his 1916 Modern Painter's Cyclopedia writes of these glue-based paints:

The decorator hardly likes to have his work known under the name of calcimine (which is all it is in fact) as the name sounds too common, so he dubs it fresco, which it is not, or distemper or watercolor painting, which it is in common with plain everyday calcimining; but the others sound more aristocratic and under those names he can command a very much higher price.63
The term “distemper” is derived from the Old French word *distemper*—“to dissolve in liquid, soak, mix,”*"* because it is made of binders dissolved in water. While the medium’s primary binder is glue, in its wet state it is made up of some 90% water, and forms its film through solvent (water) loss.*"* To improve hiding power, distemper was “made of the carbonate of lime, or chalk ground to a fine powder known as whiting, Paris white, or Spanish white.”*"* In the early part of the 20th century, zinc white was also sometimes used as a base in place of whiting, because it was believed that paints so mixed had clearer tones and provided superior hiding power.*"* When dried, distemper is a fairly amorphous coating and derives its hiding properties from its highly porous nature—"the spaces between the pigment particles are filled mostly with air." Light is thus diffused widely across its surface, making the material opaque.*"* This type of paint is also known as a *bubble coating*, because its “light scattering characteristics are derived...from small bubbles or microvoids.”*"*69

Before drying, the glue binder in distemper paint accounts for only 10 percent or less of the medium’s volume,*"* yet firmly binds the pigment particles together and adheres the material to the finish surface. Glues formulated from animal parts can be traced back to the Egyptians and have a long history of use as a binder in paint mediums.*"* “Glue-forming tissues occur in the bones, skins, and intestines of all animals,” and are generally extracted through boiling these parts in water and purifying the cooled residue.*"* When these types of glue are used in a paint formulation, they are also often referred to as “size.” In a painter’s manual published in 1868, the formula for making high quality size is described as follows: animal skin clippings are soaked in water for twenty-four hours, then strongly boiled for a further five hours. During this boiling, impurities rise to the surface as scum, and are skimmed off. The final gelatinous solution is strained through coarse cloth while still warm. If the size was to be stored for any length of time, the addition of alum (potassium aluminum sulfate) was recommended as a preservative.*"*73
The use of glue distempers in American building interiors was widely popular from the 18th century through the 1950s. They were inexpensive, easy to apply, provided good coverage in one coat, and had a translucent depth not found in other architectural coatings. In 1916, it was stated that “fully 98 per cent of all wall coloring and embellishments consist of water color painting or printing [wallpaper].” Glue-bound paints, however, remain water-sensitive after drying and thus became obsolete following the widespread use of more stable water-borne emulsion paints.

Calsomine Application

Despite the popularity of calsomine, it could be problematic when applied to porous plaster. Plaster sometimes created suction on the paint—so called “hot spots”—that would immediately suck the moisture from a brush, so that it was not “possible to spread it any distance from where the brush first touched it.” To improve application, surfaces were first treated with a coat of size, known as a surfacer. “A surfacer in reality is a varnish specially prepared with a view of filling and stopping suction” from plaster.

Calsomine was sometimes applied warm and sometimes cold. Dried and powdered animal glue could be added to cold water and left to swell overnight, or could be heated to speed the process. A 1908 recipe instructs that:

To make it, fifteen or twenty pounds of whiting are mixed with water enough to make a thick paste; half a pound of good glue...is added to it, and enough hot water is then added to make about one-fifth as many gallons as there are pounds of whiting.

Glue-bound distempers were spread on surfaces with a large brush, 6, 7, or 8 inch wide, specially manufactured for this purpose. In 1916 it was remarked that “the calsomine brush
is probably the largest and most expensive brush made for the paint trade.79 Finer-textured than whitewash brushes, calsomine brushes were meant to apply the material quickly, the painter going over the surface once or twice.80 Unlike oil paints, these materials were best left alone after initial application, and were thus not layed off to remove brush strokes because81 fussing with a surface after application would create imperfections in the coat, and leave it streaky. Distempers tended to be chemically stable and unlike oil paints they did not yellow with age, nor darken in the absence of light.82

Distemper Decoration

It was quite common to use distempers in painted decoration. In the 1906 book *Practical Stencil Work*, in the chapter entitled “Stenciling In Distemper,” Frederick Scott-Mitchell noted that decorating with distemper was difficult due to its tendency to soak paper stencils and cause bleeding between decoration and distemper field colors. Despite these problems, he tells wrote:

> it gives highly satisfactory results when properly managed, and is less likely to offend one’s sense of good taste than oil painted work...because of the native softness and beauty of distemper colours and their remarkable quality of general harmony.83

By 1916, another painter reported:

> fresco painting in water colors or distemper is very popular and a number of our largest churches, halls, theaters, and private residences as well as public buildings are decorated in that manner.84

Distemper paints dry quickly, allowing the decorator to quickly build up multi-colored decoration “providing “a relatively expedient way to achieve opulent effects of line and color and of *trompe l’oeil* architecture.”85 Most decorative work including pouncing, figure painting, and stenciling, could be carried out in distemper.
Exposing Distemper Finishes

When applied correctly calcimines provided a very colorful, homogeneous, matt finish, but remained fragile due to their high solubility in water. “Glue distempers were commonly washed off completely before repainting or papering,” allowing new decoration to be easily applied to scoured surfaces. Being water sensitive, they were also susceptible to staining, blanching, and patchiness caused by leaks or condensation from high humidity. A simple test for the distemper involves looking at a paint sample under the microscope while applying water; “distemper paints slowly absorb the water, swell, and then begin to break down.”

The practice of cleaning distempers prior to repainting, of course, eradicated much of the decoration and makes it difficult to detect even traces of distemper when investigating today. Although distemper “decorative treatments were entirely permanent from the building owner’s point of view,” when strong oil paints were applied over these susceptible materials, it could create “a strong-over-weak situation that produces severe peeling.”

