



Cultural Heritage Agency
Ministry of Education, Culture and Science

Varnishing and Inpainting/Retouching

Paintings conservation

Varnishing and Inpainting/Retouching

Paintings conservation Part 6

“Varnish is a powerful liquid” Cennino Cennini, Il Libro dell’Arte, ca. 1400.

“The boundary between paint and varnish may be anything but clear; it may be indeterminate geometrically and operationally’ Stephen Rees-Jones, ‘Science and the art of picture cleaning”, The Burlington Magazine, pp 60-62

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Varnishing and Inpainting/Retouching

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Front cover: Unknown artist, *Portrait of a Lady*, 19th C, oil on canvas, before retouching

Back cover: Unknown artist, *Portrait of a Lady*, 19th C, oil on canvas, after retouching

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Welcome to one of six brochures created for professional conservators of easel paintings, wishing to keep up with current knowledge, and learning how to apply new techniques in their field. The brochures in this series are:

1. Dirt and Dirt Removal
2. Varnish Removal
3. Consolidation of Flaking Paint
4. Filling Losses in Paint
5. Structural Conservation of Canvas and Panels
6. Varnishing and Inpainting/Retouching

These brochures were compiled to serve as a reference, bringing together current practices and new knowledge regarding materials and methods for practical use. The content provided can be used by professional conservators, who are aware of the ethical and contextual aspects and complexity of conservation decision-making.

Conservation knowledge and practice are developing at an increasingly fast pace. In many countries, this knowledge is often concentrated within a relatively small group of conservators and other professionals in larger institutions with the resources to take major steps in the development and application of new methods for preservation and treatment of paintings. New publications on focus topics are often issued through journals or editions that are costly and not easily available to the conservation field. Thus, accessing such knowledge and integrating into practice can be challenging. These brochures are designed to help bridge this gap. They are also a tool for mid-career professional conservators seeking to refresh and update their knowledge. The content is intended as a snapshot of up-to-date developments in these six focus areas and should not replace academic training in the field of painting conservation.

The need for this reference material became apparent during a series of masterclasses and conferences organised by the Foundation for Cultural Inventory (SCI) in India, Russia and Cuba, together with the SRAL-The Conservation Institute, the Cultural Heritage Agency of the Netherlands (RCE) and Dutch embassies in partner countries. These gatherings, focussing on the mutual exchange and deepening of knowledge in relation to local context and practices, were held under the auspices of the Shared Cultural Heritage programme.

This programme has since been succeeded by the International Heritage Cooperation programme, which more than ever emphasises the comparable societal challenges countries face and the value of the exchange of learning and knowledge to address contemporary issues in conservation. These brochures show how much can be achieved through mutual exchange and understanding.

We are providing this reference material in the hope and anticipation that it will assist conservators of easel paintings in their work in all geographical areas, so that future generations can continue to enjoy their international heritage for a long time to come.

We thank Conservation Scientist René Peschar (University of Amsterdam) and senior Paintings Conservator Louise Wijnberg for their valuable input.

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Varnishing Day at the Royal Academy, 1934. © Photo: Royal Academy of Arts, London. (Image source: <https://www.royalacademy.org.uk/art-artists/work-of-art/photographs-of-the-summer-exhibition-1934>).

Varnishes and Varnishing

Introduction

Varnishes are (clear) coatings or finishes, applied to the surface of a painting as a solution of a natural or synthetic resin dissolved in solvents and left to dry to a film. Varnishes have traditionally been applied to paintings to change the appearance of the artwork (paint layer) by saturating the surface, unifying the gloss and enhancing tonal and colour contrasts, and to provide a thin protective layer from dirt, humidity, abrasion and other types of damage. Currently, the most sought-after properties of varnish are pale, clear and colourless, though coloured or tinted varnishes have been utilised in the past.¹

Natural resin varnish coatings have a highly reactive, complex chemical structure that is influenced by the ambient environment and consequently yellow rapidly. Chemical changes are induced by exposure to light, moisture, oxygen and heat. Traditionally, varnishes have been applied as a sacrificial layer; as it ages over time it darkens or yellows, becomes hazed, brittle or cloudy, and reduces the visibility of the image and the original

tonality of the paint layers, requiring its removal and replacement periodically.²

It was widely recommended not to varnish oil paintings too quickly after finishing painting. Temporary varnishes can be often found. These coatings vary in nature and include thinly applied layers of gums, gelatine layers, egg glair and other aqueous solutions or even drying oils. Often these were not removed before the application of the more permanent varnish layer and, thus, may be found below varnishes, especially in paintings that have never before been cleaned.³

By the early nineteenth century, paintings were varnished by others than the painter themselves, generally artists' colourmen, dealers or framers. Varnishing often happened sometime after completion of the painting.⁴

² This practice was suggested by Jean François Léonore Mérimée in *Art of Painting in Oil and in Fresco* (1830). He states 'One part of oil should be used for two of copal which should afterwards be diluted with oil of turpentine...The best way of preserving pictures would be to varnish them lightly with copal at first and when this layer is perfectly dry to lay over it a couch of mastic. In a few years this will become yellow or chilled then it may be removed. The copal varnish being extremely hard will not suffer by the removal of this coating but will preserve the picture so well that even the glazing cannot be endangered in the cleaning' p91-92

³ Pierre François Tingry, a Swiss writer on painting methods, declared, "Great masters rarely varnish their pictures after they are finished; they protect their tints by a coating of white of egg and do not varnish them until a year – from *The Painter and Varnisher's Guide* (London, 1804), p.136.

⁴ This happened frequently in Paris where paintings hanging in the *Prix du Rome* were varnished by the same colourman, Etienne Haro. This included, at the same show in the mid-1840s, paintings by Delacroix, Ingres, Corot, Courbet, Millet, Degas and Sisley; all varnished with the same varnish pot!

¹ Note that coloured varnishes were the trend in the late 19th and early 20th century. Still today some (curators) like a yellow tinted varnish, especially those outside of Northern Europe and America.



Bottles of different types of natural and synthetic resin varnishes.

In this period, varnishes began to be mass produced, sold in bottles and advertised widely. They were also used for other coating purposes, such as for coaches or furniture, and sold by colourmen.⁵ These early commercial varnishes often contained numerous ingredients. Additives, such as a wide variety of resins, waxes, balsams and essential oils were commonplace.

Throughout the ages, but especially since the nineteenth century, varnishes were added by artists as intermediate layers to resolve the 'sunk-in' appearance of oil paints,

especially darks, and to harmonise bright, light colours. Varnishes coat the surface of the paint saturating the colour and providing a smooth finish, especially when applied thickly by brush. Varnish resins were added to oil-medium to extend the paint and achieve high gloss and thin glazes. Thus, varnish resins can be found either as independent layers or as components of oil paint layers, especially since the late eighteenth century.⁶ Cleaning these types of paintings must be carried out with extreme caution.

⁵ White, R., Kirby, J. *A Survey of Nineteenth- and Early Twentieth-Century Varnish Compositions Found on a Selection of Paintings in the National Gallery Collection*. National Gallery Technical Bulletin Vol 22, pp 64–84. http://www.nationalgallery.org.uk/technical-bulletin/white_kirby2001

⁶ Leslie Carlyle (1990) *British nineteenth-century oil painting instruction books: a survey of their recommendations for vehicles, varnishes and methods of paint application*, *Studies in Conservation*, 35:sup1, 76-80, DOI: [10.1179/sic.1990.35.s1.018](https://doi.org/10.1179/sic.1990.35.s1.018)
Leslie Carlyle (1999) *Paint Driers Discussed in 19th-Century British Oil Painting Manuals*, *Journal of the American Institute for Conservation*, 38:1, 69-82, DOI: [10.1179/019713699806113538](https://doi.org/10.1179/019713699806113538)



Historical varnishes. (Image credit: Kate Seymour, SRAL).



The old, yellowed varnish layer from this nineteenth century landscape could only partially be removed, as it appears that varnish resins were added to oil-medium to achieve a high gloss in the darker passages of paint and to create thin glazes, built up in layers.

(J.A. Hesterman, *Mountain Landscape with River*, 1879, oil on panel).

Since the late nineteenth century, some artists, such as the French Impressionists, have preferred to have their paintings left unvarnished, explicitly giving instructions as such. Many of these paintings have been subsequently varnished, altering the original intention and appearance of the painting irrevocably. Often removing these non-original layers can return a sense of that original appearance.

Modern varnishes are solvent-resin mixtures, where the resin component is either a natural resin or a synthetic polymer or oligomer. Synthetic resins in conservation have been selected for their chemical stability and aesthetic appearance. These are pale and clear in colour and have good, though differing, saturation potentials for oil paint. The individual characteristics of the painting need to be matched with the properties of the synthetic resins when selecting the best varnishing materials and system.

The manner of varnishing, the intended aesthetic, the application and the materials used should be carefully considered when re-varnishing an artwork is required. Variations to the final appearance and aesthetic that fits with the historicity of the artwork may depend on the

artistic period, the past treatments that the artwork has been subjected to, the current condition of the surface, and geographical trends in material selection. These aspects will be discussed further below.

Historical Types of Varnishes

Resins for varnishing are traditionally composed of one or more natural resins, gums, balsams and/or essential oils. Natural resins are exuded from the tree or shrub, or they are obtained by tapping. These are semi-viscous liquids, which subsequently harden to pieces when exposed to the air. The resin pieces are powdered, and then either mixed in hot oils or dissolved in solvents to produce a liquid varnish. The coating dries by evaporation of volatiles or the partial oxidative polymerisation of some components.



Agathis dammara, commonly known as the Amboina pine or dammar pine.



Dammar (or damar) is a natural resin from the Dipterocarpaceae tree family, found in Asia.

Some typical natural resins utilised as surface coatings were sandarac, mastic, colophony, and dammar.⁷ Others, for instance amber, kauri and copal, are found buried in the ground in a so-called fossilised condition, a product of pre-historic tree resins. These resins are considerably harder and more durable than the younger, fresher tree resins. As such, they were often added to surface coatings that suffered more 'wear-and-tear', such as coatings for coaches or furniture.

Easily obtained and needing little or no processing for use, these natural resins have naturally been important raw materials from the earliest times. Chemically, the components of the majority of resins are terpenoids, a class which is further divided up into mono-, sesqui-, di-, and triterpenoids which have 10, 15, 20, and 30 carbon atoms per molecule respectively. The first two of these classes are usually liquids at room temperature (classed as essential oils and balsams) and so serve as solvents for the normally solid di- and triterpenoids.⁸

A comprehensive overview of the resins used as varnishes can be found on the American Institute of Conservation (AIC) Paintings Group Wiki.⁹ Note that in other cultures varnish materials will differ and selection of resins will relate to locally available materials. The resins covered in this brochure refer to historical and current practice in Europe and North America.

Historically, there are three types of varnishes that have been used.¹⁰

A. Oil varnishes. Here the resin is crushed to a powder and melted into a hot drying oil. Because the oil is heated, these varnishes are often darker in colour than solvent-based resin coatings. Early examples contained fossil resins such as amber or copal, or fresh resins such as sandarac or mastic. The oil was often linseed, but could also be walnut, poppy or hempseed oil, for example. Oil of turpentine, oil of spike [lavender oil] or other spirits were sometimes added as a diluent, although this ingredient was not the main component

of the varnish.¹¹ This addition would have been added to help the application of the varnish, reducing viscosity, as without it would have been thick and syrupy. Oleoresins such as spike oil, rosemary oil or balsams such as Venice turpentine were recommended in some texts as additives.

Oil varnishes were slow drying and hard wearing. In fact, these tend to dry by polymerisation rather than solvent evaporation. Oil varnishes cure by oxidative cross-linking of the oil and were often left to dry in the sun. These aged varnishes tend to darken further on aging and are difficult to remove, due to the cross-linking of the oil component.

These varnishes were used throughout Europe from the Middle Ages onward, with their recipes mentioned in early texts. Medieval tempera paintings in Italy were varnished with oil varnishes, although it was advised against varnishing any gilding and it may be that only certain colours or areas were varnished. In Greece and Russia, it was standard practice to coat the entire surface of an icon with a thick layer of durable varnish. In Spain, tempera paintings from the same period were almost never varnished. These coatings were continuously used throughout the fifteenth to eighteenth centuries. Their popularity lessened in the nineteenth century with changes in varnishing practice, the availability of more refined solvents and the increasing popularity of soft resins [mastic and dammar] and shellac spirit varnishes.

B. Spirit or essential oil varnishes. Historically, these varnishes contain either an alcohol solvent or an (oil of) turpentine solvent. Today, modern solvents substitute the earlier less refined dilutant. Fresh resin, such as mastic, sandarac, rosin and sometimes dammar (fossil resins such as amber or copal are insoluble in early solvents, though may still have been added) is dissolved in a solvent, such as alcohol (spirits of wine) or oil of turpentine (a distillate derived from tree balsams). Additives, such as oil of spike or gum juniper were often included. Some recipes add walnut oil. Modern equivalent varnishes, containing natural resins or synthetic polymers, use solvents derived from distilling petroleum, such as naphtha. Other varnish types based on gum lac (shellac) were frequently used

⁷ Dammar is a relatively 'modern' varnish resin, finding popularity in the mid nineteenth century in northern Europe and America. It was never common in southern Europe where Mastic remains popular.

⁸ The main sources of these resins fall into two categories: Coniferales - the conifers - which is divided into several families, and the Caesalpiniaceae sub-family of trees (from the Leguminosae family). Triterpene resins originate from several Angiosperm families important among which are the Burseraceae (elemis), Diptero- carpaceae (dammars), and Anacardiaceae (mastic and related resins).

⁹ https://www.conservation-wiki.com/wiki/Paintings#Varnishes_and_Surface_Coatings [accessed 15 September 2021]

¹⁰ Phenix A., Townsend J. *A Brief Survey of Historical Varnishes*, in: Conservation of Easel Paintings (2021) 2nd ed. Ed: Joyce Hill Stoner & Rebecca Rushfield pp. 262-273.

¹¹ Oil of turpentine refers to the volatile essential oil that is derived when distilling balsams or the natural distillates of conifer trees. This differs from the solvent obtained in the distillation of petroleum, commonly known as turpentine or white spirits. Both can be used as paint thinners and have been commonly used as a major component to produce varnishes. Note that rectification is the process of redistilling a distillate, and thus purifying it more.



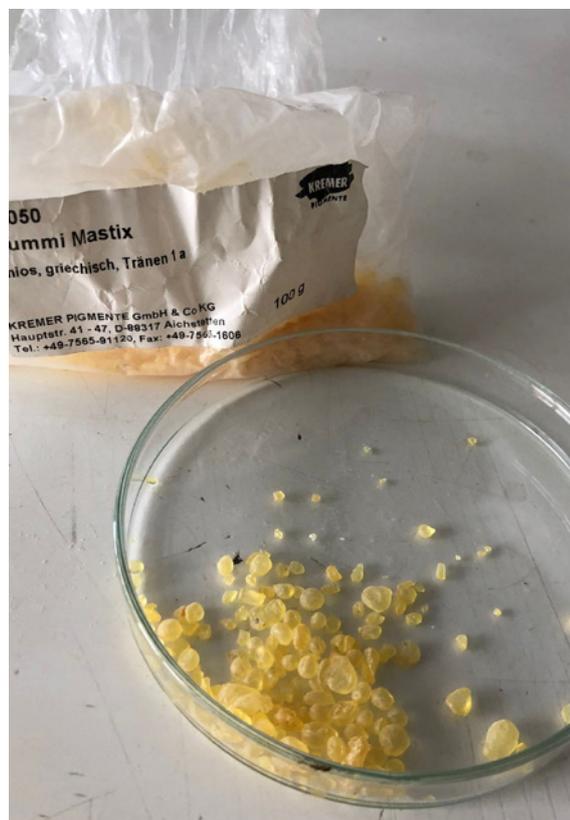
Pistacia lentiscus (Mastic tree) is an evergreen shrub or small tree which is cultivated for its aromatic resin, mainly on the Greek island of Chios.

to coat surfaces that required a more resistant finish.¹² Matting agents were added to reduce the surface gloss of the varnish. Traditionally, beeswax was used for this purpose. Modern matting agents include synthetic microcrystalline waxes or solid additives, such as silicon dioxide or rubber.

Spirit varnishes gained in popularity in the later fifteenth or early sixteenth century, potentially associated with the rapid developments in oil painting throughout

Europe. They seem to have been adopted more slowly in Northern Europe, potentially because they were felt to be less suited to the humid climate, and recipes from this area recommended the addition of (drying) oil to improve resilience. In the nineteenth century, dammar spirit varnishes gained in popularity in Northern Europe, while mastic spirit varnishes retained their favourability in the south of Europe. Dammar is more resistant to yellowing and retains its solubility in solvents of lower polarity on aging, which makes it safer for paintings on its removal. On the other hand, mastic varnishes are more elastic and prone to less cracking or hazing than dammar varnishes. Regional differences in use and practice still remain.

¹² Shellac, an excretion from an insect, has other properties than the terpenoids and though added frequently to formulations was also used as the main component for water-resistant coatings especially applied to wooden surfaces. Shellac dissolves in alcohols and is insoluble in petroleum distillates.



Mastic resin (*Pistacia lentiscus*) grown around the Mediterranean.

Commercially made varnishes of both of the above types of varnishes for oil paintings were available from the late eighteenth century. These were often mass-produced in large varnishing making factories and were sold, via artist's colourmen, bottled. Production was large-scale and intended for many uses, from furniture finishes to coaches and outdoor surfaces. Recipes for such varnishes were never simple and often included multiple ingredients and rarely singular resins. Additional ingredients were also included to enhance the performance of the dry film. Advertisements published in this period indicate that the search for a 'clear' and 'transparent' varnish was ongoing. Artist supply stores still stock, often proprietary, ready-made natural resin varnishes.¹³

C. Aqueous varnishes. These varnishes contain water soluble materials such as gums (gum Arabic), animal glue (isinglass) or egg white (glair), with some recipes calling for the addition of sugar or honey. The solubility of these varnishes shift overtime and aged coatings may no



longer be water soluble. These varnishes were most common from the Middle Ages onward to the end of the fifteenth or beginning of the sixteenth century, though they found popularity again in the late nineteenth – early twentieth centuries, and are still in current use in non-western painting practice. These varnishes are known to have been used in Italy on tempera altarpieces, although texts from the period indicate that they were used selectively especially as coatings for certain

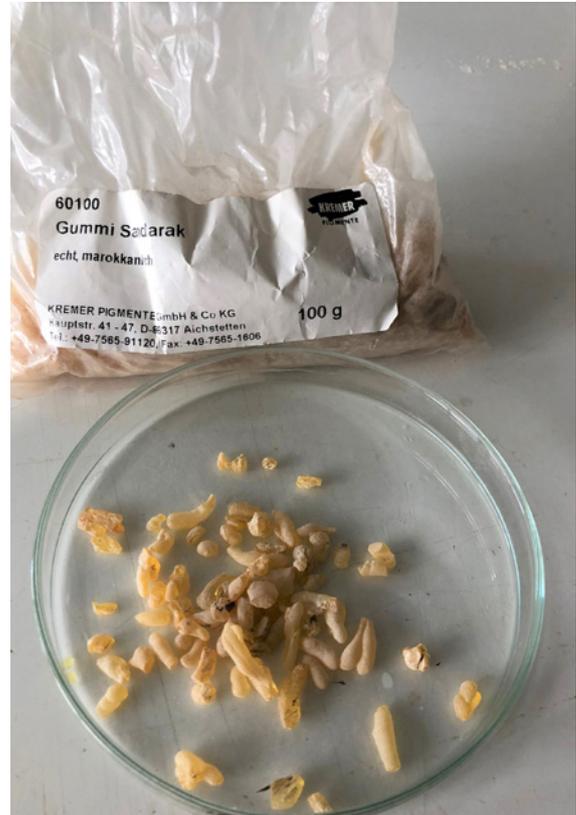


Glair is an aqueous sizing liquid made from egg white. (Image source: <http://medieval-whimsies.blogspot.com/2011/12/making-storing-glair.html>).

¹³ The authors recommend formulating studio-made varnishes rather than using ready-dissolved equivalents, as these often include undesired additives, such as matting agents.



Copal (Kauri) resin is a fossilised tree gum, sourced from Kauri trees in New Zealand.



Sandarac is a resin obtained from the small cypress-like tree *Tetraclinis articulata*. It is native to the northwest of Africa. The resin exudes naturally from the stems of the tree.

pigments, with some paintings having been shown to never have been varnished at all. Aqueous varnishes rose in popularity again in the nineteenth century with the changes in aesthetic perception of the finished painted surface. These types of varnish were often conceived as temporary, applied for saturation purposes to shift and harmonise colours if oil paints are too fresh to be varnished. Frequently, these were not removed and may be found below the upper resin coating.

The historical use of varnishes and coatings is highly dependent on artistic practice and geographical distribution.¹⁴ As discussed above, over the centuries the practice of varnishing and the materials used changed dramatically. Some artists partially varnished their paintings, while others moved away from it entirely with a focus on a matte surface, and others only varnished

when they felt it helped achieve a desired final effect. When considering removing or revarnishing paintings a thorough study of the surface, the history of the painting, and establishing the conservation history of the painting is essential. Establishing the time in which the varnish was applied will assist conservators in the identifying the materials that could be present and, thus, help in considering the solvents and system used to remove them. For this aspect, see the brochure on *Varnish Removal*. Moreover, these considerations will also aid the conservator in selecting the appropriate material and technique for revarnishing. This brochure will address some of these issues and provide guidance to those selecting varnishes for re-varnishing or retouching.

¹⁴ For the sake of brevity, the ethical and philosophical issues around partially applied varnishes, varnishes used as glazes, varnishes used between paint layers, and whether varnishes were deliberately tinted in the past will not be discussed in this brochure. These issues should be considered per painting, in the context of the time in which it was created, the school of thought to which the artist belonged and the historicity of the artwork and the applied finish.



Beeswax was traditionally used as a matting agent for varnishes.



Shellac is a resin secreted by the female lac bug on trees in the forests of India and Thailand. It is processed and sold as dry flakes and dissolved in alcohol to make liquid shellac. (Image source: <https://en.wikipedia.org/wiki/Shellac>)

Desired Characteristics and Properties of a Varnish

Since the Middle Ages, the desired characteristics of a varnish are pale, clear and colourless as possible.¹⁵ These characteristics are still desired today!

¹⁵ Note that there have periods in history where tinted or coloured varnishes were also in fashion. Long discussions have been held as to whether varnishes have routinely or sporadically been tinted in the past to imitate 'aged' varnishes, and whether artists intentionally painted in cooler tones, knowing that a later applied varnish would yellow over time, shifting the tonality of the artwork. It is also known that in some museums, 'Gallery toned varnishes' were applied to recently cleaned paintings to return to a pale yellow colour to the newly cleaned surface. This was to ensure that recently cleaned paintings did not stand out in the gallery and complied to the sense of aesthetic predominant in the late nineteenth century (see debates on Dark Varnishes by Gombrich, Kurz and Plesters in *The Burlington Magazine* in 1962).

When considering a varnish for a painting, the following properties/characteristics should be considered.

- **The composition of the varnish.** The solvents used to dissolve the resin should not affect the paint layer in any way, and any additives should be carefully considered for their potential to harm the paint layer, eventually also during its future removal.
- **Reversibility.** The varnish must remain soluble in solvents that do not swell or dissolve the paint layers, so that it can be removed from the artwork at any time in the future.
- **Stability.** The varnish should not yellow or cross-link rapidly, so as to reduce the need to be replaced.
- **Adhesion.** The varnish film should adhere well to the paint film and should have sufficient cohesive properties to accommodate any movement in the paint and substrate (i.e. it should not be brittle and

prone to cracking). It should also not shrink or exhibit any other dimensional changes on drying, or over time.

- **Transparency.** The varnish should be transparent, and maintain its transparency over time.
- **Protection.** The varnish should protect the paint layer from dirt and grime, and moderate abrasion.¹⁶
- **Hardness.** The varnish film should not be soft or tacky at room temperature after drying, so as to prevent dirt imbibing in its surface. The glass transition temperature (T_g) should be above room temperature, as at or below room temperature the varnish will retain dirt, but also not too high, as it will be too brittle.

Optical Properties of a Varnish: Gloss and Saturation

Although they are separate phenomena, the properties of gloss and saturation are intertwined. **Gloss** is a surface phenomenon that describes the degree to which light is scattered or not as it reflects off the surface of a varnish or paint film. Gloss is entirely a surface phenomenon. It can be measured in different ways and is expressed as either specular or diffuse reflection. **Specular reflection** is light observed from a mirror-like surface where the angle of reflection is exactly equal (but opposite) to the angle of the incident beam of light. **Diffuse reflection** is where the incident beam of light is evenly scattered in every direction from the reflecting surface.

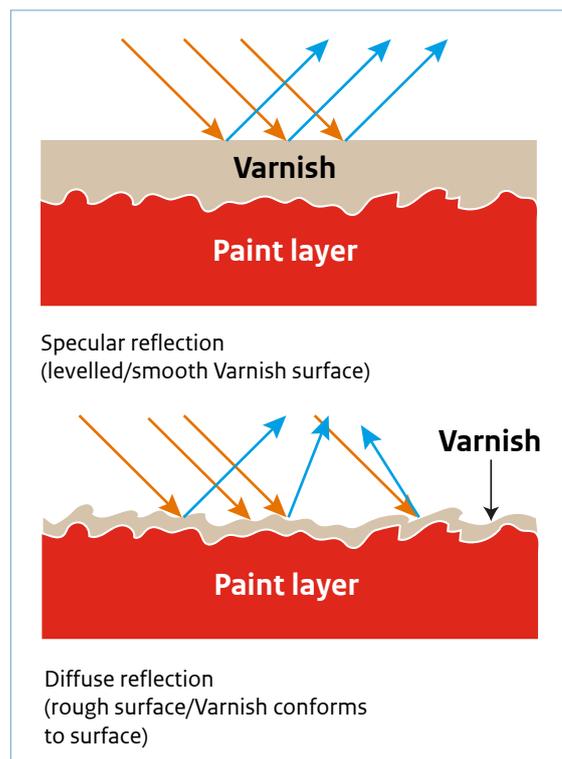
Saturation refers to the degree of depth of colour a varnish can render. Although exceptions can be made, those varnishes which are the most saturating tend to be among the glossiest. Matte or unsaturated surfaces are one extreme and highly glossy and saturating surfaces are another. Many subtleties of gloss and saturation are appropriate and achievable within these extremes. The capacity of a varnish to saturate a surface is dependent upon an interaction of three different characteristics: the varnish's ability to **wet** a paint surface or preceding application of varnish (resist flow and spread over a surface), its ability to **level** (flow and form a flat surface), and its **Refractive index** (the bending of a ray of light when passing from one medium to another).

¹⁶ Note that if a Hindered Amine Light Stabiliser (HALS) is added to the varnish, it can slow the oxidation process delaying chemical change within the polymer and thus maintaining solubility in less polar solvents. The protection offered by HALS is limited, as this chemical structure ages their effectiveness is reduced. HALS are best used when paintings are displayed in lighting conditions to filter out ultra-violet content.

Physical Properties of a Varnish

The physical properties of a varnish are intertwined with its optical and handling properties.

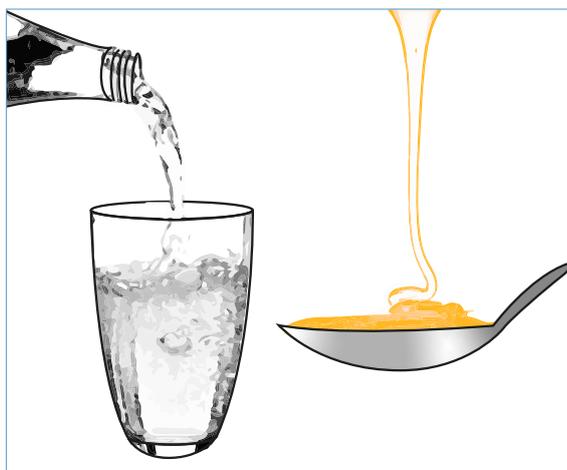
- **Molecular Weight (MW):** varnishes are classified as either high MW polymers or low MW oligomers. High MW polymers are composed of longer chains of monomers or copolymers, while low MW oligomers typically consist of smaller molecules having fewer repeating units. Generally, high MW polymers are more viscous than low MW oligomers at the same concentration in solvent. The ability of a resin to level well is also directly related to the size and structure of the polymer chain length or molecule: higher MW polymers have longer and structurally more complex molecular chains. Higher MW polymer varnishes therefore, do not 'sink in' as much as low MW oligomers. During solvent evaporation, high MW varnishes quickly form an immobile gel with relatively high concentrations of solvent left in the drying varnish and conform to the surface of the underlying layer rather than levelling. These varnishes can be challenging to brush out evenly and can produce very matt surfaces. LMW varnishes continue to flow and therefore level, even when the concentration of



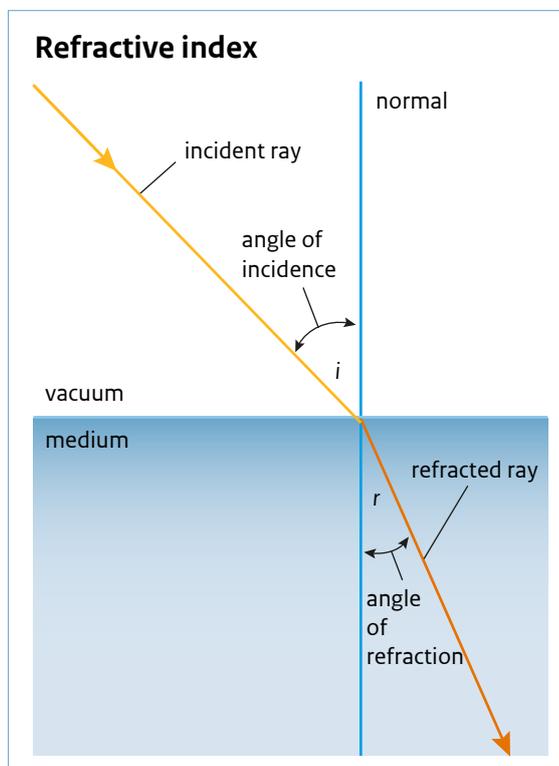
Specular and diffuse reflection.

remaining solvent is quite low. These varnishes can produce very glossy surfaces. However, the degree of gloss achieved is highly dependent on a multitude of factors, so a low MW oligomer varnish may produce a matter surface than a high MW polymer varnish!

- **Viscosity:** the measure of a fluid's resistance to flow. High MW resins are more viscous than low MW resins at the same concentration in solution. The handling properties of high MW resins are more suitable at low concentrations, whereas low MW resins can be used at quite high concentrations without adversely affecting the handling properties. The handling properties will affect the ability to brush out a varnish. The synthetic LMW oligomer varnishes have a similar 'brushability' to natural resin varnishes and can be handled similarly. Note that natural resin varnishes consist of both high MW and low MW molecules. Some synthetic resins, such as Laropal A81, also have this characteristic.
- **Refractive Index (RI):** RI refers to the measure of the bending of a ray of light when passing from one medium into another. A varnish with a high RI will give a better saturation than one with a lower RI. The RI of a paint is the product of the combination of the binding medium RI and that of the pigment. This will shift overtime as the binding medium undergoes chemical change, increasing the RI. Fresh linseed oil has an RI of around 1.48 which will increase over time to around 1.5-1.6 as it cross-links.¹⁷ Varnish resins that have a similar RI (whether natural or synthetic) will saturate oil paint surfaces well. This includes dammar



The viscosity of a fluid is a measure of its resistance to deformation at a given rate. For liquids, it corresponds to the informal concept of "thickness": for example, syrup has a higher viscosity than water.



The Refractive Index (RI) refers to the measure of the bending of a ray of light when passing from one medium into another. A varnish with a high RI will give a better saturation than one with a lower RI.

and mastic (RI 1.53), Paraloid B72 (RI 1.48), Laropal A81 (RI 1.53) and Regalrez 1094 (RI 1.52).¹⁸ As the difference between RI of the paint surface and varnish increases, there will be more inter-reflections in the varnish and less saturation. It is thus preferable to select a varnish material that has a similar RI as the binding medium.

- **Brittleness/Flexibility/Hardness:** These characteristics are related and can be generally predicted from several of the properties found in the materials section on each individual varnish. A varnish with a high glass transition temperature (T_g) is more brittle and therefore more easily scratched than one with a low (T_g) at room temperature. A varnish with a low T_g has a higher propensity for dirt attraction, as it is softer and dirt is more likely to stick on the surface. A large molecule or high-polymer varnish is more flexible and therefore less likely to be scratched and/or sheared from a paint surface. Hardness tests may predict the scratch resistance of a particular varnish. This factor will also influence the durability of the varnish and its ability to pick-up dirt.

¹⁷ <https://royalsocietypublishing.org/doi/10.1098/rspa.1937.0061>

¹⁸ https://www.researchgate.net/publication/272252901_The_Effect_of_the_Refractive_Index_of_a_Varnish_on_the_Appearance_of_Oil_Paintings

Factors Influencing the Varnish Appearance

The final appearance of a varnish on a painted surface is influenced by several different factors. The physical properties of the resin, such as the Molecular Weight, viscosity and ability to flow, will influence whether the resin sinks into the paint layer, or whether it is more likely to level to a flat surface. The solvent used will affect the application properties of the varnish, the viscosity, the workability with either a brush or sprayed onto the surface and the gloss of the final varnish film.

Additives

The addition of matting agents, such as wax will reduce the gloss of a varnish and polymeric additives such as rubbers act as plasticisers to reduce the brittleness and increase the flow capability of the varnish. Waxes, typically beeswax, have been a traditional modifier to natural resin varnishes. Modern synthetic waxes, such as Cosmolloid H80, are added to synthetic resins and are considered more stable and more resistant to dirt pick-up. The addition of rubbers, such as Kraton G1650, to the low MW oligomer resins are recommended by the conservation scientists who introduced these resins to our field. These increase viscosity and reduce the propensity of the varnish to sink-in.

Stabilising Additives

A note on stabilising additives. All resin materials whether natural in origin or synthetic will degrade over time. Absorption of oxygen from the atmosphere and



Tinuvin 292 is a Hindered Amine Light Stabiliser, that can be added to a varnish to reduce the photo-chemical degradation process of the varnish. There are few studies on the effect of HALS on paint layers.

environmental conditions, such as exposure to UV radiation and temperature fluctuations, will influence the chemical stability of the resin as a coating. Photo-chemical degradation processes are also exasperated when the coating material is exposed to high levels of light containing UV radiation. Additives can be included to mitigate these induced chemical changes meaning that the resin remains for a longer period chemically unchanged. These additives are typically Hindered Amine Light Stabilisers (HALS) and consist of a reactive amine-containing molecule. HALS do not absorb radiation, but instead protect the coating against the damaging effect of photo-chemicals by neutralising 'free radicals'. The HALS molecule neutralises the formation of free radicals, hindering chemical degradation of the surrounding material, reducing discolouration, and retaining for longer the solubility characteristics of the resin. The inclusion of a HALS results in the stabilisation of the coating and thus a delay in chemical deterioration. HALS molecules are regenerated, rather than consumed, through the stabilisation process.¹⁹

One HALS that has been used in conservation is Tinuvin 292, which has a stabilising reaction that continues to function in the dried varnish film. There is current debate on the inclusion of these materials, as few studies have



Cosmolloid H80 is a modern synthetic wax used to make a varnish more matte.

¹⁹ This process is very different from that of a UV absorber, which sequesters radiant energy. UV absorbers have a much more limited lifespan as they are consumed when energy is absorbed. Varnishes containing UV absorbers do not auto-fluoresce when irradiated with UV light – they appear dark and thus any retouches applied to the paint surface therefore cannot be distinguished. These additives are discouraged by organisers of major art fairs.



Brushed coatings of varnish are applied initially to provide a protective coating before inpainting/retouching, and as a final protective layer.

been carried out to establish their effect on paint layers, however studies carried out on their effectiveness at stabilising the chemical degradation of the resins themselves are very promising.

Application Processes

The application process will also greatly affect the final appearance of a varnish. A varnish applied with a brush can be worked for longer creating a different final effect than a varnish applied with a spray gun. In turn, the brushing out time of the varnish and the distance of the spray gun to the painting will affect the final outcome. The application method is also influenced by the solvent used and the concentration of the resin in the solvent.

It is also important to note that there are different stages of drying within an applied varnish film. During the first few minutes a rapid evaporation of solvent occurs and preliminary levelling of the film occurs. In the following hours, days and weeks, a gradual curing and hardening of the film takes place, and eventually the residual solvent completely evaporates out of the film and paint matrix.

Brushed application of varnishes

Brushed coatings are usually used to provide initial layer(s) directly on top of the paint layer, providing the

desired saturation. The initial, lower layer of varnish is often known as an isolating varnish or separating layer, as it forms a barrier between the original paint layer and subsequent layers of conservation treatment, when the subsequent layers are formed with resins soluble in lower polar solvents than the initial varnish layer. In porous layers, however, they may sink into the paint. Application of coatings by brush may be also used in later layers, provided that lower layers of varnish and inpainting/retouchings are not soluble in the solvents of the varnish being subsequently brushed on. Many studios will not have the potential to spray varnish coatings and so brush varnish application will be their 'go-to' method for varnishing.

Brushes for varnishing are known as 'Spalter'. These are wide, thin brushes, generally with natural hairs such as hog hair or badger hair. Badger hair brushes are generally better quality (and therefore more expensive), with very long, soft hairs.²⁰ The type of hair used is one factor that can influence the final appearance of the coating.

²⁰ Robinson P., *Brush varnishing at the Studio of J.H. Cooke & Sons*, The Picture Restorer, 1995, Nr.8 pp 14–15

The equipment required for varnishing a painting: a wide Spalter, a soft brush for dusting off the surface, a bowl or jar with a wide opening, varnish, a flat, stable surface.



The surface of the painting is first given a dusting with a soft brush, to ensure that the varnish is applied to a clean surface and prevent any remaining dust or other particles becoming entrapped.



A small amount of varnish (enough for the painting) is poured into a bowl or jar with a wide opening.



The lower portion of the spalter is dipped in the varnish.





Excess varnish is removed from the spalter by dabbing it with a lint-free cloth or paper towel.



The varnish is brushed out over the surface of the painting, here first with strokes in a vertical direction.



The varnish is then brushed out with strokes in a horizontal direction.



The painting is checked with lighting from different angles for gloss and saturation.

To obtain an even application, the varnish layer should be applied using systematic brushstrokes. The size of the painting and the orientation of the painting (horizontal, vertical or tilted), as well as a personal preference developed by the conservator over time will influence the pattern of brushstrokes used. It may be beneficial to divide larger paintings into sections and apply varnishes to individual segments, ensuring that varnish to the overlap divisions are applied evenly. Generally, a large brush (wide ferrule) with springy, powerful, high-quality white bristles is ideal for varnishing. The size of the brush will depend on the painting being varnished, with very large paintings requiring brushes up to 150-200 mm wide. Loading the right amount of varnish onto the brush will take practice. When varnishing a larger painting, applying too much varnish to adjoining sections should be avoided.

However, in some cases the paint surface may have differing surface conditions depending on paint zone or condition. In other words, some paints may require more varnish material than other areas to achieve an even

surface appearance after varnishing. In this case, local applications of varnish can be used to enhance saturation and gloss in specific areas before a full varnish coat is applied to the whole surface. Varnishing in this way can be complex as subsequent varnish applications may dissolve and pick-up earlier local areas. Spraying the full coat in these cases may be a work-around.

Health and Safety: Varnishing requires the use of solvents that effectively solubilise the varnish resin for sufficient time for the applied coating to level and form a film. The solvents used have varying degrees of severity for health hazards and the conservator should take adequate precautions before use. Personal Protective Equipment (PPE) should be utilised. This includes a respiration system with the appropriate filter, gloves and protective clothing. Varnishing should take place in a well ventilated area with appropriate air extraction to reduce solvent vapours. The conservator should also inform others working in the studio that varnishing will occur and needs to ensure that they are also protected.



Large paintings may be varnished vertically, in sections. Care should be taken to varnish methodically (in sections) from top to bottom and from one side to the other to ensure an even layer. Image credit: Ivo Hoekstra, Mauritshuis.

Brush Application Method:

- The varnish should be placed in a jar or bowl with a wide opening for ease of access.
- Enough varnish should be placed in the bowl to cover the entire painting. This amount can be added to for larger paintings!
- The lower portion of the brush is then dipped in the varnish and excess removed by wiping and draining the brush against the sides of the jar or bowl. It is also possible to remove excess varnish by wiping it on a lint-free, absorbent paper towel or cloth.
- The varnish is then brushed evenly onto the painting using systematic brushstrokes until the section is entirely saturated.
- The process is repeated for the next section, with the brush being re-dipped and reloaded with varnish. A good tip is not to apply the varnish adjacent to the previously brushed out area, but to apply at a set distance and then work backwards to the section already completed.
- The process is repeated until the surface of the painting is covered with varnish.
- When sufficient brushing time is possible, the varnish may be finished with continuous light strokes over the entire area of the painting, using the same varnish brush. Alternatively, a clean brush can be used to brush out the varnish over the entire surface of the painting.
- In some cases, for instance for panel paintings, a lint-free cloth can be used to apply the varnish or rubbed over the brush coating to moderate the surface finish.

The painting can be brush varnished in different orientations.

- **Horizontal:** This orientation is useful for small to medium sized paintings. The painting lies face up on a table with good lighting. Varnish drips are mitigated by varnishing horizontally, and even pressure over the surface during brushing out is easily achieved. Once varnishing is completed, the painting is placed vertically to off-gas and reduce the amount of dust that may become imbedded in the varnish layer while it hardens. It may be necessary to place a support system below a canvas painting to ensure the pressure of the brush does not push the canvas out of plane. (Slightly) warped panel paintings should never be varnished in a horizontal position.
- **Vertical:** Some conservators prefer to varnish a painting vertically whenever possible as it allows for the conservator to view the painting during varnishing in the orientation in which it will be hung. Sometimes a vertical position is the only option available due to the size of the painting, or the location in which it is held.

Drips may be a problem with varnishing vertically, but this issue may be resolved by varnishing from the top edge of the painting and methodically working toward the bottom edge, and brushing away any drips as soon as they are observed. A vertical position also naturally guards against the possibility of excess varnish building up on the surface.

- **Tilted:** This orientation of the painting may aid in determining the gloss by using raking light on the painted surface.

***Note:** To manipulate the final appearance of the varnish, the varnish can be brushed out for a longer or shorter period.

Tip: Covering a brush with a velvet cloth and buffing the surface of the painting will help reduce its gloss. Other lint-free cloths can be used in a similar manner.

Sprayed application of varnishes

Spray application of a varnish enables good control over the quantity, gloss and uniformity of the resin. The main benefit of spray varnishes is that they may be applied without direct contact with the paint surface, which is crucial for paintings with retouchings, or previously applied varnish layers, that would be disturbed or removed by brush varnishing. Very dilute resin solutions may also be applied to contemporary paintings where an 'unvarnished' finish is required, but the paint layer requires a thin protective fixative or consolidant.

Spray systems depend on compressed or accelerated air flow to draw, atomise and disperse a varnish solution. Electronic compressors compress the air to elevated pressures and are rated for the cubic feet per minute (or CFM). They can deliver at a given pressure per square inch (psi). For most spray applications, an industrial spray gun provides the capacity needed for a variety of varnish techniques. Spray guns require a minimum of 2.5-4.0 cfm or higher and a working pressure of 20-40 psi. The size of the spray head, the needle opening (generally 1.2 or 1.4 mm needle dimension is used), the fineness of atomisation and pattern of spray options will vary the final finish achieved. Many spray systems use a low-pressure, high-volume air flow, warming the air before mixing it with the varnish. Warm air spraying reduces ambient moisture and improves film-forming properties, and the low pressure will generally produce less over-spray. Warming solvents can be dangerous and adequate precautions should be taken. The cost of spray guns with heating capacity increases and many studios may not have this option. As mentioned, in general, sprayed solutions of varnish are more dilute than those used for coatings applied by brush.



A spray gun used for spray application of varnishes. This spray gun is a gravity feed with the cup above the spray gun. Other types include siphon-feed with the cup under the gun and pressure-feed where the varnish is fed to the gun through a hose connected to a separate pressurized pot.

Always pre-test spray settings and solutions on a scrap of cardboard or paper prior to spraying the artwork, to fine-tune the handling and forming of the varnish and to judge a suitable distance for holding the nozzle from the painting.