In some circumstances, distemper decorative work was varnished, or given an additional layer of strong size to protect it, and could therefore be successfully painted over with solvent-based oil paints. Most complex, multi-layered distemper decorative painting schemes that have survived intact beneath a modern oil and/or latex paint chronology are therefore likely to have been varnished. While these varnish coats can be exploited to allow segregation of painting schemes during exposure, they must be considered an intrinsic part of the distemper painting campaign, as it is rarely possible to remove them, leaving these
frail paints undisturbed. This situation may permit the selective removal of overpaint through either mechanical or chemical means. In the Library of the Michigan State Capitol, for example, concave ceiling moldings were stenciled in distemper to look like mosaic tiles and then varnished—probably just after execution. The later coats of oil-based overpaint were easily removed with methylene chloride strippers to reveal the designs, which were documented so they could be replicated.

Morgan Phillips reported an experience involving two layers of distemper decoration that had been overpainted with oils in a church constructed in the 1840s. Although the oil paint was readily removed with methylene chloride strippers, leaving the first layer of distemper decoration intact enough to be documented, the physical properties of the earlier distemper decoration was so close to that above it that they could not be separated, and the lower strata were never revealed. In 1998 exposures were executed on an early 20th century stage curtain at the Stoughton Opera Theater and City Hall, in Stoughton, Wisconsin. The curtain had advertised local businesses, was painted in distemper, and later overpainted with the same water-soluble media. A solution of 30% water in 70% isopropyl alcohol proved effective in exposing the earlier layers.

Whitewash

The use of “whitewashes predate oil paints in American architectural painting, and continued in widespread use until the mid-twentieth century,“ when the introduction of water-based emulsion paints made them obsolete. In 1908, Alvah H. Sabin wrote:

“whitewash costs almost nothing; it is sanitary, easily applied, may be made as to resist the weather tolerably well, and is and always will be the paint for the million.” In 1965 the fourth edition of the Painting and Decorating Contractors of America’s Craftsman’s Manual
still recommended the use of whitewash, particularly for masonry surfaces, referring to it as "the granddad of water paints."^94 Ten years later, in 1975, however, whitewash had fallen from favor with professional painters to the extent that the fifth edition of the Craftsman's Manual mentions whitewash "only for historical purposes because latex paints of equal cost and much better quality are available."^95 Whitewash was popular because it was "versatile, easy-to-make, non-yellowing, and, above all, cheap."^96

Whitewash in its simplest form is produced by thinning slaked lime—Ca(OH)₂— with enough water to allow it to be brushed onto surfaces. It cures through carbonation, a recrystalization of calcium. A great number of ingredients including salt, alum, tallow, linseed oil, and milk were commonly added to improve its adhesive properties. Like distemper, "whitewashes also consist ultimately of calcium carbonate, but in their case the calcium carbonate forms a matrix of interlocked crystals as the binder, while in glue distempers it exists as separate pigment particles." Whitewash was ordinarily used to brighten interiors and impart a white, clean look to surfaces. It was also occasionally tinted with inorganic pigments such as "iron oxide yellows, reds, and browns (the earth pigments), and carbon black."^100 A number of 18th century American decorative treatments executed in tinted whitewash have been documented. These tend to be simple bands, "spatters," or sponge-painted designs. Decoration in this paint media usually survives by virtue of architectural elements being reused or areas being covered by additions. ^101

Exposing Whitewash

Methylene chloride-based paint removers have no effect on whitewash because they can neither swell nor solubilize calcium carbonate. These paints are also insoluble in water, and can thereby often be distinguished from glue distempers, which, as noted, are very
sensitive to water. Since it is an inert material, traces of whitewash often survive on dimensional masonry surfaces for centuries. Paint samples removed from the unrestored interior window quoin in Cotswald Cottage for example, constructed in Chedworth, Gloucestershire, England in 1620, and moved to Greenfield Village, Dearborn, Michigan in 1930, revealed some 16 layers of whitewash. Whitewash can often be distinguished from other flat, porous types of paint by its flaky, brittle properties. As noted by Morgan Phillips:

Determination of the chronological order of whitewash, some colored, in early buildings can be exasperating: a bit of one layer is found in one place; portions of another remain only at some other location.

Also, unlike paints with organic binders, whitewash does not soften when heated.

While the unique properties of whitewash make the removal of whitewash-from-whitewash problematic, its lack of reactivity can be a virtue if it has been overpainted with organic paints. In much the same way alkaline or methylene chloride paint removers can be utilized to remove overpaint from true fresco, these materials can be used to exploit the differences in solubility between whitewash and organic paints that have been applied over them.

Casein

The word casein came into use in the mid-19th century, and is derived from the Latin case-us, "cheese," plus the English preposition in, meaning "in cheese." It is a "substance belonging to the class of Proteins or Albuminoids, forming one of the chief constituents of milk." Casein paint is one of the most chemically complex of the traditional paints used extensively in American architecture. "It is amphoteric; i.e., it functions both as an acid and as a base." Casein is produced through precipitation by adding hydrochloric, sulfuric, or lactic acid to skim milk. The effective use of casein in paints...is dependent on
controlling the water solubility of casein by causing it to react with various materials."\textsuperscript{108} By increasing the pH through the addition of alkalis such as borax, sodium hydroxide, hydrated lime, or ammonia, a caseinate salt is formed\textsuperscript{109} and "the casein becomes water soluble and thus readily useful as a binder in a water-borne paint."\textsuperscript{110} The alkali chosen for the reaction determines the solubility of the cured casein paint film. Using sodium hydroxide or ammonia for example, produces a paint which remains water soluble after it has dried, while hydrated lime reacts with casein to form a paint that "is highly water-resistant."\textsuperscript{111}

The formulation of casein paints was further complicated by the addition of other materials. "These supplementary binders made many casein paints into hybrids, with respect to composition, drying mechanisms, and final properties."\textsuperscript{112} Like whitewash, casein was often a home-made product, and small amounts of linseed oil might be added, substantially increasing its flexibility.\textsuperscript{113} As late as 1955, the National Lime Association advocated the home formulation of a casein made from 7 gallons of skimmed milk, 3 pints of formaldehyde, and 8 gallons of slaked lime paste; some of their other published recipes included the addition of animal glue, white Portland cement, trisodium phosphate, or salt.\textsuperscript{114}

**Casein in The Exposure Process**

Pure casein formulated with lime produces calcium caseinate,\textsuperscript{115} which is "insoluble in water, alcohol, and other natural solvents."\textsuperscript{116} It is also insoluble in toluene as well as methylene chloride paint removers.\textsuperscript{117} In opening exposures, this insolubility can be an asset or a hindrance. When target layers were executed in casein, and layers of overpaint are composed of solvent-sensitive paints, overpaint can be removed leaving the lower strata
unaffected. If layers of overpaint are casein, however, proprietary paint removers will have little or no effect on them. On the contrary, when methylene chloride paint removers are applied to casein-over-oil paint, they can penetrate into target layers through microcracks and remove paint stratigraphies down to the substrate. Casein is, however, soluble in alkaline paint removers composed of sodium or potassium hydroxide, but these removers are extremely destructive to all paint layers and are difficult to control. Casein is also soluble in ammonia, which can sometimes be successfully employed to expose paint below layers of casein. Ammonia does not swell casein, but will soften it enough that it can be scraped, rubbed or wiped from a surface.

**True Fresco**

True fresco is a process in which “painting [is] executed on fresh plaster whilst still moist in such a way that the pigments are fixed by the carbonatization of the lime (calcium hydroxide) contained in the plaster ground.” As noted above, the term “fresco” has often been used to denote not only painting carried out on wet plaster, but also “decorative treatments in distemper and in oil.” True fresco, however, is rarely encountered in America, except in very high-style interiors such as the United States Capitol in Washington, D.C. “No references to its use for the common purposes of house painting have been encountered to date.”

Overpainted true fresco is a good example of an ideal exposure situation. In true fresco, pigments become locked within the crystalline matrix of plaster, making the painted surface a three dimensional affair. When such a surface is overpainted, fairly strong removers formulated towards the alkaline end of the pH scale can be applied with little affect on the
original fresco below. This is the manner in which frescoes were exposed throughout the outer rooms of The Sistine Chapel in Rome.123

Metallic Finishes and Glazes

Two particularly complex decorative coatings are regularly encountered in the exposure of decoratively painted surfaces: metallic finishes and glazes. While metallic materials gave gleam and shine to a surface, glazes imparted translucence and depth to decorative schemes. Although these two types of material represented the most important decorative treatments in the decorator’s repertoire, they were both applied very thinly, making them difficult to preserve and sometimes detect.

Metallic Finishes

Highly reflective metals have been applied to painted decoration since Egyptian times, when their gleam and shine were used to highlight tomb decoration. In America, metallic finishes have been used extensively to draw the eye to their opulence, and have often been applied in conjunction with glazes in high-style interiors.

Metallic finishes are bound to surfaces in two ways: as a very thin sheet, or as fine metal particles suspended in a clear medium. When applied as a discreet layer of metal, these finishes are referred to as leaf, and create a film often only a few microns thick. The application of metal leaf is known as gilding. Gold, silver, copper, and aluminum are among the most common types of decorative leaf found in American architectural decoration. Metal leaf is applied with oil-based size, or with a water-borne
glue/clay/pigment mixture known as bole. These application techniques are known, respectively, as oil-gilding and water-gilding. In oil-gilding a high-tack varnish is used as an adhesive to bind the metal to the surface. Water-gilding relies on the adhesive qualities of animal glue, as well as the hydrophylic nature of metal leaf, to attach and hold the leaf in place.¹²⁴

To attain a high degree of reflectance, different powdered metals have also traditionally been mixed with resin to adhere them to surfaces. During the Middle Ages, gold leaf was sometimess ground in a mortar with honey, and the honey then washed away with water, so it could be mixed with egg white, resin or gum and used as a paint. “River gold or gold dust was used on certain English manuscripts.”¹²⁵ Finely-ground reflective metals suspended in a clear medium such as spirit varnish create a film upon drying that appears very much like a sheet of the metal itself.

The most common metal powder used in American architecture was bronze powder. Applying bronze powder was known as bronzing. “Bronzing is not gilding although its main object is to create an impression in the mind of others that it is.”¹²⁶ Bronze powder could be applied in two ways: it could be applied to a high-tack size, like metal leaf, or it could be suspended in a clear media and painted on. The latter of these techniques was the most common, due to its simplicity and speed of application. The most common bronzing liquids were “solutions of nitrocellulose in amyl acetate (banana oil) or other organic solvents.”¹²⁷ The primary problem with bronzing is that it is susceptible to oxidation, and thus loses its brilliance in a very short time. Bronze powder was used so often in painting cast iron radiators that it is sometimes reffered to as radiator paint.
Exposing Metallic Finishes

There are many problems related to the exposure of gilded elements. In cases where leaf is made from a reactive metal—for instance silver or copper—the overpainted leaf itself often tarnishes to the point where it no longer retains any brilliance. Patterns, however, often continue to be discernable during exposure through visual differences between the leaf and field colors. With unstable types of leaf, replication is ordinarily the only option to reestablish aesthetic integrity.