Spray Application Method:

- Once the correct settings have been found, start spraying next to a far corner of the painting, continuing across the entire surface in an uninterrupted motion. Constant distance is maintained the entire motion, and spraying finishes when the outer edge of the painting has been passed.
- The next spray motion (in an S direction) returns to the starting side, slightly overlapping the parallel stroke of varnish just applied. Spraying continues working horizontally from side to side till the entire surface of the painting is covered.
- For subsequent varnish applications, the spray orientation may be switched to vertical motions to ensure a

uniform distribution over the surface.

- The shape of the spray created by the compressed air should be noted. Some spray guns have outlets at the nozzle that create a 'fan' shape to the spray produced. When spraying horizontally (from left to right), it is beneficial to spray with this 'fan' in a vertical position. When spraying vertically (from up to down), it is beneficial to spray with this 'fan' in a horizontal position.

Tip: Prior to spraying a painting, practise spraying on a large piece of coloured (grey) cardboard using water in the spray gun. Observe the saturation of the cardboard and the size and orientation of the spray 'fan'. Establish the required distance between the spray 'lanes' as you move across the surface.

Tip: To make a sprayed varnish **more matte**, a number of techniques can be used:

- Standing further away increases the mattiness of the final finish of the varnish,
- as does increasing the volume of air in the spray,
- increasing the viscosity of the spray solution,
- using a fast-drying solvent with a higher evaporation rate,
- chilling the spray can, or
- add a small amount of microcrystalline wax.

To increase the gloss of a sprayed varnish, the opposite of the above must be done:

- standing closer to the painting,
- decreasing the amount of air in the spray,
- decreasing the viscosity of the spray solution,
- using a slower-drying solvent with a lower evaporation rate
- warming the spray can, or
- using a viscous solution of pure varnish without additives.

Tip: It is possible to brush the surface of the painting lightly after spray varnishing with a soft, dry badger hair brush to remove excess varnish from the surface and to help create a more uniform effect. This can only be done if the under layers of varnish and retouching are not soluble in the diluent.

***Note:** The ambient conditions of the studio when spray-varnishing will also affect the outcome of the sprayed varnish. On a warm or dry day, the amount of air (cfm) and pressure (psi) must be decreased to allow sufficient film-forming before the solvent evaporates. Conversely, on a cold or humid day, the amount of air (cfm) and pressure (psi) must be increased as otherwise the varnish may dry too slowly.



Equipment required for spraying a painting: Pressurised spray gun with air compressor and hose, low concentration varnish, a large piece of card to practice on and ensure the spray (nozzle) is working as desired.



The lid of the cup is removed and the jar of varnish opened.



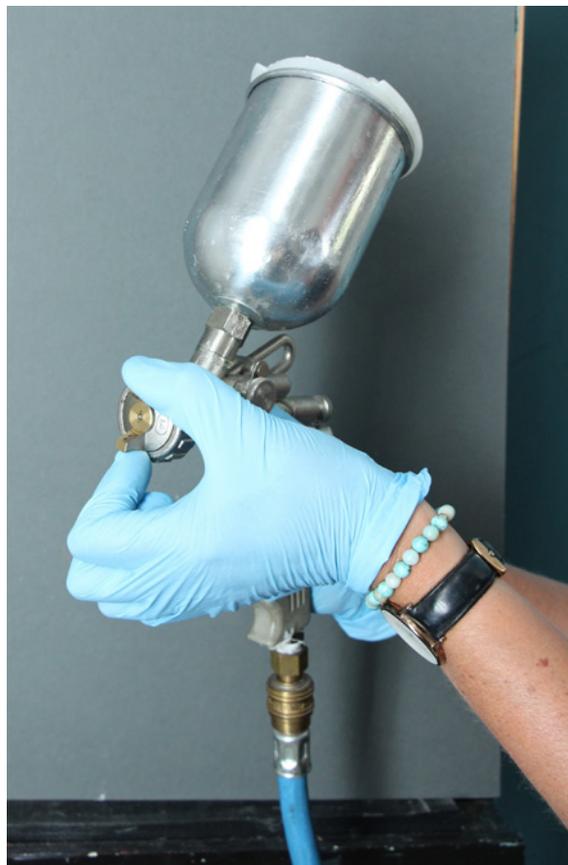
The desired amount of varnish is poured into the cup of the spray gun and the lid placed back firmly. Generally, less varnish is required for spraying than brushing, and more can be added to the cup if required.



It is always wise to test the spray gun and nozzle on a large piece of cardboard prior to the actual painting. A dark cardboard will easily show if the varnish is being applied evenly and that other parameters are correct (distance of spray gun to cardboard, direction of the nozzle, pressure of spray etc.). Here the cardboard is being sprayed from left to right. The spraying is started next to the left edge of the cardboard, then the gun is moved slowly and evenly across the length of the cardboard, and spraying is stopped past the right edge of the cardboard. This avoids an initial blast of spray along the edge, and ensures that an even layer is sprayed across the entire width of the cardboard.



The spray gun should be held upright when spraying, and the gun should sit comfortably in the hand for optimal control.



The nozzle of the spray gun can be adjusted, if necessary, before commencing spraying the painting. It is always wise to check after adjusting the nozzle that the varnish is being sprayed as desired.



Once the settings of the spray gun and air compressor are correct, the varnish can be sprayed onto the painting. Again, it is important to work systematically across the painting to ensure an even layer of varnish, moving either from side to side (as shown here) or from top to bottom. As during the testing on the cardboard, start spraying next to the painting and move evenly and slowly across the artwork in one fluid movement, ensuring that the spray nozzle is held at the same distance from the artwork the entire time. Once the edge of the painting has been reached, move down slightly to apply the next band of varnish.

Wiping or dabbing varnish

Wiping or dabbing on varnish is particularly useful for localised varnishing where a painting has areas that are highly absorbent. This method can also be used on entire painted surfaces, though it is more frequently used on artworks on panel supports. A ball of cotton is wrapped in silk or chamois to make a tampon, and dipped in the varnish. Any excess varnish is gently squeezed out and the varnish is applied by rubbing the tampon over the area with circular motions until the varnish is fully worked into the surface. Alternatively, varnish can be added to a lint-free cloth and gently rubbed over the surface.



A ball of cotton can be wrapped in silk or chamois to make a tampon, to dip in the varnish. Excess varnish is gently squeezed out and the varnish is applied by rubbing the tampon over the area with circular motions until the varnish is fully worked into the surface.

Layering of Varnishes

When treating a painting, varnishes are often applied in several layers. The first layer of varnish, that which is in contact with the paint layer, may be used to even out gloss/matte differences in the paint layer. It can be of a different resin than later applied varnishes. Some conservators prefer to fill any losses in the paint and

substrate layers after applying this coating. Others prefer first to fill any losses, with the reasoning that an even gloss over the surface is more easily achieved when applying the first varnish layer over the original paint layer and fills simultaneously and therefore an easier surface to retouch or inpaint on, and reducing the need to either apply a second varnish layer or coating or separately varnish each fill, sometimes resulting in an uneven effect. The method chosen will depend on the needs of the painting and the conservator's preference.

Depending on the requirements of the painting, several more varnish layers can be applied, to help integrate the variations in gloss and saturation of the original paint layers and retouchings. These may be applied locally or over the entire surface. The final varnish layer, if necessary, should bring the painting together, unifying the gloss and saturation over the surface of the artwork.

Because of the different functions of the different layers of varnishes, different properties are required. Generally, the gloss of the first varnish layer should not be too high, as the addition of subsequent layers of varnish will only increase the gloss and potentially create difficulties in the retouching phase. The first varnish layer should also not sink in to the paint layer too much, meaning that a high MW varnish is more suitable (the higher the molecular weight, the longer the resin chains, which means that the varnish does not 'sink in' as much). The use of a high MW resin can unify the gloss and absorbency of the paint surface, resulting in a more even varnish surface.

As a general rule, it is best to use fresh resins and solvents for varnish mixtures, as dissolved resins degrade. It is a good practice to mix small batches and discard the unused portions periodically. Avoid making stock solutions unless they will be used quickly. A word of caution about stabilising additives: Mixtures with HALS (Hindered Amine Light Stabilisers), such as Tinuvin 292, should be discarded after three months because these stabilisers may be rendered non-functioning in solution. The stabilising reaction of Tinuvin® 292 involves the scavenging of free radicals produced by oxidation processes in a dried resin film.²¹

²¹ When in solution, the promotion of free radicals may be increased and thus the functionality of the HALS will be reduced as the potential to scavenge free radicals is diminished. Unlike UV absorbers, HALS are regenerated rather than consumed during the stabilization process, however, the rate of conversion is insufficient to keep up with the production of free radicals when in solution (or when a coating is exposed to high UV containing radiation for considerable periods).

There has been a great increase in modern resins for varnishes available to conservators since the latter part of the 20th century. Synthetic resins have been used as coatings since the 1930s. Early synthetic polymers, typically high molecular weight (MW), proved difficult to re-dissolve on aging in solvents that would leave paint layers unaffected. The use of early PVAc coatings, and their difficulty in removal, have caused conservators to be cautious when using synthetic polymers as varnishes. However, scientifically approved research into new polymers, developed by industry for coatings and finishes, have given confidence to many conservators to use these resin types, often preferring them to natural resins.

Varnishes used in conservation today can be grouped according to varying categories: High Molecular Weight (MW) resins and low MW resins (known as oligomers), and polydisperse resins. Polydisperse resins contain a non-uniform mixture of (often similar) molecules of different molecular weights. This gives these types of varnishes unique application characteristics, as their film forming ability is influenced by their non-uniform molecular nature. These resin types often can be brushed-out longer giving an ability to 'work' the surface. Dammar (a natural resin) and Laropal A81 (a synthetic aldehyde polymer) are polydisperse.

Synthetic polymers and natural resins used by many conservators fall into these three categories. Materials used for coatings can also be categorised according to the classification of Robert L. Feller: class A (excellent, stable no changes) class B (Intermediate, relatively stable) and class C (unstable and fugitive).²² The resins discussed below are all class A resins, except for dammar, which is a class B resin. The classifications of these materials may be different if used for a different function, such as an adhesive or consolidant.

We will provide here some varnish formulations for some of the common resins used today for picture varnishes.²³

Natural Resins

Dammar

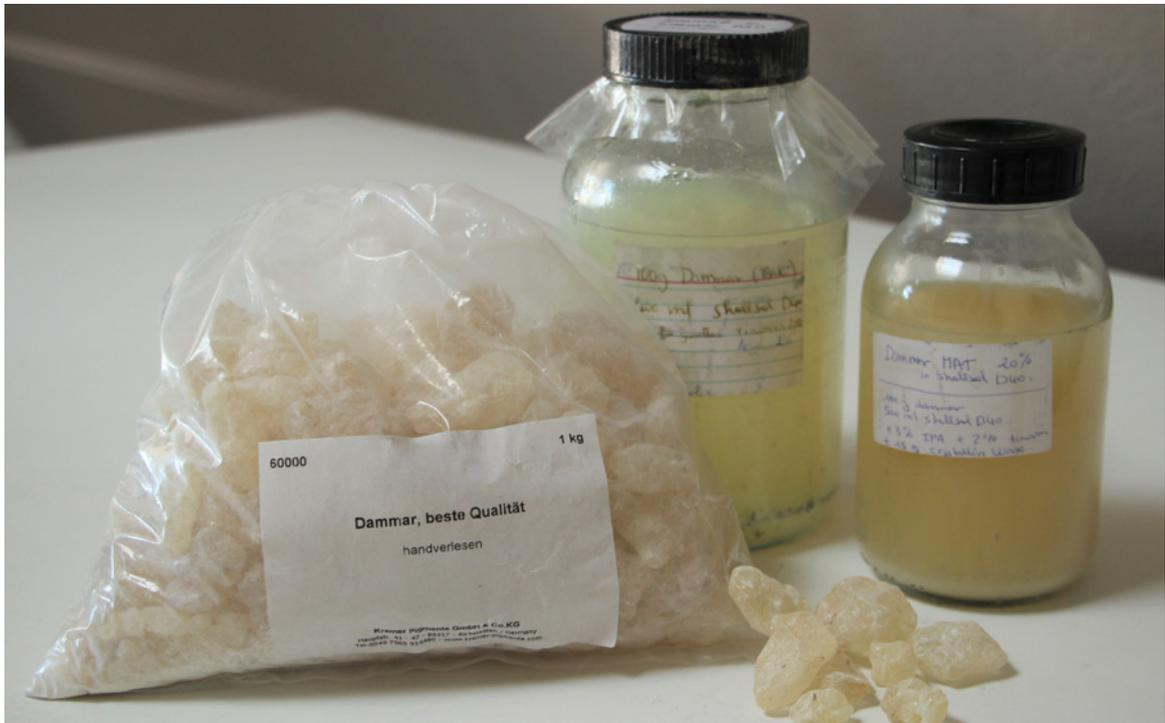
Dammar is a polydisperse - low MW natural resin that many conservators still use today. It was first introduced to western restorers early in the nineteenth century, and quickly became widely popular due to its clarity and gloss. As a natural material, dammar consists of many closely related terpenoid molecules of non-uniform size and molecular weight. There are lower and higher MW polymers and fractions in the average nugget of the dammar resin. The majority of these are triterpenoid molecules (containing 30 carbon atoms in its chain). The dammar (pieces) are extracted from trees in the Dipterocarpoideae subfamily of the Dipterocarpaceae family, consisting of 15 genus and over 400 species of trees. These grow mainly in Asia. It has an average molecular weight of 424-506 g/mol, a refractive index of 1.535-1.538 (when fresh) and a Tg of 67-75° C (See *Comparative Table of Resins*).

Dammar is soluble in many hydrocarbon solvents prior to oxidation, but does require some aromatic content to dissolve fully due to the higher molecular weight fractions. For example, White Spirits with 15-20% aromatic content. It is best to either powder the resin pieces or suspend these in a nylon bag to improve solubility. Dammar should always be filtered after being dissolved in the chosen solvent, as it is a natural resin and will contain some impurities. Some practitioners, especially in Germany, prefer to dissolve only the lower molecular weight fractions as they believe these yellow (and cross-link) less. This theory still requires validation. After dissolving, it may be a little cloudy in the bottle, but the film dries up transparent. It is best to use fresh resin, as an older resin may require a higher polarity solvent to dissolve it. Because dammar is a low MW and low viscosity resin, it is suitable for application by brush or spray. Concentrations of 20-30% can be brushed on, lower concentrations of between 5-15% are more suitable for spraying. Dammar will produce a high gloss finish, but additives or method of application can affect the final finish.

Because it is a natural resin, dammar will oxidise and yellow over time. Aged dammar will become more polar and less soluble. The lifetime of dammar is heavily dependent on the environmental conditions in which it is kept and upon the thickness of the film. Slight discoloration or changes have been noted in the first three months after application. It is therefore not recommended to add a HALS to formulations where the painting is kept in an environment without UV filtering.

²² Feller R.L., *Accelerated Aging: Photochemical and Thermal Aspects* (1994) Ch.1 http://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/aging.pdf

²³ Please consult the AIC Wiki for more information about the history and chemistry of these resins. https://www.conservation-wiki.com/wiki/Varnishes_and_Surface_Coatings:_Introduction



Dammar resin

Thereafter, the shift in polarity and discolouration are noticeable after 25–50 years, depending on storage and exhibition conditions. This leads to paintings being subjected to the ‘varnishing cycle’ as yellowed varnishes are removed around once every generation.

Research lead by René de la Rie, in the late 1980s encouraged the addition of a HALS, such as Tinuvin 292, to dammar varnishes that would be exposed in conditions where the UV content of the exhibiting light was removed. UV radiation from any source breaks down chemical bonds, causing cracking, chalking, colour changes, and degradation of physical properties. De la Rie’s research shows that the inclusion of Tinuvin 292 hindered the ageing of these surface coatings for at least 20–30 years, reducing the ‘necessity’ to remove the discoloured layer.²⁴ Note that these stabilisers do not function effectively in unfiltered UV light conditions. The inclusion of HALS is disputed by some who discourage the inclusion of a highly reactive amine component in a layer in close contact with the paint surface, especially oil and acrylic paints, that maybe chemically altered by these materials. However, the high molecular weight of the HALS means they do not migrate easily and makes them capable of providing extreme long term thermal and light stability.

Recipes

Note: All proportions can be adjusted to modify viscosity

Note: All recipes that contain Tinuvin 292 should be discarded after 3 months

20% Dammar in Shellsol D40/Shellsol A100

20 g Dammar resin
 85 mL Shellsol D40
 15 mL Shellsol A100
 0.6 g Tinuvin 292 (3 % weight of resin;
 approximately 3 drops)
 2.5 mL Isopropanol (Isopropylalcohol)

Mix 50 mL Shellsol D40 and 15 mL Shellsol A100. Dissolve the dammar in the solvent mixture (this can be done by putting the resin in a lint-free porous cloth and suspending in the solvent mixture or by powdering the resin pieces and using a magnetic stirrer). Add an extra 35 mL Shellsol D40 once dissolved. Add 0.6 grams Tinuvin 292 to the solution, and add 2.5 mL of isopropanol. It may be necessary to further strain the varnish solution to remove any impurities. Straining should take place before Tinuvin is added.

²⁴ See the section on Stabilising Additives for further explanation on HALS.

20% Dammar solution in White Spirits

20 g Dammar
 100 mL White Spirits (with 15–20% aromatic content)
 2.5 mL Isopropanol (Isopropylalcohol)
 0.6 g Tinuvin 292 (3 % weight of resin;
 approximately 3 drops

Dissolve 20 grams dammar in 100 mL White Spirits (this can be done by putting the resin in a lint-free porous cloth and suspending it in the solvent or by powdering the resin pieces and using a magnetic stirrer). Add the Isopropanol. It is likely that not all of the resin will dissolve. It may be necessary to strain the varnish solution to remove any impurities. Add 0.6 grams Tinuvin 292 to the varnish, just prior to use.

weight of 630 g/mol, a Tg of 43°C and a Refractive Index of 1.519. Regalrez 1126 has a slightly higher MW than its cousin of 1250 g/mol, a Tg of 67°C and a Refractive Index of 1.519 (See *Comparative Table of Resins*).

Both resins are aliphatic hydrocarbons, and are soluble in aliphatic and low aromatic content solvents such as Shellsol T, Shellsol TD, Shellsol D38 and Shellsol D40, White Spirits and Stoddard solvent. They are and remain insoluble in glycol ethers, glycol ether esters, and alcohols. Both Regalrez resins are highly stable over a long period of time, are reversible in low to medium polarity solvents (but not polar solvents) and do not yellow. Regalrez 1094 produces a high gloss film and saturates well, it is often used as a finishing varnish, often sprayed. It is also useful as a localised varnish for dry or blanched areas of a painting, to bring up the gloss, before the first varnish layer is applied. Because it is insoluble in polar solvents like acetone, ethanol, or isopropanol, inpainting systems that employ the use of alcohol (PVA or Paraloid® B-72) work extremely well on top of this resin. Regalrez 1126 forms a slightly more resistant coating and is often used in furniture conservation as a final layer. Regalrez 1126 is not often used as a varnish coating for easel paintings.

Both resins come as small, clear granules and when dissolved in solvent will produce a clear solution. They do not need to be filtered. Because these are low MW resins,

Synthetic Resins

Regalrez 1094 and 1126

The Regalrez series of resins are relatively new polymer additions in the field of conservation (introduced in the 1990's). These are manufactured by Eastman. They are oligomers consisting of styrene and alpha-methyl styrene. Regalrez 1094 is a low MW resin with a molecular



Regalrez 1094

they can be quite brittle, but the addition of a synthetic rubber, such as Kraton G1650 or Kraton G1657 will improve the scratch resistance of the final varnish film. The addition of 1-3% of rubber to the weight of the resin also increases the viscosity of the varnish solution, and gives a feeling of resistance when the varnish is applied with a brush (closer to the feel of a natural resin). In some instances, the addition of Kraton G rubber to a Regalrez 1094 varnish will prevent the low MW resin from “sinking in”. A matte varnish can be formulated by adding a high MW micro-crystalline wax such as Cosmoloid H80. On panel paintings or pictures with smooth surfaces, it is possible to apply the varnish (also locally) with a cotton ball wrapped in silk (tampon). Tamp the ball on a blotter and rub in small circles for less gloss and good saturation.

Recipes

Note: substitute Regalrez 1094 for 1126 as required

20% Regalrez 1094 in Shellsol D40

20 g Regalrez 1094 resin
100 mL Shellsol D40
0.4 g Tinuvin 292 (2% weight of resin; approximately 2 drops)

Add 20 grams of Regalrez 1094 resin to 100 mL Shellsol D40. When the resin has fully dissolved, add 0.4 grams of Tinuvin 292 (2% to weight of resin).

***Note:** Shellsol D40 can be substituted with Shellsol T or Shellsol TD in this recipe. Shellsol T (BP 179-194°C) has a slower evaporation rate than Shellsol D40. Shellsol T (BP 179-194°C) has an evaporation rate of 0.2. Shellsol D40 (BP 130 - 193°C) has an evaporation rate of 0.9. Shellsol TD (BP 174-187°C) has an evaporation rate of 0.16. (note: evaporation rates are calculated when comparing to nBuAC=1). Using a solvent with a slower evaporation rate will extend the working time allowing further brushing out.

Matte Regalrez 1094 varnish with Cosmoloid 80H wax

20 g Regalrez 1094
100 mL Shellsol D40
2 g Cosmoloid 80H wax (10% to the weight of the resin)
0.4 g Tinuvin 292 (2% to weight of resin; approximately 2 drops)

Add the 20 g Regalrez 1094 resin to the solvent. Once dissolved, add 2 g Cosmoloid 80H wax. Warm the solution in a double boiler with the lid slightly open to allow the wax to fully dissolve. Finally add 0.4 g of Tinuvin 292 when the solution has cooled. The resulting varnish solution will be slightly cloudy. If the wax settles to the bottom you may need to shake the container. Do not rewarm as this will alter the functionality of the Tinuvin 292.

10% Regalrez 1094 in Shellsol D40 with synthetic rubber Kraton G1650

10 g Regalrez 1094 resin
95 mL Shellsol D40 (aliphatic solvent)
0.3 g Kraton G 1650
0.2 g Tinuvin 292 (2% to weight of resin; approximately 1 drop)

Dissolve the Regalrez 1094 resin in the Shellsol D40. When the resin has dissolved, add the Kraton G1650 rubber. Finally add the Tinuvin 292.