The exposure of gold leaf is intrinsically difficult because of the exceedingly thin application of the leaf. Gold is extremely ductile, and can be beaten thinner than any other metal. One ounce of gold will produce more than 2,500 gold leaves, 3 1/4 inches square; or enough gold leaf to cover more than two and a quarter football fields. The extreme thinness of gold leaf makes it quite fragile. Although the size used in oil-gilded decoration can often withstand the chemical action of paint removers long enough for exposure to occur and the remover to be neutralized, the mechanical action necessary to clear overpaint usually damages the gold itself. Size was often tinted to lend a particular cast to gilding—yellow size made gold more crisp and brilliant, and red size made gilding richer and warmer. Exposed oil gilding thus often appears as patterns in red or yellow, with areas of brilliant metallic gold.

Water gilding is much more sensitive to solvents than oil gilding, making its exposure more difficult than the exposure of oil gilded decoration. The animal glue component of the clay bole used in water gilding is soluble in water, methylene chloride, and most other organic solvents and is thus usually removed along with the overpaint. The exposure of water gilding, however, can be moderately successful in cases where a glaze or varnish was applied over the gold prior to overpainting. In this situation, the glaze or varnish act as both
a isolating coat for the remover, as well as a consolidant, adhering the gilding to the surface.

Exposing bronzed decoration is difficult because the material is unstable and has ordinarily decayed to the extent that it appears brown and lifeless. Most formulations used as a binder for bronze powder are quickly solubilized by methylene chloride, as well as the oxygenate and petroleum-based solvent paint removers. Bronze powder applied with size is even more sensitive to solvents. Although stencilling executed in bronze powder can often be detected through exposure, due to its inherent instability it is rarely found in a state worthy of conservation. Patterns, however, can often be distinguished sufficiently to be documented and replicated. Replication with more stable materials that very closely resemble freshly-applied bronze powder is thus often the only alternative to preserve the appearance of bronzed decoration. Among the modern metallic materials now used by decorators are titanium-coated mica crystals, that can be procured in a wide variety of colors, and are quite stable. As of this writing, the titanium-coated mica crystals in an acrylic medium that were applied to the pilasters of the House Chamber in The Michigan State Capitol eight years ago have lost none of their luster and brilliance.

**Glaze**

Next to stencilling, glazes were the most important decorative technique used in American interiors. “Glazing may generally be described as the application to a wall done in an opaque color of another color or combination of colors which are sufficiently transparent to allow the foundation color to show through.” Glazing was executed to produce a number of effects, including graining, marbling, the highlighting of decorative plaster, as well as the textured, translucent decoration of expanses of flat wall surface. Glazing “imparts to painted surfaces an indescribable look of depth and effect which can be obtained in no other
manner.” Glazes were made by adding small concentrations of lakes or dyes to transparent media, or could be a simple lightly-pigmented linseed oil or varnish.

In graining, glaze was brushed, dragged, or stippled over a painted surface to simulate the grain of a specific type of wood. A reddish-brown glaze pulled across a soft-pink paint, for example, could mimic walnut. Marbling imitated the colors, textures, veins, fissures, and bedding planes of different kinds of decorative stone through building up paints and glazes one over the other. When carried out by a competent craftsman, grained and marbled finishes could be astoundingly convincing in their imitation of wood or stone. In other instances, graining and marbling could be executed with the intent of merely suggesting the visual properties of these materials.

Glazes were also often applied over decorative plaster and then stippled and wiped to accentuate recesses and raised areas. Wide expanses of wall could be glazed and stippled to simply lend texture and depth, or could be rolled or dabbed with a wadded-up rag to create gentle patterns. In simple textured glazes craftsmen worked to “avoid repetition of pattern or texture and in working on large areas [to] leave the edge ragged or irregular to join on with the following stretch.” The intent was to create a continuous distressed effect that would not unduly draw the eye to any specific area. When applied correctly, glaze added depth and life to a surface, yet did not call attention to itself.

The Exposure of Glazed Decoration

Glazes can be difficult to detect and uncover due to their thin application and their translucency. In microscopic cross-sections, strata with aged glazes look much like very thin dirt layers. Many instances of complex graining, marbling, and textured glaze have
likely been misinterpreted as their simple undercoatings. If, for example, the dark glaze component in a sample of walnut graining is missed, the finish could be erroneously interpreted as a soft-pink.

Glazes are notoriously fugitive when exposed to most solvents. Depending on the specific composition of the glaze, methylene chloride, toluene, xylene, and alcohols may all fully solublize them. Most strong paint remover formulae will quickly erradicate evidence of their presence. Glaze treatments rely on subtle variations in texture for their effect, and this texture is easily lost when they are exposed to solvents. Even with careful application and gentle removal, the solvent action of removers can instantaneously turn softly-textured glazed strata into a muddy film impossible to interpret.

As with many decorative treatments, glazed surfaces were often coated with protective varnish, and this can make them easier to expose. Varnish can act as a buffer-zone between the sensitive glaze and overpaint, giving paint removers a sound stopping place for their action. The majority of decorative treatments in the Art Deco Ohio Departments Building (1934), in Columbus, Ohio, for example, were rag-rolled glazes, covered with a clear, hard varnish. Methylene chloride paint removers allowed the exposure of these finishes to the extent that the specific rag marks could be documented to exactly replicate the texture of the original treatments.

Modern Emulsion Paints

"Perhaps the most important of the water-based synthetic resin systems to be used commercially for house painting are the so called “latex” paints.” This type of paint came into general use following World War II, and “quickly replaced the less durable glue-based
distemper paints used for interior painting." The term latex is inaccurate, as most modern water-bourne emulsion paints are made from polyvinyl acetate, styrene-butadiene, or acrylic resins. The acrylis, however, are the most popular polymer in current use in these formulations, having superior elasticity, hardness, and permeability.