***Note:** Kraton® G 1650 comes in the form of a white powder and is of a higher molecular weight than the Kraton® G 1657 which comes in translucent pellets (Kraton Polymers for Coatings). Both of these Kraton® rubbers will dissolve slowly in aliphatic solvents such as Shellsol D40 and Shellsol T. These Kraton® rubbers will dissolve more quickly with the addition of a few percent of an aromatic solvent.

Tinuvin® 292 was added at 2% to the weight of the (combined) resins

Laropal A81

Laropal A81 is a relatively new resin in the field of conservation. In industry it is added to paint to improve hardness, increase gloss and decrease yellowing. Laropal A81 is a urea-aldehyde resin²⁵ which produces a varnish with a high gloss, is characterised by high resistance to ageing (it does not yellow and is stable over time) and has optical properties which are comparable to those of natural resins. Laropal A81 is a low MW resin, with a MW of 1750 g/mol. It has a Refractive Index of 1.503 and a Tg of 49°C (See *Comparative Table of Resins*). Because of its low molecular weight, it has a low viscosity and excellent levelling capacity, which makes it ideal as a finishing varnish and is able to produce a well-saturated, silken finish. The resin comes as semi-transparent beads which produce a clear liquid when dissolved in solvents. Laropal A81 requires approximately 30-40% aromatic content in a solvent to dissolve, and accelerated aging tests show it to still be soluble in low polarity solvents. To increase stability, Laropal A81 does require the addition of Tinuvin 292 (a Hindered Amine Light Stabiliser, HALS). The addition of 2% (to the weight of the resin) to the dissolved resin in solvent is sufficient. Laropal A81 is also an excellent binder for pigments, and is the resin used for

Gamblin Conservation Colours.²⁶ Note that some conservators find that Laropal A81 has a slightly 'cool' appearance, however this is often only noticed by the expert eye.

Recipes

20% Laropal A81 in Shellsol Aoo/Shellsol D4o

20 g Laropal A81
40 mL Shellsol A100²⁷
60 mL Shellsol D4o
0.4 g Tinuvin 292 (2% to weight of resin;
approximately 2 drops)

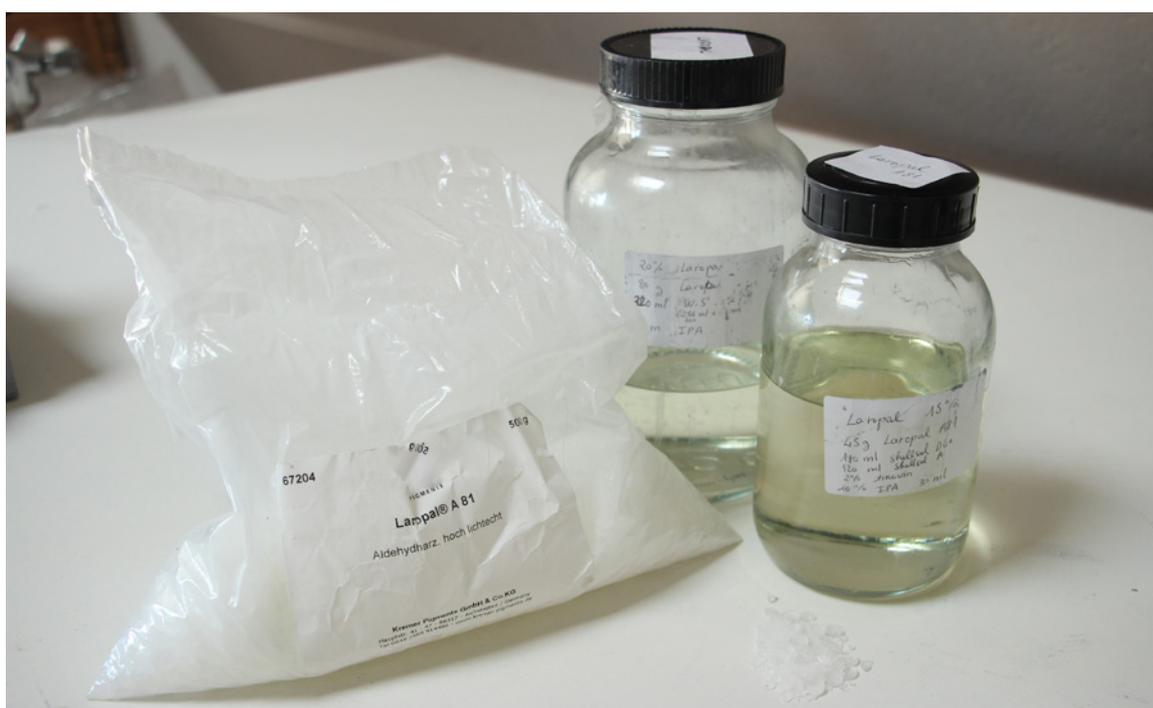
Mix the Shellsol A100 and Shellsol D4o (a ratio of 2:3). Add the 20 grams Laropal A81 to the solvent mixture. Add 0.4g of Tinuvin 292 (2% of the weight of the resin- approx. 2 drops).

Note: some batches of Laropal A81 require a slightly higher percentage of aromatic content to go into solution. If the resin does not dissolve, increase the proportion of the aromatic content by adding more Shellsol A100.

²⁵ Rene de la Rie E., An investigation of the photochemical stability of films of the urea-aldehyde resins Laropal® A 81 and Laropal® A 101, <https://www.icom-cc-publications-online.org/2310/An-investigation-of-the-photochemical-stability-of-films-of-the-urea-aldehyde-resins-Laropal-A-81-and-Laropal-A-101>

²⁶ <https://conservationcolors.com/conservation-colors-21st-century/>

²⁷ In Australia, New Zealand and Singapore Shellsol products are sold under the name Vivasol. So Vivasol A100 is the same as Shellsol A100



Laropal A81

Matte 10% Laropal A81 varnish with Cosmoloid 80H wax

10 g Laropal A81
 40 mL Shellsol A100
 60 mL Shellsol D40
 2 g Cosmoloid 80H wax (10% to the weight of the resin)
 0.4 g Tinuvin 292 (2% to weight of resin; approximately 2 drops)

Mix the Shellsol A100 and Shellsol D40. Add the 10 grams of Laropal A81 resin to the solvent mixture. Once the resin has dissolved, add 2 grams of Cosmoloid 80H wax. Warm the solution in a double boiler with the lid slightly open to allow the wax to fully dissolve. Finally add 0.4 g of Tinuvin 292 when the solution has cooled. The resulting varnish solution will be slightly cloudy. If the wax settles to the bottom you may need to shake the container. Do not rewarm as this will alter the functionality of the Tinuvin 292.

Recent Developments: MS3 (previously MS2A)

MS2A (a polycyclohexanone resin), was extremely popular in the UK and USA as a picture varnish, used as an alternative to natural resins. Developed on recommendations from the museum sector in the late 1950s, it was sold as a picture varnish from 1961 by Howards of Ilford (England). It was prepared by modifying a pre-existing industrial resin MS2 with sodium borohydride to reduce the reactive carbonyl functional groups to less reactive hydroxyl groups on the polymer chain. This resulted in a less brittle, less yellow derivative of the original resin. The formulation of the starting resin, MS2, shifted in the mid-1960s causing the resulting product to be unsuitable for conservation purposes. The formulation was taken up again in the early 1970s by Howards, but again discontinued when Laporte Industries acquired Howards in 1973. Conservators stockpiled MS2A before it went out of production and lobbied Laporte to recommence production. Laporte started to reproduce the resin in 1984, selling on the production rights to Linden Chemicals in 1993. The resin continued to be produced in small batches for another 15 years – and was sold at rather an expensive price through all the major conservation suppliers. The manufacturer of this resin changed over the years, eventually being produced on

demand, but it was discontinued of late²⁸. Linden Chemicals went out of business in 2014, leaving the conservation community up-in-arms without one of its favourite products. The popularity of this resin ensured continued interest and recently an Australian company has taken up the challenge producing a new version named MS3²⁹. Costs remain high due to the small volume produced.

MS2A and MS3 are chemically reduced cyclic ketone resins. MS2A was always produced for conservation purposes, but has unfortunately gone out of production. Recently, MS3 has been developed by CSIRO (Commonwealth Scientific and Industrial Research Organization) in collaboration with leading museums in Australia and Europe, and is available from companies such as Deffner and Johann, but may be considered prohibitively expensive compared to other available resins. MS3 (and its predecessor MS2A) has an average molecular weight of 769 g/mol, a Refractive Index of 1.518 and a Tg of 54-57°C (See *Comparative Table of Resins*). MS3 is a Class A resin: it remains soluble in low aromatic solvents, and is reported not to yellow and is stable over a very long period of time. MS3 comes as small yellow granules which are dissolved in the solvent. Larger pieces can be broken down into smaller pieces to speed the dissolution rate. MS3 is soluble in low aromatic content solvents such as Odourless Minerals Spirits (OMS) ca.1% aromatic content, Stoddard solvent (10-20% aromatic content) or White Spirits (15-20% aromatic content). The downside to MS3 is that it is quite brittle, however a little microcrystalline wax or synthetic rubber (such as Kraton G1650 or Kraton G1657) can be added to reduce this.

Recipes

15% MS3 solution in Shellsol D40

15 g MS3 resin
 100 mL Shellsol D40
 0.4 g Tinuvin 292 (2% weight of resin; approximately 2 drops)

Add the 15 grams of MS3 resin in 100mL Shellsol D40 and dissolve. Add 0.3 grams Tinuvin 292 to the solution when the resin has dissolved.

²⁸ <https://cool.culturalheritage.org/waac/wn/wn22/wn22-2/wn22-206.html> [accessed 15th September 2021]

²⁹ <https://www.csiro.au/en/work-with-us/industries/manufacturing/ms3-resin> [accessed 15th September 2021]

20 % MS3 solution in Stoddard Solvent

20 g MS3 resin
 100 mL Stoddard Solvent (10-20 % aromatic content solvent)
 0.4 g Tinuvin 292 (2% weight of resin; approximately 2 drops)

Add the 20 g MS3 to the solvent and dissolve. Add 0.3 grams Tinuvin 292 to the solution when the resin has dissolved

***Note:** For a basic Spray varnish, adjust the weight of the resin to 5–15% MS3 weight/volume in Stoddard Solvent. So, in 100 mL solvent, 5-15 g of resin. The amount of Tinuvin 292 must then also be adjusted, depending on the weight of the resin.

10% MS3 in White Spirits/Ethyl Acetate with Kraton G rubber (to reduce brittleness)

20 g MS3
 100 mL White spirits (17% aromatic content)
 100 mL Ethyl Acetate
 4 mL Shellsol A100
 1.5 g Kraton G 1650 (rubber) (10% weight of resin)
 0.4 g Tinuvin 292 (2% weight of resin; approximately 2 drops)

Add the different solvents (White Spirits, Ethyl Acetate and Shellsol A100) together. Dissolve the MS3 resin in the solvent mixture. When the resin has fully dissolved, add the Kraton G1650 rubber and finally add the Tinuvin 292.

Matte Varnish for Spray Application

10 g MS3 resin
 100 mL Stoddard Solvent
 1 g Cosmoloid wax 80H

0.2 g Tinuvin 292 (2% weight of resin; approximately 1 drop)

Add the MS3 resin to the solvent. Add Cosmoloid 80H wax. Warm the solution in a double boiler with the lid slightly open to allow the wax to fully dissolve. Finally add 0.4 g of Tinuvin 292 when the solution has cooled. The resulting varnish solution will be slightly cloudy. If the wax settles to the bottom you may need to shake the

container. Do not rewarm as this will alter the functionality of the Tinuvin 292.

High Molecular Weight Resins

Paraloid B72

Paraloid B-72 is a long chain acrylic resin, composed of a 70:30 copolymer of ethyl methacrylate and methyl acrylate. Paraloid B72 is considered one of the most stable varnish resins available in conservation. This is one of the many acrylic resins sold under the name Paraloid (previously called Acryloid in the US) that have been used in conservation as adhesives and coatings since the late 1950s. The methacrylic solution resins were introduced in 1936, and used already since the 1950's in conservation. It is commercially used in many industries. It was manufactured originally by Rohm and Haas, and is now produced by DowDupont Inc. In industry it functions as a flexible ink binder and is included in aerosol spray paint. Paraloid B72 is non-yellowing, and does not require the addition of Tinuvin 292 (a HALS) to stabilise it. As a varnish, it should remain colourless and soluble in the solvents in which it was originally dissolved for over 200 years. In addition to its use as a varnish, Paraloid® B-72 is used in conservation as a consolidant for paint both locally and for overall impregnation of oil paintings and wall paintings. It finds considerable use as an adhesive for glass and ceramics. As it weathers well, it can be used for outdoor surfaces. It is used as an inpainting medium, and is the resin used in Kremer Pigmente Retouching chips.³⁰ It is used in many different conservation disciplines, including wood, stone, and ethnographic objects, glass and ceramics and paper conservation. The dry resin comes in the form of small transparent beads. Paraloid B72 has a molecular weight of 11.397 g/mol, a Refractive Index of 1.487 and a Tg of 40°C (See *Comparative Table of Resins*). It requires 100% aromatic content (or highly polar) solvents to completely dissolve, such as acetone, ethanol, xylene, Shellsol A100 (100% aromatic content) and other high polarity solvents. Paraloid B-72 is considered a medium-hard thermoplastic acrylic resin, and relatively flexible, compared to other resins. The properties of Paraloid B72 (as with any other resin) will vary according to the solvent used to dissolve it. When dissolved in acetone it is more brittle (after evaporation of the solvent) and when dissolved in Xylene is more viscous than when the same percentage of resin is dissolved in Shellsol A100.

³⁰ <https://www.kremer-pigmente.com/en/ready-made-colors/kremer-retouching-chips-in-paraloid-b-72/>



Paraloid B72

Paraloid B-72 is a medium gloss varnish that has the potential for providing good saturation on many paintings, but some conservators find it doesn't provide enough saturation on "Old Master" paintings or those that have a darker tonality, have very damaged paint surfaces, or have been overcleaned.

Paraloid B-72 does not have the levelling properties of low MW resins. It does work well as a first 'isolating layer' of varnish, as most other media and resins can be used on top of it without disturbing the Paraloid B72 underlayer. It is generally applied with a natural bristle brush. Low percentage solutions of Paraloid B-72 sprays are useful for slightly reducing the gloss of lower MW resin films as well. Paraloid B-72 may also be used as a spray over resins which are more likely to retain dirt.

Recipes

10% Paraloid B72 in Shellsol A100

10 grams Paraloid B72
100 mL Shellsol A100

Dissolve the Paraloid B72 in the Shellsol A100 solvent.

Note: Paraloid B72 is quite 'stubborn' at going into solution. The crystals tend to clump together and form a sticky mass. Use a magnetic stirrer to counteract this issue.

***Note:** anything above a 20% solution of Paraloid B72 will be used very rarely, this is quite viscous and really only suitable for paintings which have been treated multiple times (so generally older works of art) and/or where the paint components have been leached, leaving a 'dry' appearance/paint. Generally, a 10-15% concentration provides an excellent saturation, especially of darker paint colours. This concentration is best applied with a brush. Lower concentrations of around 3-5% can be applied by spray gun.

Because Paraloid B72 consists of long-chain molecules, it works very well as the first varnish layer in a multi-layered varnishing approach (other varnishes applied later will not re-dissolve it) and is an excellent base to build up layers of retouching/ inpainting with a variety of mediums.

Low concentration Paraloid B72 varnish, suitable for spray varnishing

5 grams Paraloid B72 in 100ml Shellsol A100

***Note:** Spray solutions: some literature recommends up to 10% resin in solution for spraying, however personal experience has proven this often to be too viscous.

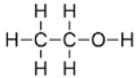
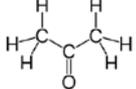
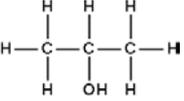
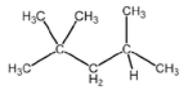
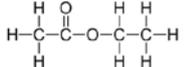
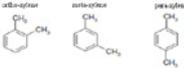
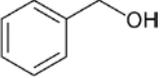
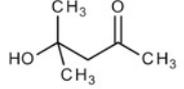
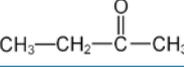
Comparative Table of high and low MW Resins

High Molecular Weight	Low Molecular Weight
Paraloid B72	Regalrez 1094 and 1126
High Aromatic content solvent (99%) required (or highly polar such as ethanol) E.g. Shellsol A100/xylene Relatively matte finish	Low to no aromatic solvent content required E.g. Shellsol D40/Shellsol T/Cyclohexane High gloss finish compared to other varnishes
	Laropal A81
	35-40% Aromatic content required Soluble in aromatics/cyclohexane/acetates/alcohols
	Dammar
	Around 15- 20% aromatic content required Soluble in White Spirits/Stoddard Solvent
	MS3
	Soluble in 15-20% aromatic content (white spirits) Soluble in Shellsol D60, Shellsol D40 (when fresh)

Comparative table of Resins

Resin	Molecular weight (MW)	Refractive Index (RI)	Tg at temperature - Tg (°C)
Dammar	424-506 g/mol	1.535-1.538	67-75
MS3	769 g/mol	1.518	54-57
Regalrez 1094	630 g/mol	1.519	43
Regalrez 1126	1250 g/mol	1.519	67
Laropal A81	1750 g/mol	1.503	49
Paraloid B72	11,397 g/mol	1.487	40

Table 1 Comparison of BP/Evaporation rate and Solvent Properties^{1,2,3}

Name	Classification	Chemical Name (IUPAC) Alternative name CAS	Empirical and Molecular Formulae	Structural Formula	Toxicity: Parts per Million (ppm) TLV (mg/m ³) Acute Oral LD ₅₀ (mg/kg)
Ethanol (95%)	Alcohol	Ethanol Ethyl Alcohol CAS: 64-17-5	CH ₃ CH ₂ OH		PPM: 1000 TLV (mg/m ³): 1880 Acute Oral LD ₅₀ (mg/kg): 10470
Acetone	Ketone	Propane-2-one Propanone Dimethyl Ketone CAS: 67-64-1	CH ₃ COCH ₃		PPM: 750 TLV (mg/m ³): 1780 Acute Oral LD ₅₀ (mg/kg): 5000
Iso-Propanol	Alcohol	Propan-2-ol Isopropyl Alcohol CAS: 67-63-0	C ₃ H ₈ O CH ₃ CH(OH)CH ₃		PPM: 400 TLV (mg/m ³): 983 Acute Oral LD ₅₀ (mg/kg): 5480
Iso-Octane	Aliphatic hydrocarbon	2,2,4-trimethylpentane Pentane CAS: 540-84-1	C ₈ H ₁₈ CH ₃ C(CH ₃) ₂ CH(CH ₃) ₂		PPM: 1000 TLV (mg/m ³): 1450 Acute Oral LD ₅₀ (mg/kg): > 2500
White Spirits (17%)	Hydrocarbon mixture	[generic] Mineral Spirits Turpentine CAS: 64742-82-1	Hydrocarbon mixture (Aliphatic hydrocarbons, alicyclic and alkyl aromatic hydrocarbons)	Mixture Aromatics: c. 17% v/v	PPM: 100-110 TLV (mg/m ³): 560 Acute Oral LD ₅₀ (mg/kg): 5000
Ethyl Acetate	Ester	Acetic Ester Ethyl Ethanoate CAS: 141-78-6	C ₄ H ₈ O ₂ CH ₃ COOC ₂ H ₅		PPM: 400 TLV (mg/m ³): 1440 Acute Oral LD ₅₀ (mg/kg): 4934
Xylene	Aromatic hydrocarbon	Para-xylene 1,4-Xylene 1,4-dimethylbenzene CAS: 116598-94-8 CAS: 1330-20-7	C ₈ H ₁₀ C ₆ H ₄ (CH ₃) ₂		PPM: 100 TLV (mg/m ³): 210 - 434 Acute Oral LD ₅₀ (mg/kg): > 2000
Shellsol D40 (no longer sold)	Naphtha hydrocarbon	Hydrocarbon C ₉ -11 Naptha CAS: 64742-48-9	Mixture of paraffinic and naphthenic hydrocarbons: C ₉ -11	Mixture Aromatics: < 2%	PPM: 150 TLV (mg/m ³): 871 Acute Oral LD ₅₀ (mg/kg): > 5000
Shellsol A (100)	Aromatic hydrocarbon	Aromatic hydrocarbon: C ₉ -C ₁₀ CAS: 64742-95-6	Mixture of aromatic hydrocarbons: C ₉ -C ₁₀	Mixture Aromatics: > 98 % v/v	PPM: 50 TLV (mg/m ³): 150 Acute Oral LD ₅₀ (mg/kg): > 2000
Shellsol T	Isoparaffins - synthetic hydrocarbon	Aliphatic hydrocarbon: C ₁₁ -C ₁₂ CAS: 64741-65-7	Mixture of aliphatic hydrocarbons: C ₁₁ -C ₁₂	Mixture Paraffines: > 98 %m/m Naphthenes: < 2 %m/m Aromatics: 100 mg/kg	PPM: 150 TLV (mg/m ³): not known Acute Oral LD ₅₀ (mg/kg): 15000
Benzyl Alcohol	Aromatic and alcohol	Phenyl methanol Phenylmethanol Benzenemethanol CAS: 100-51-6	C ₇ H ₈ O C ₆ H ₅ CH ₂ OH		PPM: 10 TLV (mg/m ³): 44 Acute Oral LD ₅₀ (mg/kg): 1250
Diacetone Alcohol	Aliphatic hydrocarbons, ketone and alcohol	4-hydroxy-4-methyl-2-pentanone 4-Hydroxy-4-methylpentan-2-one CAS: 123-42-2	C ₆ H ₁₂ O ₂ (CH ₃) ₂ C(OH)CH ₂ COCH ₃		PPM: 50 TLV (mg/m ³): 240 Acute Oral LD ₅₀ (mg/kg): 4000
Methyl Ethyl Ketone	Ketone	2-Butanone Butan-2-one MEK Methyl Acetone Ethyl Methyl Ketone CAS: 78-93-3	C ₄ H ₈ O CH ₃ COCH ₂ CH ₃		PPM: 200 TLV (mg/m ³): 590 Acute Oral LD ₅₀ (mg/kg): 2737

¹ Solvent purity: Reagent grade solvents are sufficient for conservation purposes. When sourcing solvents check for the 'ACS Reagent Grade' or equivalent.