Emulsion paints are made up of polymers dispersed in water. These paints form films through coalescence—or the merging of polymer droplets—which occurs as water in the paint evaporates. “In this case the water is not a solvent for the polymer but merely the medium in which it is dispersed.” It is ordinarily undesirable for a polymer to be fully soluble in water because water-soluble binders remain unstable through their sensitivity to water after curing.

Emulsion paints contain many additives that assist and speed cure. Surfactants are added to help polymer droplets merge during coalescence. Acrylic emulsions are subject to biodeterioration; fungicides and biocides are therefore blended with them to help resist this sort of attack. Water-soluble thickening agents impart “a very high low shear viscosity, so that it appears like a stiff jelly in the container.” “An advantage of acrylic emulsion paints is that the best ones are highly resistant to yellowing.”

Removing Emulsion Paints

Emulsion paints are sensitive to most solvents and caustic materials. In a residence in Royalston, Massachusetts, for example, Brian Powell reports that a “single coat of overpaint was a latex which we were able to dissolve with acetone on cotton.” Methylene chloride-based paint removers are also extremely effective for removing this type of finish, but can solubilize the paint so quickly it may be difficult to control exposures. Very thin films of emulsion paint can be difficult to remove with methylene
chloride because the swelling action of the remover may not be sufficient to break the paint's bond and pull the softened paint away from a surface. In this circumstance, the plastic, solubilized emulsion paint can simply be rubbed off with a soft cloth.

The Appearance of Historic Paints

Historic paints looked and acted very different from those applied by the modern painter; exposed decorative finishes might therefore appear somewhat odd to those experienced with the perfection and gleam of replicated decorative painting. Although traditional lead and linseed oil paints were superior to other available period materials, their performance was still well below the standards of modern coating materials. In the 19th century, “a freshly painted house often looked blotchy, lumpy, mottled, and wet (early paints took an eternity to dry).”

Prior to the general availability of mechanically manufactured paints and the introduction of levelers, brush marks remained a permanent part of painted surfaces after they had cured. These were considered a regular component of most painted finishes, and the final strokes of the painter were made so as to “leave clear directional markings.” This technique was known as “laying off,” and ordinarily ran parallel with the architectural elements being finished (wooden elements, for instance, were usually laid off in the direction of the grain). Early paints used coarse, hand-ground pigments leaving a gentle unevenness of color and texture across their surface. Paints were also often stippled to even-out surfaces and remove brush-marks. Stippling involves beating a freshly applied finish end-on with a brush, leaving a texture of fine impressions across its surface.

Traditional raw linseed oil and lead paints also had variable longevity, depending on the preparation of the surface, the climate, the formulation of the paint, and the skill of the
painter. Although seven years was a likely life-span for a job carried out competently in traditional linseed oil and white lead paint, as late as the 1940s, it wasn't uncommon to have to repaint a house every two to three years, if it was carried out in traditional linseed oil paint. Even in 1913, however, if a project was executed in raw linseed oil paint “it was not an unusual thing to find exterior painting in good condition after twenty years of exposure and wear.” Although interior painting could potentially last a longer time than exterior painting, the yellowing of linseed oil, the use of wood and coal heating, and open-flame illumination all lowered the aesthetic life expectancy of these finishes.

Modern Coatings

Although it is important to understand traditional paint media when carrying out the selective removal of overpaint, it is equally important to understand modern coatings, as these will often be among the materials being removed. In recent years industrial needs have encouraged paint technology to develop at an exponential rate, with materials such as highbred metal-plastics, water-borne oil paints, and electrostatically applied ionic powder-coatings being researched and developed for specialty applications. The “coatings which are particularly difficult to remove are catalyzed epoxies, polyurthanes, and thermosetting acrylics.” Fortunately, it is rare to encounter these exotic materials in buildings. Although infrequently encountered, the conservator will occasionally find the use of epoxies and urethanes in industrial applications, the most common modern paints used on the exteriors and interiors buildings are water-borne emulsions, alkyds, and the transparent, semi-transparent and opaque stains. “With the introduction of progressively more resistant finishes, the paint stripper industry is constantly being challenged to develop more efficient removal methods,” and it is hoped that “with further work and with further technological help...the exposure of decorative paint schemes will become increasingly affordable and commonplace.”
Chapter 5
The Health Hazards of Performing Paint Exposures

Most of the materials used in paint exposures have negative physiological side effects. The chemical formulations used in breaking the chemical bond between paint layers are generally not well tolerated by humans, and many historic paint materials themselves pose a threat to human health. The chlorinated hydrocarbons, particularly methylene chloride, have been closely examined for their toxicity, and a number of hazards have been identified. Many of the co-solvents used in these formulations are also dangerous if ingested, inhaled, or, in some cases, left in contact with skin. Long-term chromic exposure to disturbed paint surfaces can be exceedingly harmful, with exposure to lead-based paint representing a particularly serious hazard. Creating a buffer between the architectural conservator and these materials is an important consideration in developing a practical methodology for selectively removing paint.