² When handling solvents appropriate gloves should be worn. See: <https://www.osha.gov/sites/default/files/publications/osh43151.pdf>

³ Relevant information was taken from a variety of sources, accessed October 2020. See list beside table. Please check the Safety Data Sheets of each chemical before use.

Table 1 Comparison of BP/Evaporation rate and Solvent Properties^{1,2,3}

Name	Molecular Mass (g/mol)	Boiling Point (°C)	Vapour Pressure (@ 20°C) kPa	Evaporation Rate (BuAc=1)	Hildebrand Solubility Parameter (δ , SI)	Teas Fractional Parameters			Kauri-Butanol Number (solvency)
						Fd	Fp	Fh	
Ethanol (95%)	46.07	78	5.9	2.4	26.5	36	20	44	307.5
Acetone	58.08	56	30	5.6 - 14.4	20	47	32	21	145
Iso-Propanol	60	82-83	4.2 - 6.0	3.9	23.5	41	16	43	232.5
Iso-Octane	112.3	99	5.1	> 1.55	14.3	100	0	0	2.5
White Spirits (17%)	N/A	Range: 150 - 200	Not known	Not known	16.1	77	18	5	36
Ethyl Acetate	88.11	77.1	9.83	4.5 - 6	18.1	56	19	25	97.5
Xylene	108.15	138.4	0.87	0.7	18.2	81	5	14	98
Shellsol D40 (no longer sold)	N/A	Range: 130 - 193	0.17	0.2	15.5	-	-	-	33
Shellsol A (100)	N/A	Range: 165 - 180	0.25	0.16	18.0	-	-	-	90
Shellsol T	N/A	Range: 178 - 191	0.11	0.08	15.1	-	-	-	26
Benzyl Alcohol	108.14	205	13	7	12.32	46	16	36	240
Diacetone Alcohol	116.16	166	0.108	0.12	20	45	24	31	165
Methyl Ethyl Ketone	72.11	80	10.5	4.0	19.3	53	30	17	87

Useful websites:

<https://www.sigmaaldrich.com/NL/en>

<https://www.shell.com/business-customers/chemicals/our-products.html>

<https://pubchem.ncbi.nlm.nih.gov/>

<https://webbook.nist.gov/chemistry/>

<https://www.kremer-pigmente.com/en/shop/solvents-chemicals-additives/>

[http://ws.eastman.com/wizards/esolvents/ESolvProperty.](http://ws.eastman.com/wizards/esolvents/ESolvProperty.asp?Solvent=10069&Property=-1)

[asp?Solvent=10069&Property=-1](http://ws.eastman.com/wizards/esolvents/ESolvProperty.asp?Solvent=10069&Property=-1)

<https://pubs.acs.org/doi/book/10.1021/acsreagents#>

<https://cool.culturalheritage.org/coolaic/sg/bpg/annual/v03/bpgao3-04.pdf>

<https://www.sigmaaldrich.com/chemistry/stockroom-reagents/learning-center/technical-library/solvent-properties.html>

https://www.merckmillipore.com/NL/en/product/msds/MDA_CHEM-808691?Origin=PDP

[http://ws.eastman.com/wizards/esolvents/ESolvProperty.](http://ws.eastman.com/wizards/esolvents/ESolvProperty.asp?Solvent=10069&Property=-1)

[asp?Solvent=10069&Property=-1](http://ws.eastman.com/wizards/esolvents/ESolvProperty.asp?Solvent=10069&Property=-1)

¹ Solvent purity: Regent grade solvents are sufficient for conservation purposes. When sourcing solvents check for the 'ACS Reagent Grade' or equivalent.

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³ Relevant information was taken from a variety of sources, accessed October 2020. See list beside table. Please check the Safety Data Sheets of each chemical before use.

Every hue throughout your work is altered by every touch you add in other places. (John Ruskin, 1819-1900)

Introduction

Deterioration of and damage to the ground and/or paint layers result in losses in and/or abrasion of these layers. These changes to the surface appearance, together with any residual dirt or other unwanted superficial materials, may distort the artist's original image, making the legibility difficult. The conservators' task is to retain the original layers, remove unwanted material safely and restore damages to an acceptable state. The recovery of the aesthetical qualities of the artwork, or restoration of the image, is called inpainting or retouching. The key to this technique is to create the illusion that the damage is not there. Inpainting should be reversible, non-competitive with the original paint layers, and should not conceal or alter the undamaged original paint layers. Inpainting or retouching should be visibly distinguishable from the original image, and should be historically and aesthetically informed. Materials used for this technique should not cause chemical interactions with original materials and should remain chemically stable so that they can be removed easily without damage to the original materials in the future.

There are various types of losses which can be distinguished by their location, size and the number of layers that they penetrate. These are described by Mora, Mora and Phillipot in *Conservation of Wall Paintings* (1984), but can be adapted to paintings conservation.³¹ The different types are:

1. Abrasion of patina (the surface skin), which generally in Western paintings conservation is reintegrated
2. Loss of the top paint layer(s) (which should be reintegrated)
3. Loss of ground and paint layers (which should be filled, textured and reintegrated),
4. Small losses in inconsequential areas (which can be reintegrated without filling)
5. Larger losses in the background (which can be integrated using form, line and colour from the surrounding area)
6. Larger losses in areas of significance (which require filling, texture and reintegration with invention).

A strategy should be devised from the start regarding the extent to which the damage should be retouched. This may be relatively straightforward for some paintings where the areas of loss are easily reintegrated, whereas for others additional research and collaboration with other conservators, curators, owners and living artists is necessary to determine the degree and extent of reintegration. The type of and extent of loss or damage will dictate the degree of retouching required.

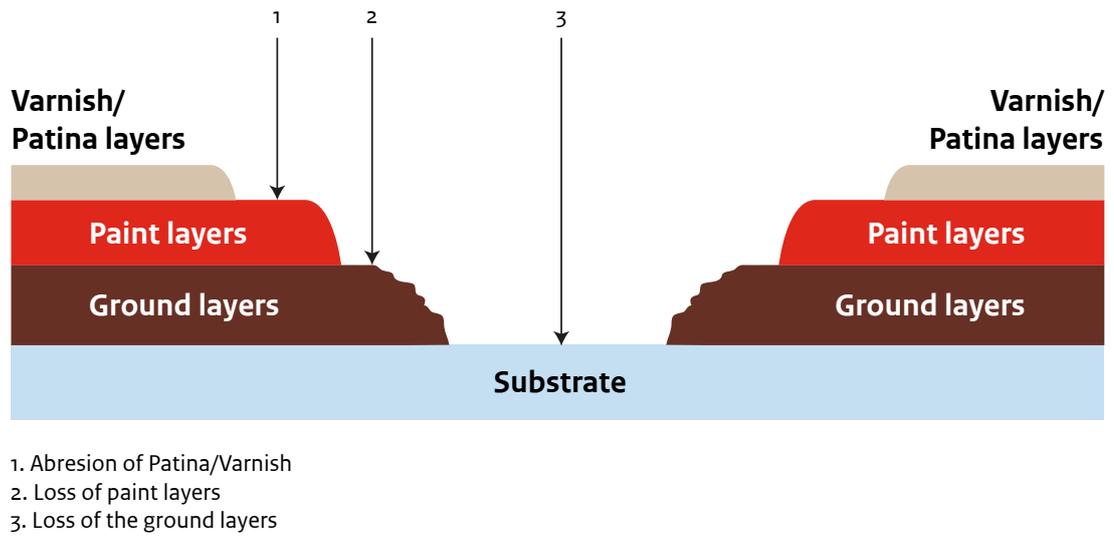
In the case of contemporary works, the artist can be consulted to determine the intention of the work when approaching conservation and restoration of an artwork. Different countries have different laws regarding the extent of the (living) artist's input in any treatment after the artwork has been sold, and these laws will have a deciding influence when there is a conflict of opinions. When possible, the artist's views should be sought and taken into consideration but balanced with those of the owners, conservators and curators managing the collections to which they belong.



The recovery of the aesthetical qualities of the artwork, or restoration of the image, is called inpainting or retouching.

³¹ Mora P., Mora M., Phillipot P., *The Conservation of Wall Paintings*, Butterworths, London&NY, 1984 pp 304-317 <https://vdoc.pub/documents/conservation-of-wall-paintings-3jgrqmo7eicg>

Types of losses according to the depth of damage



The different types of losses according to the depth of damage. Modified from Mora P., Mora M., Phillipot P., *The Conservation of Wall Paintings*.

Inpainting should not be confused with overpainting, which involves the addition of paint layers over original layers, obscuring the original image and often changing the original design or form. The removal of layers of previously applied overpaint may embrace ethical decisions due to their potential historical or creative significance, and should be evaluated prior. These decisions are discussed in the Brochure on *Varnish and Overpaint Removal*.

Prior to inpainting or retouching any losses, it is imperative to accurately document the painting, as this is its true condition.

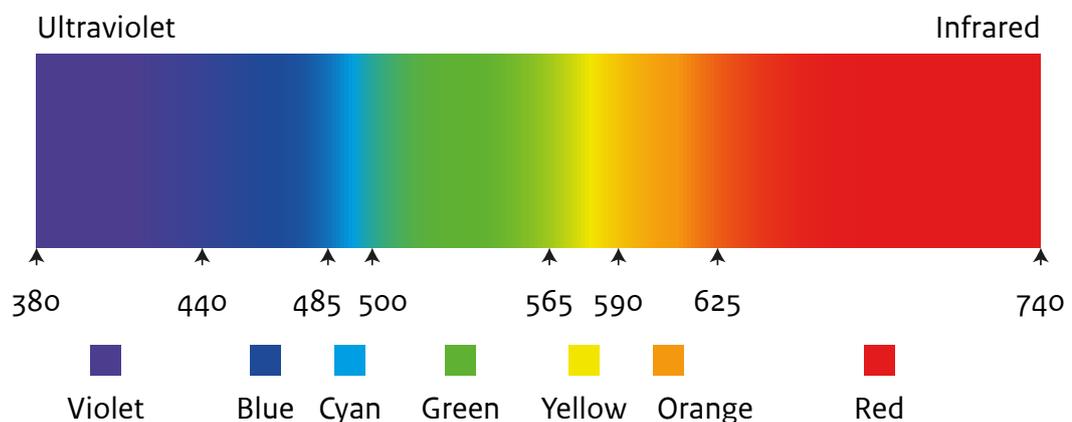
Colour Theory

A good knowledge and understanding of colour properties and mixing of colours is vital to any successful inpainting or retouching campaign. The principles and colour are explained below.

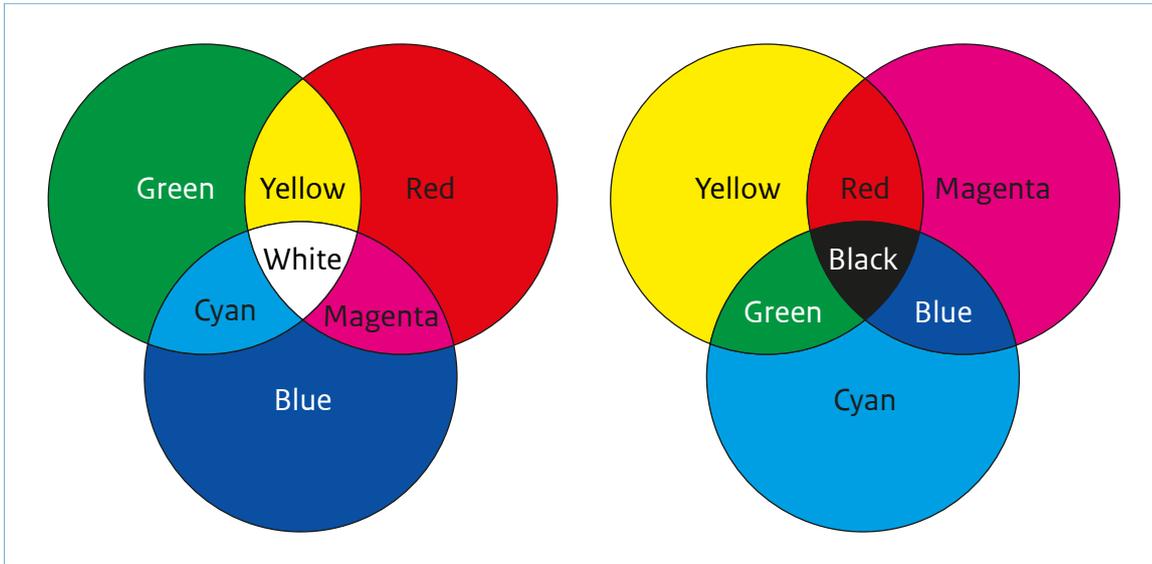
Visible wavelengths of the electromagnetic spectrum can be split into various colours.

Generally, above 750 nm is Infrared Radiation, below 380 nm is Ultraviolet Radiation (this is dependent on the

Visible spectrum



The visible wavelengths of the electromagnetic spectrum.



Additive and Subtractive colour mixing: (Left) The additive mixing of red, green, and blue. (Right) The subtractive mixing of magenta, yellow, and cyan.

individual person's ability to process the wavelengths). The visible spectrum falls there in, with white light being composed of all visible wavelengths (380-750 nm). Coloured objects appear to have a certain colour because they absorb some wavelengths and reflect back the remainder of the light. This is called additive colour theory and is opposed to what happens when paint is mixed. Colour theory is therefore based on two methods of producing colour, additive and subtractive.

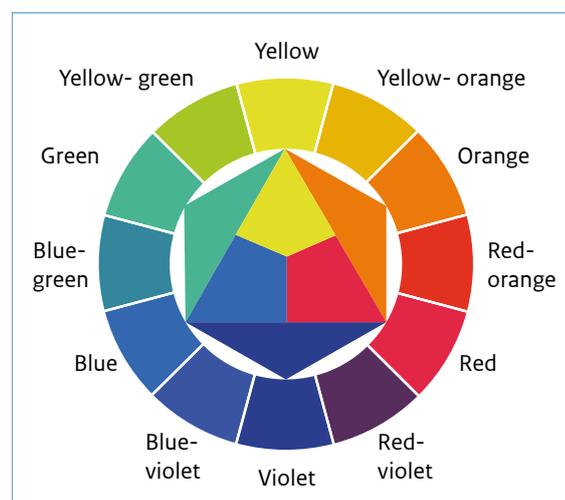
Additive colour involves light emitted directly from a source, and a mixture of all three colours (red, green and blue) gives white light. One set of wavelengths is added to another to produce the new colour. In essence, the additive reproduction process mixes various amounts of red, green and blue light to produce other colours. For example, green and blue to produce cyan, red and green to produce yellow, and blue and red to produce magenta. We 'see' colour because of additive colour mixing taking place before our eyes.

Subtractive colour mixing involves the absorption and selective transmission or reflection of light. In essence, this is the removal of wavelengths from light containing a broad set of wavelengths. It occurs when colorants (such as pigments or dyes) are mixed. For example, a red pigment seen in white light absorbs all the components except red, which it reflects. The subtractive colours are yellow, magenta and cyan (often mistakenly known as red, yellow and blue). When these three are combined they produce black.

Where colour mixing for painting purposes is concerned, the subtractive primary colours are utilised. The 'Circle of Itten', devised by Johannes Itten (1888-1967) demonstrates the structural theory of colours based on their chromatic effect. Itten was a Swiss expressionist

painter and colour theorist associated with the Bauhaus movement. He taught art in Vienna and in Amsterdam, and was greatly influenced by nineteenth century colour theorists such as Johann Wolfgang von Goethe (1749-1832). He taught an innovative 'preliminary course' at the Bauhaus aimed at providing students with the basics of material characteristics, composition, and colour. His colour wheel, colour mixing theories and seven colour contrasts are most useful to the modern conservator learning how to obtain the right hue, shade and transparency of a retouching system.

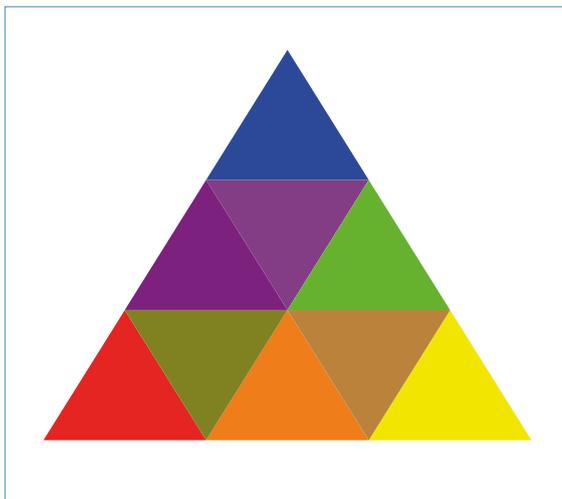
In Itten's colour circle (1961), the three subtractive primary colours are reproduced in the internal equilateral triangle. Mixing two primary colours together arrives at a secondary colour, shown adjacent to the two constituent primary colours in the larger inner triangles.



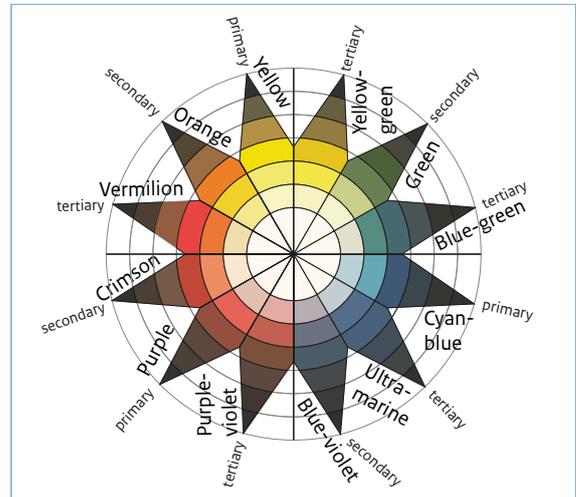
Circle of Itten, 1961. Image source: <http://www.huevaluechroma.com/113.php>

Consequently, the complimentary colour for each of the primary and secondary colours is represented in the triangle directly opposite (for example, yellow is complimentary to violet). The ring surrounding the primary and secondary colours contains tertiary colours which are composed of a primary colour plus a secondary colour. Again, the complimentary colours of each colour are directly opposite (red-violet is the complimentary of yellow-green). The Colour Circle of Itten, then, demonstrates the range of twelve colour hues available by mixing different proportions of primary and secondary colours together. Additional colours can be achieved by mixing two secondary colours together. This range of mixtures produces three brown hues that are similar to the earth pigments available on the artists' palette. It is extremely useful for a conservator to be able to create these brown tones using the three primary colours when colour mixing for retouching purposes.

- Green + orange = yellow brown (raw sienna)
- Green + violet = blue brown (raw umber)
- Orange + violet = red-brown (burnt sienna)



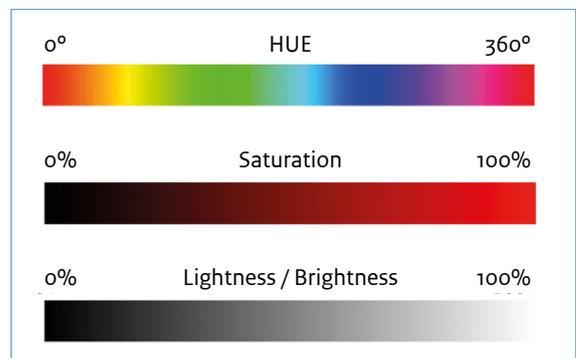
A third range of colours can be achieved by mixing two complementary colours together (positioned opposite on the ring of the Colour Circle of Itten). When mixed, the complementary colours produce a grey-black tonality. Adding white or black to these mixtures will create a series of tints and shades that vary in greyness from cool to warm and can be most useful in recreating flesh tones.



Circle of Itten, 1921. Image source: <http://www.huevaluechroma.com/113.php>

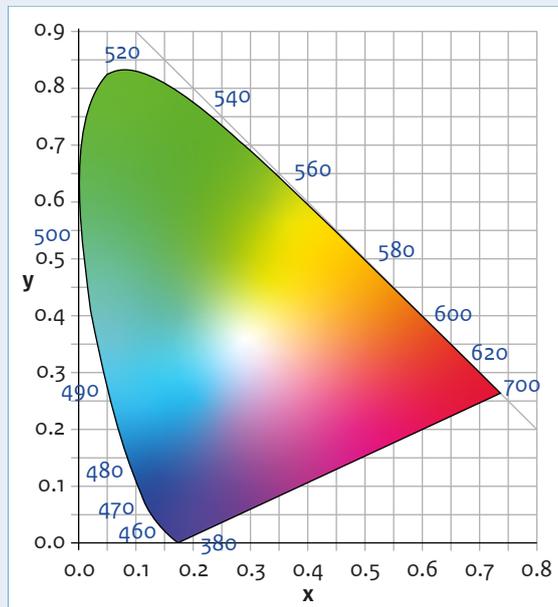
The hues attained through the mixing of various portions of primary colours may aid the conservator during the process of inpainting. In theory, it is possible to attain all the hues needed or inpainting losses in an original paint film from the three primary colours. Generally though, additional hues are added. These reflect the pigments traditionally used by artists, or their modern replacements.

A coloured substance has three attributes: *hue* (the colour of an object as classified in reference to the colour spectrum and its tint), *luminosity or brightness* (the grade of lightness or darkness of the tint) and *saturation* (the degree of luminosity and the purity of the tint). Additionally, the chromatic effect of any colour can be enhanced or weakened by contrast.



Hue, luminosity and saturation.

The **CIE 1931 RGB colour space** and **CIE 1931 XYZ colour space** were created by the International Commission on Illumination (CIE) in 1931.³² The **CIE 1931 colour spaces** are the first defined quantitative links between distributions of wavelengths in the electromagnetic visible spectrum, and physiologically perceived colours in human colour vision. The mathematical relationships that define these colour spaces are essential tools for colour management, important when dealing with colour inks, illuminated displays, and recording devices such as digital cameras. A colour space maps a range of physically produced colours from mixed light, pigments, etc. to an objective description of colour sensations registered in the human eye. The CIE XYZ colour space encompasses all colour sensations that are visible to a person with average eyesight. The CIE colour model is a mapping system that uses tristimulus (a combination of 3 colour values that are close to red/green/blue) values, which are plotted on a 3D space.

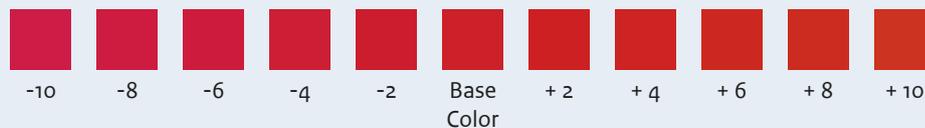


CIE 1931 RGB Colour Space graph.

Terminology:

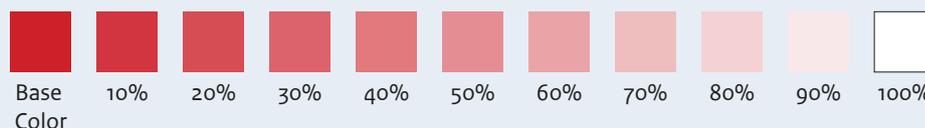
Hue: a hue is one of the main properties of colour. It refers to the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, orange, yellow, green, blue, violet, ie pure colours. In the 1931 CIE colour space, a hue can be represented by a single number. In painting a hue is a pure pigment without a tint or shade (respectively adding white or black).

HUE (Pure Color)



Tint: a tint is a colour (hue) mixed with white. Tints increase in lightness from the pure hue. Adding white may shift the hue towards blue - especially in reds.

TINTS (Hue + White)



³² Smith, Thomas; Guild, John (1931–32). "The C.I.E. colorimetric standards and their use". *Transactions of the Optical Society*. 33 (3): 73–134. doi:10.1088/1475-4878/33/3/301 The CIE 1931 RGB colour space theory is rather complex and will not be explained at length here. For this brochure, it is sufficient to acknowledge its existence and know that it is occasionally used in museums when using a tristimulus colorimeter for colorimetry analysis of paints and paintings.

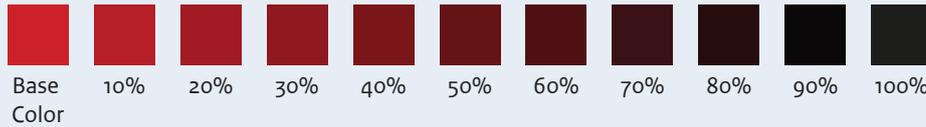
More information can be found here:

Johnston-Feller, Ruth. 2001. *Color Science in the Examination of Museum Objects: Nondestructive Procedures*. Tools for Conservation. Los Angeles, CA: Getty Conservation Institute. http://hdl.handle.net/10020/gci_pubs/color_science and https://en.wikipedia.org/wiki/CIE_1931_color_space



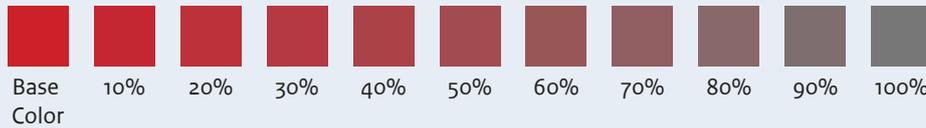
Shade: a shade is a colour (hue) mixed with black. Shades increase in darkness from the pure hue. Adding black may shift the hue towards green – especially in yellows.

SHADES (Hue + Black)

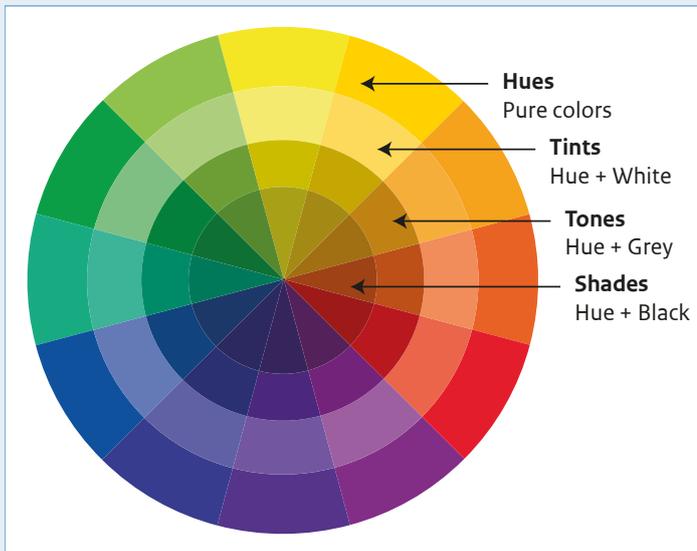


Tone: a tone is created by mixing a colour (hue) with both white and black. This creates neutral colour with reduced chroma.

TONES (Hue + Grey)



Adding the complimentary colour will darken the hue. Adding an adjacent colour on the colour wheel will lighten the hue.



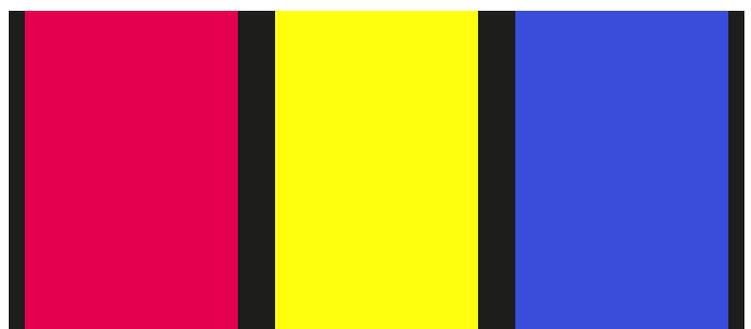
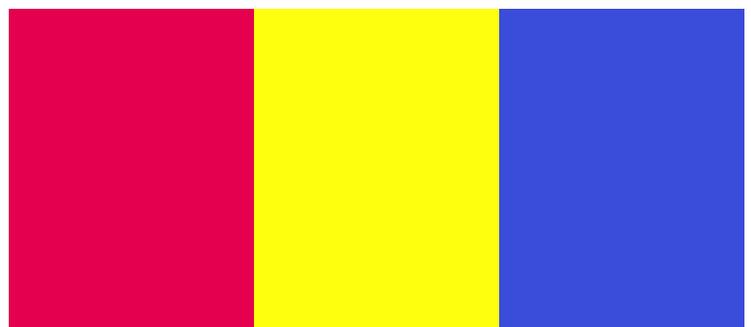
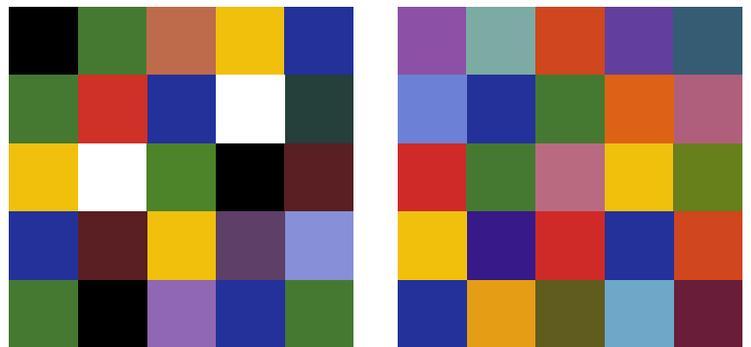
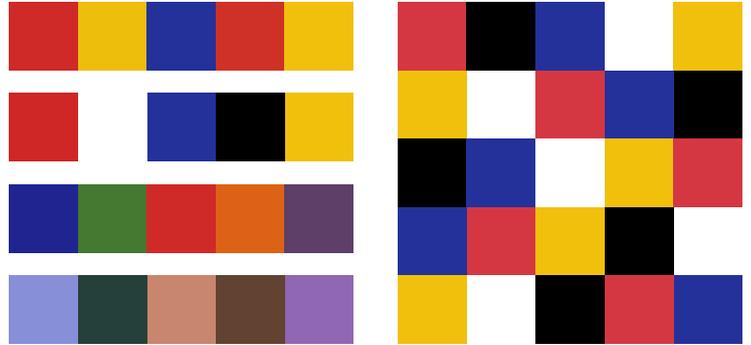
Hue, tint, tone and shade, as illustrated on the colour wheel. Below, one colour, red, has been taken out and gradations of hue, tint, tone and shade are illustrated more fully.

When studying the characteristics and chromatic effects of each colour, Itten described seven distinct types of contrast:³³

The contrast of pure colours

This maximum contrast is achieved by placing the three primary colours side by side. When the colours are separated by white or black lines, the chromatic effect is modified. White lines minimise the luminosity of the colours, resulting in a darkening effect, black lines enhance the luminosity, causing a lightening effect.

Contrast of hue is illustrated by undiluted colours in their most intense luminosity. Some combinations are: yellow/red/blue; red/blue/green; blue/yellow/violet; yellow/green/violet/red; violet/green/blue/orange/black.



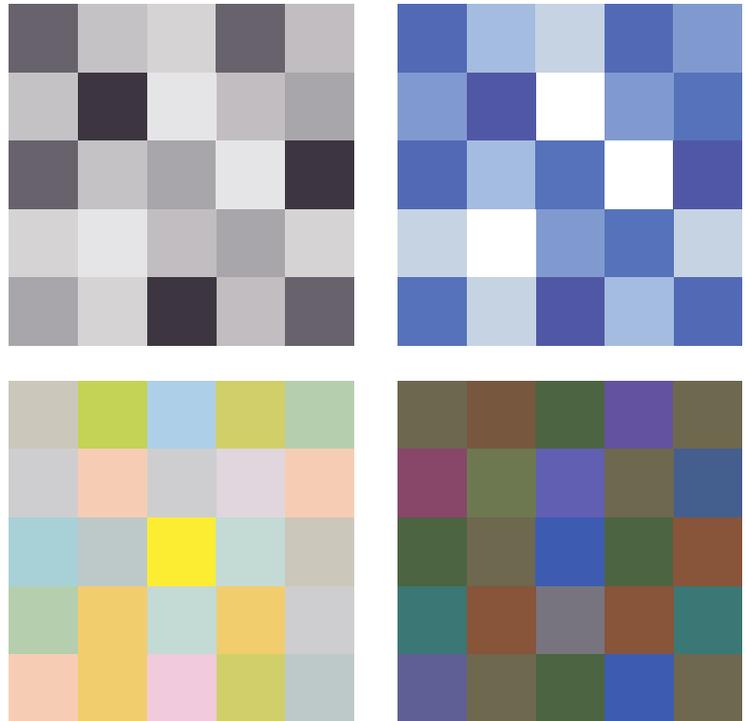
Contrast of Hue

³³ The images used to illustrate this section have been taken from: Itten, J., *The Art of Colour: The subjective experience and objective rationale of colour, The Elements of Colour*, https://monoskop.org/images/4/46/Itten_Johannes_The_Elements_of_Color.pdf

Contrast between light and dark

The maximum contrast is between black and white. White represents the maximum luminosity possible, and black represents the total absence of light. Between these two poles there is an infinite range of greys. The luminosity scale for shades of grey can be implemented in the chromatic scale, where, from yellow to violet, the colours become progressively less luminous. Their luminosity values can be modified by mixing with white or black. The addition of black results in not only the loss of their luminosity value but also their chromatic value. Values of grey can be achieved by mixing the following:
 White + black
 Three primary colours (yellow, magenta, cyan) + white
 Two complementary colours

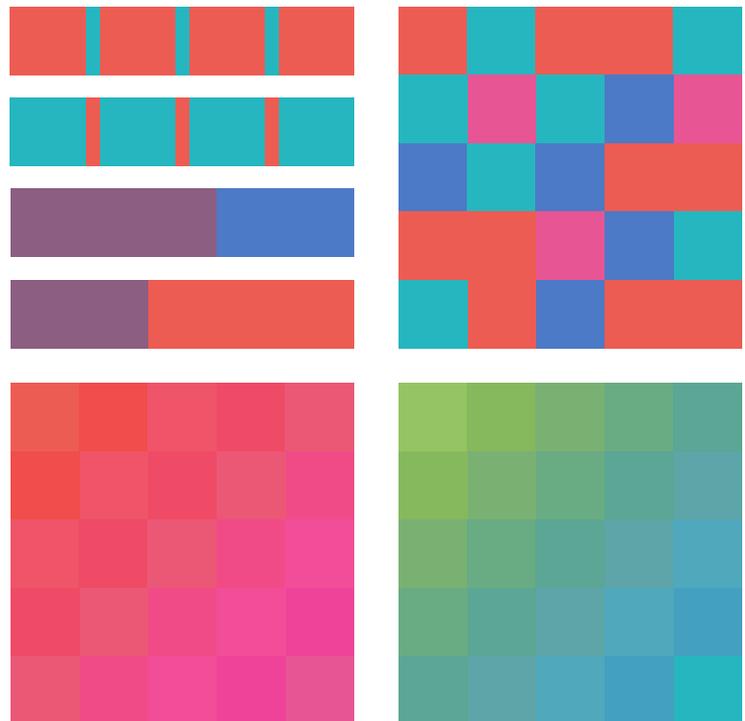
Contrast between light and dark: The painter's strongest expressions of light and dark are white and black. The effects are opposite with the realm of greys and chromatic colours between them. Top left: light-dark composition in black, white and greys, top right: the same composition in blue, below left: colours of equal brilliance, below right: colours of equal darkness.



Contrast between hot and cold

When the Colour Circle of Itten is divided in half along the vertical axis (from yellow to violet) the colours can be divided into two zones. The warm colours on the right (yellow, orange, red) and the cool colours (green, blue, violet). The warmest colour is red-orange, and the coolest is green-blue. These values however are not absolute as the value of hot-cold depends on the contrast between the two colours. Cool colours are more transparent and distant, while warm colours appear denser and nearer to the observer.

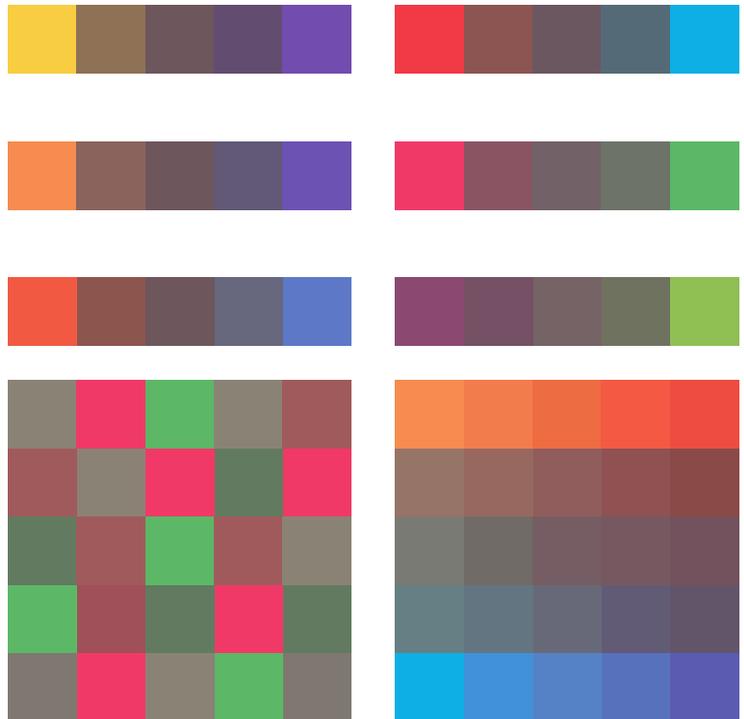
Contrast between hot and cold: The strongest cold-warm contrast is red-orange/ blue green (top left). Below: an inversion of proportions, red-violet seems warm relative to blue, red-violet seems cold relative to orange. Top right: a checker composition contrasting cold-warm colours. Below left: cold-warm modulation in red, below right: cold-warm modulation in green.



Contrast of complementary colours

As mentioned above, when two complementary colours are mixed, they will produce grey. When they are placed next to each other, they reach their maximum luminosity. A complimentary colour exists for every hue. The human eye constantly searches for the complementary colour to the colour it perceives.

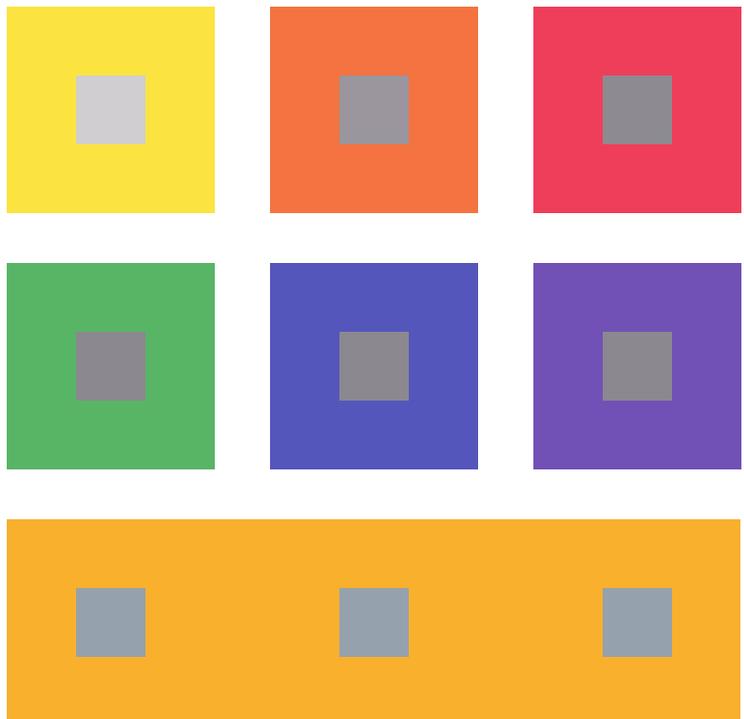
Contrast between complimentary colours: Top left and right: mixtures of six complimentary pairs. Below left: composition in the red-green complimentary pair mixtures, below right: mixture square of two complimentary pairs: orange/blue and red-orange/blue-green.



Contrast of simultaneity

This refers to the way in which two different colours affect each other. The theory is that one colour can change how we perceive the tone and hue of another when the two are placed side by side. The actual colours themselves don't change, but the human eye sees them as altered, as it will search for the complementary colour when subjected to any given colour. Thus, when observing a grey shade next to a pure colour, the eye tends to turn the grey towards the complement of the pure colour. The effect of simultaneity will also occur between two pure colours which are not exactly complementary. In this case, the eye will try to change each of the two colours towards its complementary, resulting in the loss of their true characteristics and luminosity.

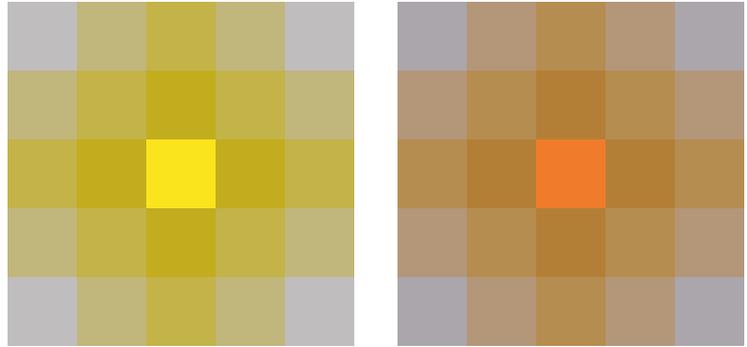
Contrast of simultaneity: the different ways in which colours affect each other. Above and centre row: Each of six pure colour squares contains a small neutral grey square, matching the colour in brilliance. Each grey square seems to be tinted with the complimentary of the background. Below: Three grey squares, surrounded by orange. They are all tinted slightly. The first grey is bluish, and intensifies the simultaneous effect; the second grey is neutral, and suffers simultaneous modification; the third grey contains an admixture of orange, and therefore fails to be modified.



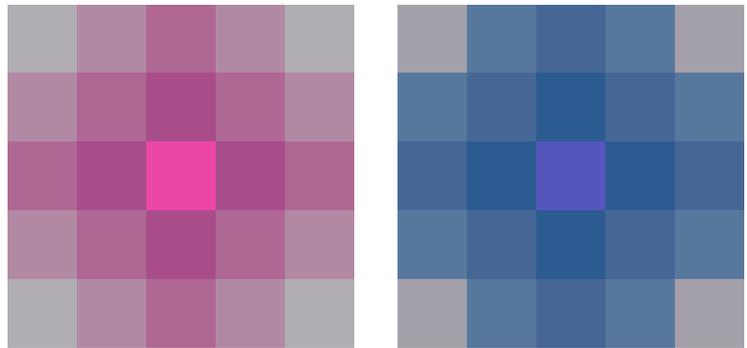
Contrast of quality

in this contrast, the quality refers to the grade of purity or saturation of colour. The contrast of quality concerns the contrast between saturated and mixed colours.

Unsaturated colours may be formed by mixing with white (resulting in a cooling effect), mixing with black (dampening the luminosity) mixing with grey (which 'muddies' the colour) mixing with the complementary colour (which darkens the colour until an achromatic mixture is formed).



Contrast of quality or saturation. The four squares all have a pure colour placed in the centre. The four corners are neutral grey, in the same brilliance as the pure colour. Graded mixtures of grey and pure colour produce the intermediate shades with degrees of saturation.

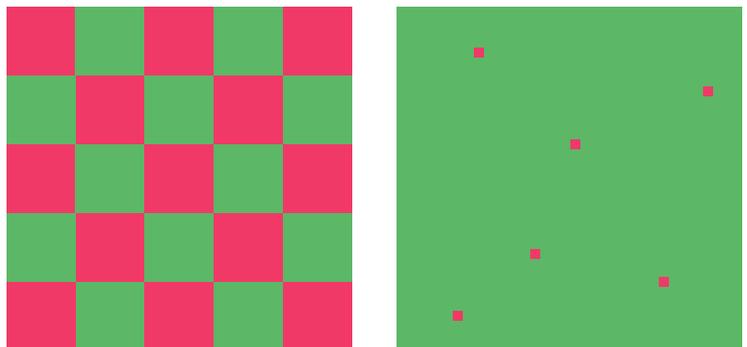


Contrast of quantity

This contrast is based on the quantitative rapport between the surface area and the colour. As every colour possesses a diverse luminosity resulting from the contrast with adjacent colours, by varying the quantity of warm colours (which advance) and cool colours (which recede) can be made to appear at the same distance from the observer. For example, a larger area of yellow (warm) will be compensated by a smaller area of violet (cool).



The principles of colour mixing and contrasts should be taken into account by the conservator during the inpainting process. The perceptive properties of complementary colours have a direct influence on the criteria by which a pictorial restoration is executed. If complementary colours are placed side by side, then the maximum values of intensity and luminosity are reached. The importance of these principles becomes apparent if the conservator has to use more than one pigment to achieve the desired replacement hue.