Methylene Chloride

Methylene chloride is also known as dichloromethane. It is a colorless, volatile liquid that has a pleasant, mild odor.\(^1\) It is made from methane gas or wood alcohol. In addition to being a primary ingredient in paint removers, its extreme volatility also makes it useful in forming the coatings on pharmaceuticals, in aerosols, and in the processes of coffee decaffeination and the drying of hops for beer-making.\(^2\) It is an aliphatic hydrogenated hydrocarbon, in the same class of solvents as carbon tetrachloride and chloroform.\(^3\)

At relatively low concentrations, the primary health hazards related to the use of methylene chloride are "irritation of the skin and eyes [which] may be caused by direct contact."\(^4\) "Eye
contact will be painful but not likely to cause serious injury.\textsuperscript{5} "Extended skin contact is usually limited during use because of the immediate discomfort when the remover touches the skin."\textsuperscript{6}

The human physiological responses to extreme exposure "include renal and hepatic damage [and] possible cardiac sensitization." A number of instances have been in which "the startle response, which is associated with a large and rapid release of adrenaline from the adrenal gland, has precipitated a heart attack in individuals who were breathing large quantities of chlorinated hydrocarbons."\textsuperscript{7}

The main "industrial health problems resulting from excessive exposure are the symptoms of drunkenness and incoordination that result from dichloromethane intoxication and the unsafe acts and consequent accidents to which these symptoms may lead."\textsuperscript{8} The toxicity of methylene chloride "is complicated because it decomposes into carbon monoxide in the body." The narcotic effects experienced due to exposure are therefore "most likely caused by carbon monoxide in the blood rather than the chemical itself."\textsuperscript{9} Hemoglobin in human red blood cells takes up carbon monoxide molecules much more easily than molecules of oxygen; this can cause an oxygen deficiency in the body and, in essence, self-induced carbon monoxide poisoning.\textsuperscript{10}

A further hazard of using methylene chloride is related to the instability of the chemical in the presence of open flame. When burned, methylene chloride vapor degrades to phosgene gas and hydrogen chloride; therefore, "methylene chloride-type removers should not be used in the presence of an open flame or other heat sources such as kerosene heaters."\textsuperscript{11} Phosgene gas (carbonyl chloride, COCl\(_2\)) was used during World War I and World War II in chemical warfare. Phosgene acts as a powerful choking agent and was utilized because it was "so powerful, one or two breaths will cause a casualty."\textsuperscript{12} It is a reactive irritant to the
lungs. Following exposure, "in the terminal end of the alvelole, complete hydrolysis occurs with irritant effects on the epithelium." This irritation causes extreme edema, until up to half of the body's plasma has accumulated in the lungs; the poisoned individual thus expires from drowning in the body's own fluids.\textsuperscript{13}

To date, testing results from studies to determine if methylene chloride is a carcinogen have been inconclusive. While the National Toxicology Program (NTP) has "concluded that these studies show 'clear evidence of carcinogenicity,' based on lung and liver tumors in the mouse... its relevance to man is questioned because of the high dosages used (1000, 2000, and 4000 ppm), the specific animal response... and the negative results observed in other studies on methylene chloride."\textsuperscript{14} "Interestingly, the compound does not cause tumors in rats, and this has been related to the fact that the rate of metabolism via the glutathione pathway is much lower in rat tissue than in mouse tissue." Many believe that in this instance rats are much more accurate models for human health simulation studies, because rat glutathione pathways more closely resemble those in humans. It is thus argued that this lack of cancer formation in rats indicates humans are "thus presumed safe from the carcinogenic effects of methylene chloride."\textsuperscript{15}

A serious problem with methylene chloride relates to difficulties in personal protection equipment during its use. "The latest information indicates that the use of cartridge respirators is not recommended because methylene chloride tends to saturate or "break through" the carbon absorbers fairly quickly, thus rendering the mask an ineffective barrier against solvent vapors."\textsuperscript{16} Further, due to the high odor-threshold of methylene chloride, technicians can be exposed to high concentrations long before they are able to smell it. Using inadequate canister respirators can create a false sense of security that may increase exposure to the chemical. To protect workers using methylene chloride it is necessary to provide adequate ventilation, supplied-air, or a self-contained breathing apparatus.
Though methylene chloride is relatively poisonous, it is “one of the least toxic of the chlorinated hydrocarbons.”\textsuperscript{17} While accidents can occur due to the narcotic effects of exposure, methylene chloride “causes a ‘drunken’ state only at high concentrations.”\textsuperscript{18} “In most cases, these effects will stop shortly after exposure ends.”\textsuperscript{19} Good ventilation, however, prevents vapors from reaching unacceptable levels. Methylene chloride is not photochemically reactive, and is not regulated as a volatile organic compound (VOC), nor as an ozone (qv) depleter,\textsuperscript{20} as are the majority of the paints and solvents used in the finishes industry. Methylene chloride is nonflammable when “used in amounts of 78% or more, even with flammable co-solvents.”\textsuperscript{21} With the use of flammable paint removers such as the petroleum-based and oxygenate removers, the possibility of fire becomes a very serious hazard. Although methylene chloride does burn smartly when it comes in contact with skin, this is seen by some as a positive rather than a negative characteristic. Alkaline strippers, for example, numb when they get on the skin, often delaying the technician’s reaction until serious burns have already been inflicted. Methylene chloride can usually be neutralized with water before serious harm occurs. While methylene chloride can be absorbed through the skin and gastrointestinal tract, absorption is slow and therefore unlikely to cause poisoning.\textsuperscript{22} Paint removers containing methylene chloride, however, are dangerous to plant and animal life, and “for health and environmental reasons, alternatives to methylene chloride are currently being investigated.”\textsuperscript{23}

**Toluene and Xylene**

Both tolene and xylene are used in many petroleum-based paint removers. These solvents are members of the group known as *aromatic hydrocarbons* and are distilled from crude oil. They are chemically related to benzene.\textsuperscript{24} Although in the past benzene was used in many paint removal formulae, its extreme hemological toxicity caused it to be removed from
commercial distribution. Paint removers that contain toluene and benzene usually utilize toluene as the primary solvent and xylene as a co-solvent. Methanol, butyl alcohol, and n-butanol also often appear as co-solvents to toluene in commercial mixtures.25

Toluene is “a clear, colorless, noncorrosive liquid with a sweet, pungent, benzene-like odor.”26 Toluene is also known as toluol, methylbenzene, and methylbenzol. Although “toluene is a more powerful CNS depressant than benzene, no definitive evidence links toluene to permanent blood disorders.”27 “Concentrations of toluene in most commercial products are not sufficient to produce dangerous exposures in most restoration-related activities.”28 Acute overexposure to toluene can, however, cause central nervous system depression, and symptoms can “include headache, dizziness, fatigue, muscular weakness, drowsiness, incoordination with staggering gait, skin paresthesia, collapse, and coma.”29 Interestingly, ethyl alcohol (the alcohol in beer, wine, and liquor) causes most of the toluene in a person’s body to migrate to the blood, resulting in increased exposure to vital organs such as the brain.”30 The effects from drinking alcoholic beverages can therefore be severely intensified through prior exposure to toluene.