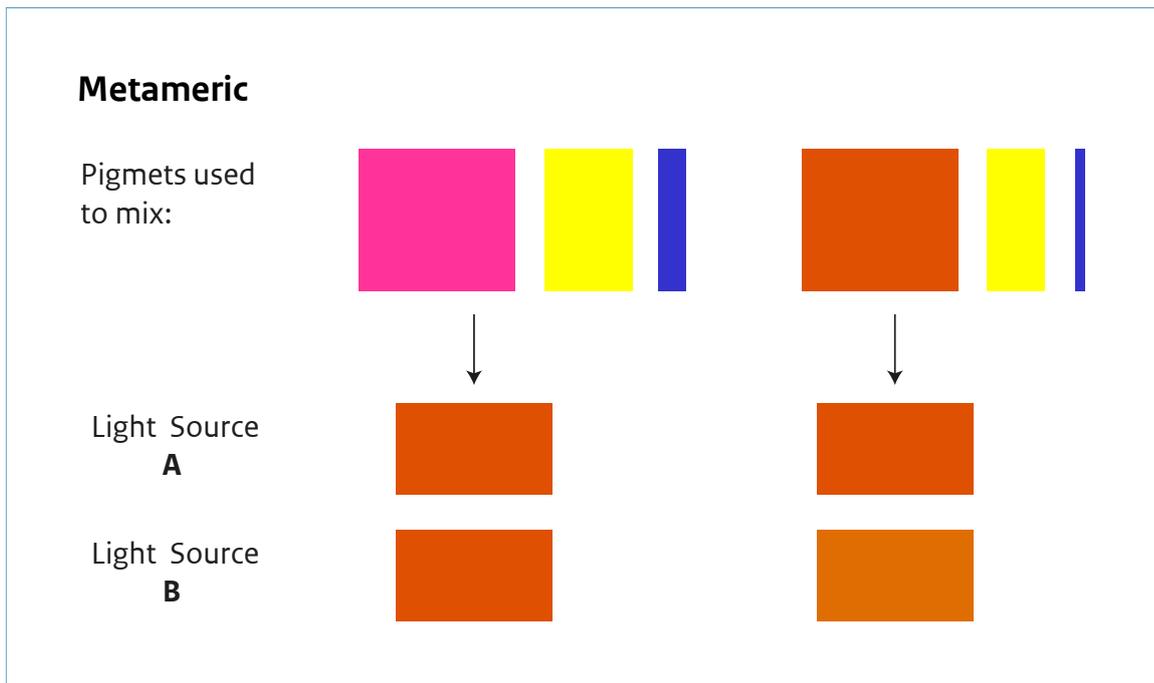


Contrast of quantity or extension. Top left: the harmonious proportions of area for complementary colours are Yellow: Violet= ¼ : ¾, Orange: blue= 1/3 : 2/3, Red: Green= ½ : ½. Top right: the circle of primary and secondary colours in harmonious proportion, bottom left: equal portions of red and green, bottom right: a little red with a large amount of green makes the red highly active.

Metamerism

Colours which match in one set of viewing conditions, but not in another, are said to be metameretic, and the phenomenon is called metamerism. Thus, inpainted areas which match when viewed in daylight may become visible if viewed under artificial light, or when photographed. This phenomenon is particularly applicable to the matching of blue, but also some green,

brown, purple and yellow pigments. Metamerism may occur if modern substitutes for traditional artists' pigments are used when restoring a painting. It can be avoided by choosing modern substitutes with similar spectral reflectance curves to the traditional pigments. For example, ultramarine can be replaced with French ultramarine, and Manganese blue can be used to replace azurite.³⁴



Colours which match in one set of viewing or lighting conditions but not in another, are said to be metameretic, and the phenomenon is called metamerism.

³⁴ Staniforth, S., *Retouching and Colour Matching: The Restorer and Metamerism*, Studies in Conservation, Vol. 30, No. 3 (1985), pp. 101-111

Inpainting Techniques

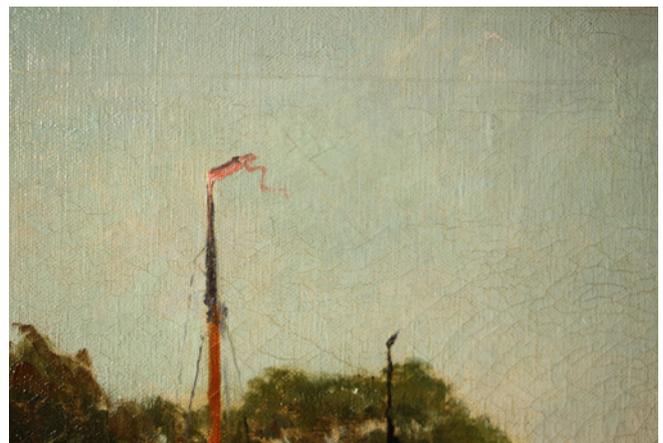
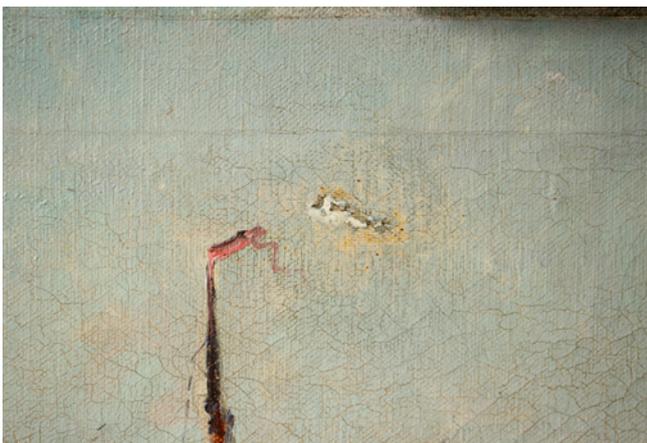
The technique used for inpainting should suit the individual painting and the school of painting from which it derives. There are three main inpainting styles that historically have been used:

Deceptive/Imitative Retouching: Also known as mimetic or fully integrated retouching. The retouching seeks to match the losses to the surrounding areas as perfectly as possible. The inpaintings should always remain distinguishable, although not necessarily in visible light. It may be necessary to use other diagnostic techniques, such as UV light to distinguish the inpainting from the original paint layers.³⁵ Alternatively, it may be necessary to examine the surface with a microscope to distinguish them by their structure. Often, retouching paints bridge

³⁵ Note: this is why it is important not to include a UV blocker in the newly applied varnish

or flow into cracks in the original paint structure and can thus be identified when viewed up close. Furthermore, the pigment particle size of modern pigments is often greatly smaller than pigments created historically.

Visible Retouching: inpaintings may return integrity to the original image whilst remaining consistently and intentionally distinguishable from the original paint film in visible light. This technique is often carried out in Italy where there are two distinct schools of practice – *Tratteggio* and *Rigatini*. Both systems utilise short brushstrokes of pure colour placed adjacent to each other. The eye merges the combination of these colours to a hue that is similar to the original. *Rigatini* (a Roman tradition) is the purer form of this technique and utilises vertical brushstrokes parallel to each other applied in watercolour on a white background. *Tratteggio* (Florentine) is more adaptive – the brushstrokes follow the ductus or form of the original brushstrokes and are slightly hatched. Pure, unmixed colours are used, though the palette may be extended, and the ground may be coloured. Both techniques suit retouching fresco and



Imitative retouching: the retouching seeks to match the losses to the surrounding areas as perfectly as possible.



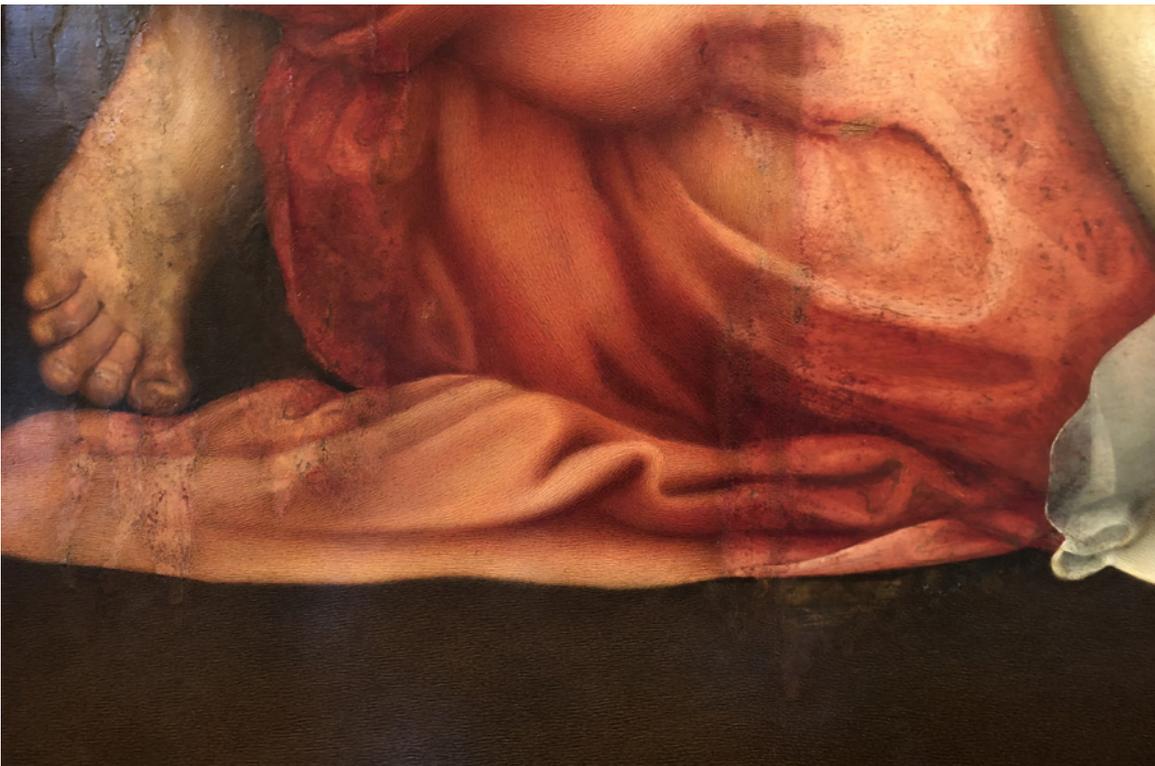
Visible retouching (*tratteggio*): inpaintings may return integrity to the original image whilst remaining consistently and intentionally distinguishable from the original paint film in visible light. Detail of: Sandro Botticelli, *Coronation of the virgin*, ca. 1480, Uffizi Gallery, Florence.

tempera painting styles, but may be discordant with oil painting techniques. This theoretical retouching system is still successfully practiced at *Opificio delle Pietre Dure* (OPD) in Florence and at Istituto Centrale di Roma (ICR in Rome). It is taught in many southern European countries

(Greece, Spain, Portugal) but is not favoured in northern European countries or outside of Europe.

Neutro: commonly used in the 1950's-1970's, this is when the retouching is applied in a uniform colour to achieve a neutral appearance, without any attempt to reinstate the appearance of missing parts, and often used when neither the form nor detail can be reliably reconstructed. The neutral tone is provided by a single layer of the painting's structure and generally complimentary to the local colour. It is clearly distinguishable from the original paint film. The technique is more suitable for two-dimensional images, as no attempt at depth is carried out.

Within these three main styles of retouching/inpainting, there are many gradations of each system that have become popular during previous centuries of restoration, and later conservation, to then be reconsidered, refined, or discarded. Each country also developed its own history and ethics in retouching, with some styles or techniques practiced more widely or for longer than in other countries. For example, suggestive differentiated retouching (*tratteggio*), a type of visible retouching where the retouching provides a general indication of lost form using a variation in either or both colour and shape, but no detail and is perceptible at all viewing



Tratteggio has been used to complete the folds of the garment. Detail of: Fra Bartolomeo, *Pietà*, 1516, Palazzo Pitti, Florence.



Another example of Neutro used to finish the image. Detail of: Giotto Maria Magdalena, ca. 1334, Magdalene Chapel of the Bargello, Florence. Image credit: Kate Seymour (SRAL).



Neutro: the retouching is applied in a uniform colour to achieve a neutral appearance, without any attempt to reinstate the appearance of missing parts, and often used when neither the form nor detail can be reliably reconstructed. Detail of: Paolo Uccello *Creation and Fall*, ca. 1420-1425, Santa Maria Novella, Florence. Image credit: Kate Seymour (SRAL).

distances, started to be used in the late 18th or early 19th century, and gained popularity in many countries, especially Italy, where it was extensively used on frescos and easel paintings.³⁶ In Northern Europe and Northern America, imitative or mimetic retouching is the preferred style of retouching used since the mid-twentieth century.

Retouching Media

'Restoration is a necessary evil' Max Friedlander (1867-1958)³⁷

Any restoration is finite, and will be removed in the future and redone. This is because the original materials and any later additives will deteriorate and age at different speeds, eventually becoming visible, disturbing and hindering the reading of the artwork. With this in mind, it is important that retouching materials fulfil the following criteria:

- They are inert toward the original artwork and materials used;
- They are removable from the remaining original at any time without bringing any harm to it;
- They are reasonably stable and likely to alter chemically and physically as little as possible over time to ensure maximum duration of any restoration, thereby minimising exposure to potential damage or swelling of the paint film through solvent action when the retouching is removed in the future;
- They are compatible with the structure and appearance of the original, with good handling and optical properties;
- They are compatible with other materials used during the treatment such as other layers of retouching, varnishes, fills and consolidation;
- They are familiar to the conservator.

Retouching involves the successful use of pigment, binding medium and diluent. Depending on the requirements of the painting, one of these components may take priority over the others. Pigments selected should be suitable in hue to the period of the painting requiring retouching, stable, and non-toxic. Historical pigments that change chemically or physically should be avoided to prevent retouches becoming visible in the future as the paint alters due to light exposure or alteration. Particle size, shape and behaviour will affect



A conservator's pigment box is often their prized possession.



Pigments can be mixed with various binding media and diluents to create tailormade retouching paints.

the final outcome of the retouching paint; machine ground modern pigments are much finer with regard to particle size than traditional hand ground pigments which may require adjustment for replicating old paint films. Historical pigments may be light sensitive or prone to chemical alteration and thus many are avoided in the modern conservator's pigment box. Pigments selected for retouching should also be chosen to avoid metamerism. For example, on a painting with degraded azurite, metamerism can be avoided by selecting the (synthetic) blue pigment manganese.³⁸

While many paint manufacturers and conservation suppliers will provide a range of pre-made retouching sets, studio formulations where the conservator selects, dissolves and prepares their own paints can be advantageous. The selection of the binding medium will be based on a number of different factors: the choice of varnish coating, the handling of the paint, the degree of gloss/mattness of the required retouching, the solubility

³⁶ Nadolny J., *History of visual compensation for paintings* in: Hill Stoner J., Rushfield R., (eds.) "The Conservation of Easel Paintings" pp 573-585

³⁷ For one discussion on the historical and philosophical aspects of restoration, see: <https://cool.culturalheritage.org/waac/wn/wm19/wm19-1/wm19-108.html>

³⁸ Staniforth S., *Retouching and Colour Matching: The Restorer and Metamerism*, Studies in Conservation Vol. 30, No. 3 (1985), pp. 101-111



The choice of pigment, binding medium and diluent or pre-made retouching medium is dependent on a variety of factors.

of the retouching medium especially in relation to subsequent treatment including varnishing, etc. Transparency and opacity of pigments in different binding media will vary, depending on the refractive index (RI) of the pigment and should be taken into account when selecting both pigment and binding medium.

A wide variety of polymers and resins are available for selection, including water-based systems (watercolour, gouache, acrylic, Aquazol, etc) and solvent-based systems (modern resins for retouching, such as Paraloid B72, Golden PVA retouching paints, Laropal A81, Ketone resin MS3, Regalrez 1094 and 1126). Binding media that discolour on aging and become more insoluble, such as oil paint, should be avoided. The decision to use one or other of these media will be dependent on the selection of other materials, such as for filling losses or varnishing, that are required. The filling, retouching and varnishing material selection (and their dilutants) are inter-dependent upon each other and should be considered as a unity. Note that without a good fill, the retouching will always be visible. For more information on filling and fills, see the brochure on *Filling Losses in Paint*.

For a matte, unvarnished painting, the gloss of the binding medium may be the primary concern. The desired gloss of the retouching medium should match

that of the varnish coating. The gloss of the binding medium can be adjusted by selecting a binding medium that is inherently more matte or glossy, but also by adjusting the ratio of binding medium to the pigment and the diluent.

The diluent, often the solvent used for dissolving the binding medium (resin) in, makes the mixture workable for retouching. When a painting has been varnished, the variety of diluents available may be limited due to the solubility of the varnish. However, when a painting is unvarnished, the medium and diluent chosen is based on which can be safely used without affecting the paint film. The properties of the diluent may affect the working or visual properties of the paint. A diluent with a fast evaporation rate will shorten the working time of the retouching medium and can create a more matte surface, whereas a diluent with a slow evaporation rate will enable a longer working time and the ability to create softer brushstrokes.

In general, adding extra medium to the paint will enable a more transparent layer of retouching with a higher gloss, a higher pigment concentration, the use of more diluent or leaching the medium will result in a more matte retouching.



Water-soluble retouching media (watercolour).

Water-Soluble Retouching Paints: Gum Arabic, Gum Senegal (Watercolour, Gouache)

Commercial watercolour paints are water-soluble and use gum Arabic as a binder. They are available pre-made, but can also be mixed up by the conservator. Watercolours contain the pigment and the binder, whereas Gouache paints also contain an extender which make them opaquer. Watercolour and gouache paints change colour upon drying and/or varnishing, and therefore require some practice before mastering their technique. Because these paints remain soluble in water after drying, they are easily reversible over time, provided the substrate on which they are applied is not sensitive to water. Watercolours are useful for transparent glazing and can be used quite transparently. Gouache colours are essentially matte, opaque watercolours to which extenders or white pigment has been added. They have good coverage and are more suitable where opacity is required. Gouache and watercolours provide a good base colour over a fill, prior to applying an initial varnish coat or a local varnishing over the fill so that subsequent layers of retouching can be undertaken with semi-transparent glazes using other media. Subsequent coats of varnish applied either with a brush or spray will be necessary in most cases. Watercolour and Gouache paint sets can be bought. It is best to avoid using paints that contain more than one pigment. Watercolour paints can be easily made by adding the dissolved medium (gum Arabic) to powder pigments.

Water-Soluble Retouching paints: Cellulose Ethers

Cellulose ethers include methyl cellulose (MC), carboxymethyl cellulose (CMC), hydroxymethyl cellulose (HMC), Methocel A4M (methyl cellulose), Aquacel and hydroxy propyl cellulose (Kluacel G). They are available in a range of molecular weights, viscosities, solubilities and gloss. They are easily reversible with water over time. Cellulose ethers can be dissolved in cold water, but ethanol can be added to adjust the working properties and final finish. Where possible, methyl cellulose should be used, as



Water-soluble retouching media (ethyl cellulose as a binding medium to mix with pigment).

it is more stable than other cellulose ethers. They can provide retouching paints that can vary from highly viscous to watery, and from high gloss to very matte. They are often useful on modern, matte, unvarnished paintings, and for artworks on raw canvas.

Water-Soluble Retouching Paints: Starch- JunFunori

Junfunori is made from Japanese seaweed starch extract. It is often used in consolidation of highly powdery, matte paint and has been found to be very stable. Jun (meaning 'pure') funori is preferable to funori, which contains impurities and may affect the long-term stability of the binding medium. Junfunori provides a very matte paint when mixed with pigments, and is often used for modern works with extremely matte surfaces. Although



Water-soluble retouching media (Junfunori as a binding medium to mix with pigment).

expensive, a very low percentage (0.5-1.5% is sufficient to gain a good viscosity) in water can be used. A few drops of alcohol (such as isopropanol) to the binding medium, when made up, will prevent the binding medium from going off (See: *Appendix* for recipe on making Junfunori).

Acrylic Resins: Paraloid B72, Golden MSA Paints, ArtCare B72 Retouching Gels

Solvent based acrylic resins and paints such as those based on Paraloid B72 are very stable. They dry quite quickly, depending on the diluent used, and remain soluble in hydrocarbon solvents and alcohols (such as ethanol and Shellsol A100). 1-methoxy 2-propanol (Traded under the name Dowanol) has a slower evaporation rate making the working time of Paraloid B72 paints longer. Note that this solvent will swell oil films and should be used only for retouching smaller areas. It should not be used as a varnish diluent! 1-methoxy-2-propanol has a lower MAC value than isopropanol and is therefore more toxic. With practice, layering of acrylic resins is possible. Kremer Pigmente make pre-made palettes and paint chips based on Paraloid B72.³⁹ These have a high pigment volume concentration and can be used over an initial layer of Paraloid B72 varnish. Paraloid B72 paints have little body, so it may be difficult to replicate brushstrokes and impasto with the resin alone. Modification with gelled resins can produce thicker paints that will mimic more thickly bodied original paint layers. Depending on the pigment, Paraloid B72 paints can be highly opaque and have good covering power. Paraloid B72 resin works well with both opaque

³⁹ <https://www.kremer-pigmente.com/en/shop/ready-made-colors/kremer-retouching-chips-in-paraloid-b-72/>



Paraloid B72 pre-mixed sets of retouching colours.



Golden MSA retouching paints.

and translucent pigments, and with enough drying time between layers, layering of Paraloid B72 paints is possible. It is an excellent medium for retouching traditional oil paintings, mimicking the paint well. Golden MSA (mineral spirit acrylic) is soluble in Mineral Spirits.