Xylene is a colorless liquid with a strong, sharp odor and a slightly greasy feel. Its smell is familiar to many because it is the solvent commonly used for the inks in permanent markers. “Xylene is the most acutely toxic of the aromatic hydrocarbons.”31 “The acute toxicity of the xylenes (xytol and dimethylbenzene), C₆H₄(CH₃)₂, is greater than that of toluene but the symptoms are similar.”32 These symptoms include: irritation of the mucous membranes, pulmonary edema, hemorrhaging of the respiratory system, and central nervous system depression.33

Xylene-related “death is usually caused by respiratory arrest, but sometimes the heart stops beating.” As with toluene, alcoholic beverages can cause xylene collected in body tissue to be
released suddenly, creating dangerous internal concentrations. The primary exposure pathways for both toluene and xylene are inhalation and skin absorption. Canister respirators equipped with organic solvent cartridges are effective in limiting worker exposure to toluene and xylene.

Ketones

The two ketones commonly found in oxygenate paint removers are acetone and methyl ethyl ketone (MEK). Both of these highly flammable solvents are colorless, volatile liquids "with a sharp, mint-like smell." While acetone is the primary solvent in most nail-polish removers, methyl ethyl ketone is a popular solvent used in de-greasing and other industrial operations. At low concentrations "the systemic toxicity of this class of compound is not high." Exposure to higher concentrations, however, can produce "narcosis, headaches, nausea, lack of coordination and unconsciousness."

"Acetone is one of the least hazardous of the individual solvents as far as health is concerned," and "the chronic toxicity of MEK is not well understood." The greatest hazard related to using oxygenate paint removers is probably from fire. Both acetone and methyl ethyl ketone are extremely flammable, with "flash-points of -18 °C and -6 °C respectively." When using these types of removers, it is essential that technicians not "work near an open flame, pilot lights, or electrical sparks."
Lead

Although solvent exposure is a serious health threat when exposing architectural decoration, chronic exposure to lead-based paint may represent an equally significant health hazard for the architectural conservator. The sheer volume of delaminating lead paint present in American buildings makes this material a cause for serious concern for those disturbing and removing it. With prudent work practices, appropriate personal protective equipment, and common sense, however, the hazards of lead-based paint can largely be mitigated.

Though lead was banned from American residential house paint in 1978, there are currently in the United States “over 40 million housing units that exceed federal guidelines for lead in residential paint.”^14 High levels of lead in a building’s paint, however, does not necessarily constitute a health hazard. For lead to be dangerous it has to be either eaten or inhaled. Paint must therefore be 1) in a form that can readily be taken into the mouth or nose (generally dust, chips, or vapor), and 2) accessible. In buildings that have been maintained, “lead paint is usually several layers down. If not exposed, it does not create a danger.”^15 Executing chemical exposures does not necessarily create serious lead hazards. During exposure surfaces must be kept moist for paint removers to work, and moisture keeps lead dust from becoming airborne and accessible. Dry scraping, sanding, and allowing remover/paint residue to collect, dry and be crushed underfoot, however, will quickly raise lead levels beyond acceptable concentrations.^16

Establishing prudent work practices is the primary way to lower the potential for worker lead poisoning. The area immediately surrounding the exposure site should be covered with heavy plastic and taped down to contain paint residue. After exposures have been completed this plastic can be folded up with residue and properly discarded. Eating, drinking, and smoking must be banned from areas where exposures are being executed. Microscopic lead particulates
in the air quickly settle on food and drinks, contaminating them. Smokers are at much higher risk for lead poisoning than non-smokers. “That’s because the lead travels from their fingers to the cigarette to their lips and is ingested.” Washing the hands and face before eating or drinking is crucial during exposure work to avoid self-poisoning. It is also important to be cautious with clothing contaminated during paint removal. “The hazard can be reduced if the worker wears protective clothing at work, changes clothes before coming home and showers when they get home, or, if possible, before coming home.” A HEPA (high efficiency particulate accumulator) vacuum cleaner should be used over the exposure site during clean-up to remove the fine lead dust that is missed during normal cleaning operations. A final wash-down with trisodium phosphate and water or with mineral spirits insures that all surfaces are free from lead dusts.

Lead poisoning is particularly insidious because the general lack of specificity in its symptoms can make it very difficult to diagnose. It’s wide variety of symptoms can include “anorexia, apathy, anemia, hyper-irritability, clumsiness, [and] loss of recently acquired developmental skills,” as well as a general decrease in mental ability, weakness of the hands, headache, abdominal cramps, and diarrhea. None of these symptoms are specific to lead ingestion or inhalation and therefore likely to lead to diagnosis of lead poisoning. Lead poisoning thus often goes untreated.

Three paint removal procedures should be avoided at all costs: belt sanding, dry scraping, and open flame burning. Belt sanding pulverizes lead paint into micro-particles and spins it into the air, creating an instantaneous lead hazard. Even with HEPA vacuuming and full wash-down of all surfaces, this hazard is extremely difficult to remove once it has been created. Dry scraping should be avoided because it also creates large amounts of lead dust. Moistening the surface with a hand-sprayer during scraping minimizes this risk. Open flame burning should be
avoided. Torches quickly heat paint surfaces above 1500° F—the temperature at which lead vaporizes—creating a lead-vapor hazard.

A system of personal protection equipment designed to put a barrier between workers and lead hazards should include: cartridge respirators, goggles, gloves, tyvek suits, and boot covers. Respirators equipped with HEPA cartridges should be worn whenever visible amounts of airborne dust are present. Workers should also undergo respirator fit testing to ensure that respirators seal properly around the nose and mouth. Although cartridge respirators will not protect workers from methylene chloride vapors during chemical exposure operations, HEPA filters are effective for protection against airborne lead particles. Goggles should always be worn in construction areas to protect eyes. Wearing plastic or rubber gloves during clean-up of masking materials, tools, and paint residue lowers the potential for self-poisoning through hand-to-mouth contact. Disposable tyvek suits can be worn during clean-up operations and removed before leaving the worksite to keep workers from contaminating their homes. Disposable boot covers should be changed regularly and removed at the close of every day to keep workers from taking lead dust home through footwear contamination.

Performance Criteria

Paint removal is by its nature a dangerous process. While most of the chemicals used to remove paint represent a significant risk to the health of those using them, historic paint materials themselves can also be hazardous. The performance criteria used to select a paint removal system for exposing decorative painting should always include considerations for the use and handling of these materials.
Conclusions

This thesis grew out of a general frustration over the lack of information on selective paint removal in architectural conservation. Although most architectural conservators practicing in the field regularly carry out the exposure of overpainted decoration, very little has been written on the subject. As with any foray into a subject with little scholarship, I have found it necessary to turn to a variety of sources to document the present state of selective paint removal among professionals. It may well be that architectural conservators are uncomfortable about the use of commercial paint removers in such a delicate and subtle procedure, and so, are reticent about publishing their past successes and failures. It appears, however, that more dialogue is needed between these professionals if we are to gather their knowledge and experience and move the processes forward.

The preceding pages do not attempt to be a full exegesis of paint removal, but, rather, an examination of some salient issues in the selective chemical removal of overpaint within architectural conservation. The procedures used to expose decorative painting take place within a very specialized professional border-land located between the building arts and fine arts conservation. While their development and practice owe much to both disciplines, they are very different from either. In developing standards for selective paint removal, the primary goal is to preserve the often very fugitive "meaning" that survives in overpainted architectural decoration through an unrelenting respect for immovable cultural property.

Exposing period decoration is both technically and philosophically challenging. Paints are particularly formulated to bond to one another, and the exposure process seeks to break these bonds in a controlled manner. Decisions regarding the fate of paint strata not targeted for preservation are often complex, as is the resolution of whether to conserve or replicate decorative paint schemes damaged by time, overpainting, or the exposure process itself.
Insitu testing remains the strongest tool in the conservator's arsenal for selective paint removal. Nonetheless, an understanding of both paint removers and paint materials is essential in developing paint exposure methodologies. Further, paint removal is a potentially hazardous process and its safe execution must be considered an integral part of the architectural conservator's responsibilities.

Clearly, the procedures used in selective chemical paint removal need to be further developed if we are to increase the number of historic decorative finishes that are preserved. Presently, it is very difficult to quantify or to qualify to a client or restoration team the final product of exposed finishes prior to their execution. It is hoped that developing a greater understanding of how paint removers work, carrying out controlled paint removal testing on historic startigraphies, as well as working more closely with those researching new commercial paint removers will help future conservators carry out paint exposures of a quality rarely possible at present.
NOTES

Chapter 1
"Selective Paint Removal in Architectural Conservation"


Chapter 2
"Problems In Selective Paint Removal"


Chapter 3
“Chemical Paint Removers”


41. Personal telephone interview with Jay Bardole, 12-18-96.
44. Thomas Wollbrinck, "The Composition of Proprietary Paint Strippers," p. 44.
45. Thomas Wollbrinck, "The Composition of Proprietary Paint Strippers," p. 44.
Chapter 4

"Traditional Paints and Paint Exposures"


8. Personal telephone interview with David White, President of The Paint Removers Manufacturers Association of America, 12-09-96.


44. Brian Powell, “Exposing Period Decorative Finishes,” p. 6-12.


77. F. Maire, *Modern Painter’s Cyclopedia*, p. 64.


97. Slaked lime is prepared through burning limestone (calcium carbonate) at 700—900° C., which converts the material to calcium oxide, or quicklime. Quicklime is mixed with water and left to slake from several months to several years to produce lime-putty. It hardens through evaporation of the slaking water, as well as through reacting with the carbon dioxide in the air. Well-slaked lime-putty has a “buttery” consistency highly desirable when mixing it with other materials. [Giorgio Torraca, *Porous Building Materials*, Rome, Italy: ICCROM, 1988, pp. 67-70.]


123. Private conversation with Paolo Mora, Rome, Italy, 7-16-93.


Chapter 5
"The Health Hazards of Performing Paint Exposures"


46. Dennis Livingston, Maintaining a Lead Safe Home, p. 43.


The following select bibliography is divided into five sections: *Paint Removal and Removers; Paint Chemistry and Historic Coatings; Conservation and Preservation; Period Books on Painting, and Safety and Hazardous Materials*. Although in many cases books and periodicals fit within more than one subject section, sources appear in only one section.

**Paint Removal and Removers**


Paint Chemistry and Historic Coatings


Conservation and Preservation


Period Books on Painting


Hasluck, Paul N. *House Decoration: Comprising Whitewashing, Paperhanging, Painting, Etc.*. Philadelphia: David McKay, Publisher, 1904.

Hasluck, Paul N. *Painters' Oils, Colours, And Varnishes*. Philadelphia: David McCay, Publisher, 1905.


**Safety And Hazardous Materials**


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