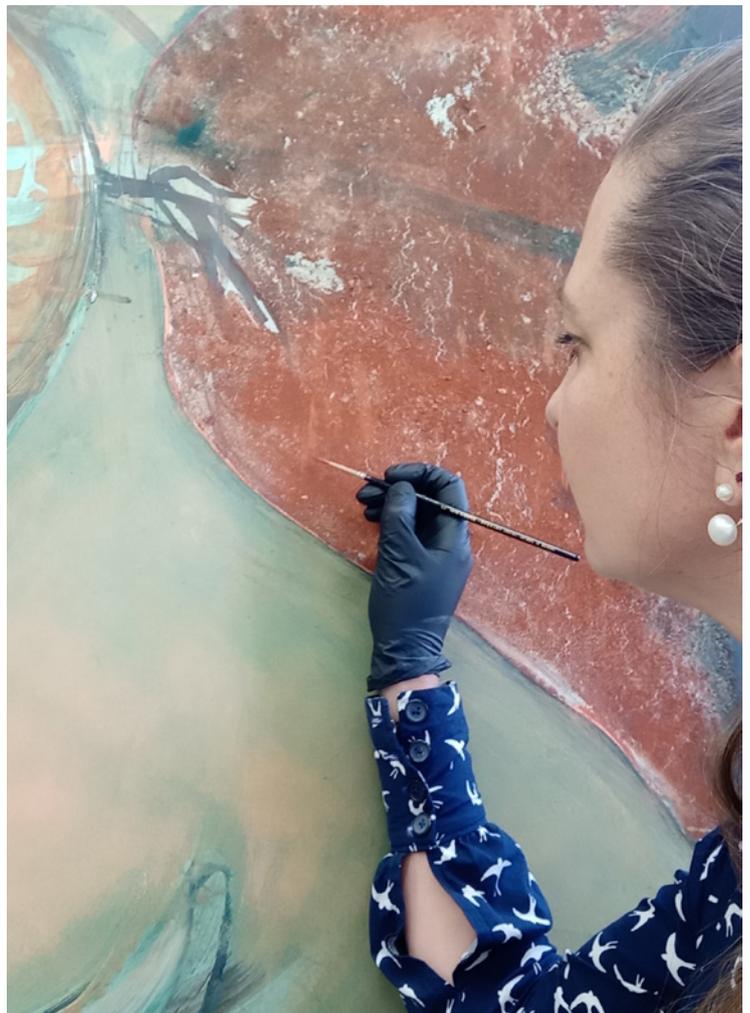
Polyoxazoline: Aquazol, PEOX and QOR (water-based colours)

Poly(2-ethyl-2-oxazoline), also known as PEOX and sold under the name Aquazol, is available in various molecular weight ranges (50, 200 and 500), with the higher numbers (relating to longer molecular chains) being more viscous. Aquazol is the medium used by Golden (USA) in their (new) watercolour brand, called QOR. It is soluble in a variety of solvents, such as water, ethanol, isopropanol and acetone. It is not soluble in hydrocarbons and thus brush varnishes dissolved in aliphatic or aromatic



Aquazol dissolved in either water or an alcohol can be mixed with pigment to create tailored retouching media.

hydrocarbons can be easily applied over retouching in this medium. Its Refractive Index is 1.52 and it has a high glass transition temperature (T_g) of 69°C. Using a lower MW Aquazol and a faster evaporating solvent such as isopropanol, a very matte retouching paint can be achieved that is ideal for modern, matte paint surfaces. Alternatively, using the high molecular weight range resin, combined with a slower evaporating dilutant such as water, can produce a glossy thick paint. Aquazol is useful for retouching acrylic paint films and surfaces with a high wax content, and is one of the few media available compatible with wax. It has also been used very successfully for retouching water gilding areas and tempera paintings. Aquazol appears to be very stable, with deterioration taking the form of decreased molecular weight rather than cross-linking. It can also be easily removed from surfaces using the same dilutants. It can also be mixed with Paraloid B72 dissolved in alcohols



Aquazol can be used to make a very matte retouching medium, here mixed with earth pigments to retouch abraded paint.



Aquazol pieces can be mixed with different solvents to create a matte or glossy binding medium for inpainting or retouching.

or ketones. Aquazol is often also used as a consolidant for matte and underbound paint, and has been successfully used to consolidate and reattach fire-damaged blisters and tenting paint. Pigments or extenders can be added to Aquazol in sufficient quantities to create a putty-like consistency. Losses in paint layers can be filled with this coloured material and if the colour matches the surrounding paint, no subsequent retouching will be required. Furthermore, Aquazol is a good binder for cellulosic materials such as cellulose ethers and Arbocel cellulose fibres.⁴⁰

Recipe for a matte retouching medium using Aquazol:

2.5 grams Aquazol 50
2.5 grams Aquazol 200
100 mL of isopropanol
Add the Aquazol 50 and Aquazol 200 to the isopropanol and stir until dissolved.

This recipe will give a very matte finish when mixed with pigments. Adjusting the amount of pigment (a higher pigment volume concentration) will give a more matte result. You can use water as a diluent or brush cleaner.

Recipe for a moderately glossy retouching medium using Aquazol:

2.5 grams Aquazol 200
2.5 grams Aquazol 500
100 mL isopropanol

Add the Aquazol 200 and Aquazol 500 to the isopropanol and stir until dissolved. This recipe will give a slightly glossy finish when mixed with pigments. Water can be used as a diluent or to clean the brushes.

Note that a 1:1:1 mixture of all three molecular weights dissolved in either ethanol or isopropanol can also be a very useful retouching medium.

Polyvinyl Acetate (PVAc): PVA 20, 30, 50, Lascaux Retouching Medium 20-50 (dispersion), Golden PVA colours, Mowilith 20

PVAc resins come in a wide range of molecular weights. They have been used since their introduction in the late 1930's as a retouching medium. Since the 1950's these resins are available as dispersions in water. Typically, as a retouching medium, the resins are dissolved in solvents, but Lascaux also produces a fluid medium dispersed in acetone, ethanol or butanone. PVA resins have also been used as coatings or consolidants, however from experience as a coating it often results in a plastic appearance and is not recommended and may cross-link on aging.⁴¹ PVAc paints, consisting of lower molecular weight resins, show excellent resistance to discolouration and are easily removable with low toxicity solvents over time such as short-chain alcohols or ketones.⁴² These resins are insoluble in several glycols, hydrocarbons, higher alcohols and water. The paints can be used both for body and glazing and can be alternated with other media such as watercolours or gouache. The downside is that the Tg of many PVAc paints is around 25°C (room temperature), which means that they are prone to dirt pick-up if not covered by a final varnish coating.⁴³ Using mixtures with higher molecular weights reduces this problem. The newer Lascaux Retouching Medium (with a slightly higher molecular weight) has a slightly higher Tg of 30-40°C. The black pigments may also appear more

⁴¹ This is especially true of PVAc coatings, often applied in the 1950's and 1960's as a varnish.

⁴² Modern retouching resins are lower MW PVAc's and have been developed for retouching paints. They differ from PVAc wood glues and earlier vinyl acetates that cross-link on aging and discolour, as these have higher molecular weight components.

⁴³ This is true especially for Mowilith 20 and Golden PVA colours (from experience). Lascaux has a higher Tg and is less prone to softening at room temperature.

⁴⁰ Seymour K., Visser C., Alapont B., Vicente M., *Innovative approaches for the re-integration of fifteenth century Spanish Panel Paintings*, RECH6, Valencia, Spain (2022) http://rechgroup.pt/Programme_rech6.html



Golden PVAc paints pre-mixed retouching colours (image source: <https://www.kremer-pigmente.com/en/shop/ready-made-colors/840800-golden-pva-conservation-paint-set.html>).

greyish when dissolved in PVAc medium, however this can be compensated with the addition of black dyes or inks. PVAc resins are soluble in ethanol, isopropanol and a 50/50 mixture of ethanol/acetone with a few drops of water. PVAc 20 and Lascaux Retouching Medium require some practice to master as a retouching medium, but can give an excellent result. These can be used below brush varnish coatings dissolved in aliphatic or aromatic hydrocarbons.

***Note:** When retouching in conditions with higher humidity, it can become a bit plastic and form long threads on the brush, however, a couple of drops of ethanol added to the diluent will solve this issue.

Urea Aldehyde: Laropal A81, Gamblin Conservation Colours, Kremer Retouching Colours (in Laropal A81)

Gamblin Conservation Colours⁴⁴ (made with Laropal A81 resin) were formulated specifically for conservation, and are stable synthetic resins with handling characteristics similar to natural resin paints. Kremer also sells a set of retouching colours bound in Laropal A81. These paints have a natural gloss when a higher proportion of the medium is used, which is useful for working on traditional oil paintings and is often used over gouache to create layered, translucent surfaces. Urea Aldehyde paints are soluble in alcohols such as isopropanol and 1-methoxy 2-propanol (Dowanol), and can be layered to

create many different effects. Gamblin Conservation Colours are available in pans or small pots; if it hardens in the pot a few drops of isopropanol left overnight will soften the paint enough to be used the following day. Gamblin Conservation Colours, or retouching paints based on Laropal A81, are the preferred retouching medium for many conservators, due to their handling properties, fine pigment particle size and final finish. Laropal A81 retouches can be applied over Laropal A81 varnishes and subsequent brush varnishes are possible if the retouches are allowed to cure well (ca. 3 months), otherwise spray varnishes in the same medium can be applied on top.

New Developments: Ketone Resins: MS3

As mentioned under varnishes, MS3 has recently been formulated by a company in Australia, to replace MS2A, a previous favourite of many conservators in northern Europe. Ketone resins, such as Keton N, MS2, MS2A, Laropal K80 and MS3, require around 20-40% aromatic content in hydrocarbon solvents when fresh, but will require a stronger solvent for removal. There are currently no commercially available paints based on ketone resins and so they require mixing of dry pigment with dissolved resin by the conservator.⁴⁵ Their drying time is relatively short and multiple layers can be built up quickly. They have a similar appearance and gloss like natural resins, and work well for retouching traditional oil

⁴⁴ <https://conservationcolors.com/conservation-colors-21st-century/>

⁴⁵ In the past Kremer has sold retouching media with Laropal K80 as the binding medium, and Maimeri paints were also based on this resin.

paintings. Ketone resins were popular in the past as both a varnish and as a retouching medium, however these resins are more unstable compared to other synthetic resins available and rarely used today. The newly developed MS3 is very pricy, and there are discussions on the long-term viability of producing this resin.

Recipe for a matte retouching medium with MS3:

7.5 grams MS3
 48 mL Shellsol D40
 2 mL Shellsol A100
 0.5 g Kraton G (for a slight amount of gloss and to reduce the rigidity of the resin)

Mix the above until the resin and Kraton G is dissolved in the solvent, then mix with the desired pigments.



Lascaux medium for retouching (image source: <https://www.labshop.nl/lascaux-retouching-medium/>).



Gamblin Conservation colours are based on the synthetic resin Laropal A81 (image source: <https://conservationcolors.com/color-chart-and-composition-of-colors/>).

Layering Varnishes and Resins

While it may be possible to achieve a perfect retouche with a single medium, often a combination of retouching media applied in layers may be necessary to give a satisfactory result, and to help imitate the original build-up of ground and (semi-translucent) paint layers. The medium of each layer should not affect or lift the layer below. Because the solubilities of the resins are different, the following table can be useful as a guide to layering varnishes and retouching media.

Note: Regalrez 1094 and 1126 resins can be used locally on dark colours to help saturate them before an initial layer of varnish is applied. Anecdotal evidence points to the success of this technique. However, recent research (unpublished) has shown that layering Regalrez resins as an initial varnish before inpainting and a final varnish will result in yellowing of the Regalrez layer. Theoretically, Paraloid B72 (when dissolved in acetone/ethanol) can be used over Regalrez, but practically this is very difficult to do.

***Note:** Water-based retouching media can be used on a fill prior to an initial varnish to give an opaque base colour, or a base retouche over which layers of translucent glazing or scumbling can be applied. The upper layers of retouching

can give the colour match required, as well as a sense of depth and patina similar to the original paint layer.

Tips and Tricks

Retouching or inpainting any artwork is not an easy task and takes time and patience. The following tips and tricks can be helpful when approaching what sometimes can be seen as a daunting task.

Tip: The fill needs to be adjusted to ensure the retouching 'disappears'. Efforts should be made to make fills level with, or slightly lower than, the surrounding paint layers, and where necessary to give a texture that will help integrate the retouching with the surrounding texture of the original artwork.

Tip: It is often advantageous to ease into the retouching by focussing first on lesser, more peripheral elements and then working up to the larger, more difficult or central areas of damage. This approach will help the conservator gain a more complete understanding of the painting before advancing to the most demanding areas. Experienced conservators note that this practice allows the painting to lead the conservator, rather than the conservator imposing their notions on the painting.

Initial Varnish	Retouching Medium	Final Varnish
Paraloid B72	• Paraloid B72	• Laropal A81 • Regalrez 1094 • Dammar • MS3
	• Laropal A81 (Gamblin)	• Regalrez 1094 • MS3 • Laropal A81 (brush after some months) or sprayed
	• Golden PVA colours (soluble in white spirits)	• Regalrez 1094 • Dammar • MS3 (as a spray varnish)
Laropal A81	• Laropal A81 (Gamblin)	• Regalrez 1094 • Spray Laropal A81
	• Golden MS3	• Regalrez 1094 • Laropal A81 (brush after some months or sprayed)
MS3	• Laropal A81 (Gamblin)	• Regalrez 1094 • Laropal A81 (sprayed)
	• Golden PVA colours	• Regalrez 1094 • MS3 (sprayed)
Dammar	• Laropal A81 (Gamblin) • Golden PVA colours	• Regalrez 1094 • Laropal A81 (sprayed)

Tip: It is imperative to constantly reassess the overall balance of the painting, as when each damage is retouched, new damages will become visible or jarring, as they are no longer overshadowed by more glaring losses and damages. It is crucial to exercise restraint at all times, as it can be easy to create an imbalance overall. Normal signs of age such as craquelure are intrinsic to works of art, and it is not desirable to totally conceal these with retouching, as this has a potential to misrepresent a painting.

Tip: On unvarnished paintings, or paintings which will be left unvarnished after treatment, it is generally not possible to apply an overall coating of initial varnish. In this case, local varnish can be applied over fills or areas of paint loss prior to retouching.

Tip: It may be beneficial to select an initial varnish that is distinct in solubility from the retouching medium, so that unsuccessful attempts at retouching may be reworked or removed without disturbing the varnish layer. Likewise, it may be beneficial to use an initial varnish and retouching medium that is chemically distinct from the final varnish so that it is potentially removable without disturbing the underlying layers of varnish or retouching.

Tip: The technique utilised may be similar to those used by the artist, employing layering, application and colours analogous to the original (with a different binder for

solubility) or may be optically similar to the original while being structurally different. The painting itself should guide the choice of materials and techniques. Generally, conservators will have preferred techniques and materials, gained through training and experience, however it is essential to have a working knowledge of a variety of options.

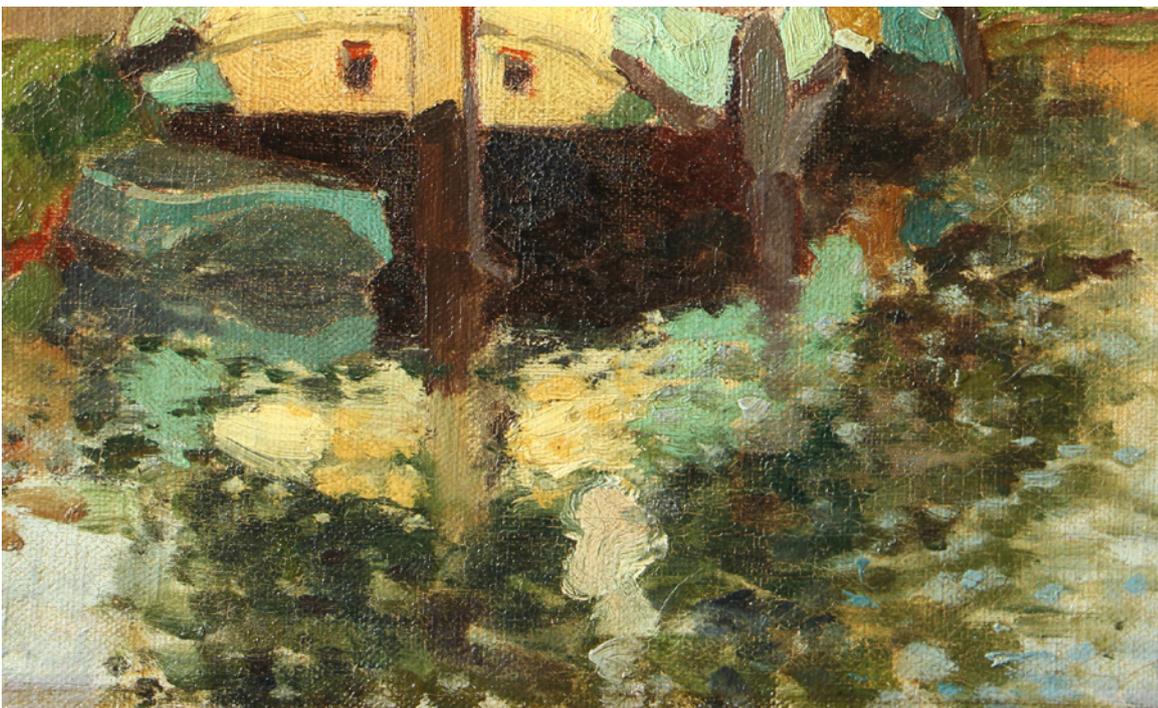
Tip: Rayleigh's law: translucent light colours applied over a dark coating appear cool and blue. Dark cracks or damage in a blue sky (such as in Old Master paintings) can be disguised by using scumbles of white and raw sienna applied to the cracks or damage, making them appear blue.

Tip: It is wise to keep the initial body colour or retouches slightly leaner than the initial varnish. Subsequent layers of retouching will add up to a higher gloss, which may become difficult to reduce at a later stage.

Tip: LIGHTER COOLER BRIGHTER Initial layers of retouching should also be kept lighter and cooler in chroma compared to the surrounding paint. Subsequent warmer glazing colours can be used to finely adjust the colour of the retouche, if necessary. Often the eye will blend cooler and lighter colours into the surrounding area. It is almost impossible to make a retouche that is too warm and too dark cooler and lighter, these become obvious spots, even from a distance.



Before and after retouching. An integrative approach has been taken to the retouching of the damages to the paint layer, which suffered an increase in transparency of the sky, due to a chemical reaction of the acidity in the wood with the oil binding medium in the paint. Paraloid B72 pre-mixed paints were used to retouch this painting.



Before and after retouching. By touching in the abrasion and drying cracks, the legibility of the image is increased.

Tip: When brown paint is found to be difficult to match with earth colours, a mix of cadmium pigments and blues, with black and white may provide a solution. Research shows that Renaissance painters created brown by mixing vermillion, white and black.⁴⁶ A touch of cadmium orange to earth brown pigments when retouching Old Master paintings can be useful if the retouching is found to be flat, or lacks depth of colour.

Tip: Mix black and yellow ochre to create green.

Tip: Solvent dyes are a useful addition to any palette. The solvent black is very useful to add intensity to blacks when Ivory black or Bone black is not found to be dark enough, or when using PVA resins, especially on Old Master paintings. The solvent yellow is useful for adding depth to brown (mix with the solvent red), and also for when it is necessary to imitate a yellowed varnish.⁴⁷

⁴⁶ Dunkerton J., *Retouching with Gamblin Conservation Colours* in: Ellison R., Smithen P., Turnbull R., *Mixing and Matching: Approaches to Retouching Paintings*, 2010, pp 92-100

⁴⁷ Solvent dyes come in powder-form and can be used with any retouching medium. <https://www.kremer-pigmente.com/en/dyes-und-vegetable-color-paints/synthetic-dyes-solvent-soluble-solvent-dyes/solvent-dye/7368/set-solvent-dye>

Appendix

JunFunori:

To dissolve JunFunori in water it has to be warmed and stirred for several hours at a temperature of between 50 and 60°C. JunFunori in solution (1g in 100 mL of deionised water) is a colourless, transparent, water-like odourless consolidant. A solution of 0.5-1.0% has been proven to be best for consolidation. A repeat treatment has also been shown to give better results than a higher

concentration than 1% in solution. The addition of 2% isopropanol (to the solution, so 2 ml in a 100 mL solution) guarantees a longer storage life of the JunFunori, and also acts as a biocide and surfactant to the consolidant solution.⁴⁸ In addition to its use alone, Junfunori® has been combined with sturgeon glue to make a strong, matte consolidant.⁴⁹

⁴⁸ Michel, F., 2011, Funori and JunFunori: Two related consolidant with surprising properties, in *Canadian Conservation Institute Symposium Ottawa*, pp 1-14

⁴⁹ Geiger, T. & Michel, F., 2005 Studies on the polysaccharide JunFunori used to consolidate matte paint, in *Studies in Conservation* 50(3) pp 193-204



Julia van den Burg

Julia van den Burg is a freelance paintings conservator who works in the Netherlands. She graduated from the University of Amsterdam in 2013 with a post-doctoral training in Conservation and Restoration, specialising in paintings. She has gained practical experience working in both the Netherlands and Australia, working on a wide variety of paintings and painted surfaces from all eras, including the ceilings of the Trippenhuis in Amsterdam and the murals of the Fremantle Prison, a UNESCO World Heritage Site. She has worked on various projects together with the Cultural Heritage Agency of the Netherlands, having also compiled the information for the Modern Paint Damage Atlas

(<https://paint.tool.cultureerfgoed.nl/info/background>).



Kate Seymour

Kate Seymour is art historian, conservator and educator. She received her MA Hons in History of Art (Aberdeen University) in 1993 and her MA in Conservation of Easel Paintings (University of Northumbria at Newcastle) in 1999, after completing a three year diploma conservation programme in Florence, Italy. She has worked at the Stichting Restauratie Atelier Limburg (SRAL), Maastricht (the Netherlands) since 1999 as a painting conservator and is currently the Head of Education at this institution. Her position entails working as part of the guest faculty at the University of Amsterdam and University of Maastricht. At the former, she supervises the practical and research work carried out by post-graduate students (paintings) following the Master of Arts Conservation and Restoration of Cultural Heritage, as well as teaching and lecturing on a variety of subjects, both academic and practical, throughout the two year Master of Science in Conservation Studies. For the latter, she also co-organises and teaches modules (FASOS and MSP) aimed at introducing conservation science, including imaging of artworks and pigment sample analysis to Liberal Arts and Science Bachelor students. Additionally, she gives workshops on conservation practice and theory to mid-career conservators internationally. Furthermore, Kate Seymour is currently chair of the ICOM-CC Directory Board (2020-2023).



Klaas Jan van den Berg

Klaas Jan van den Berg is senior scientist at the Cultural Heritage Agency of the Netherlands (RCE) and professor of Conservation Science (Painted Art) at the University of Amsterdam, Faculty of Humanities, Group of Conservation and Restoration of Cultural Heritage. He teaches organic chemistry, technical art history and other chemical aspects of painted art. His main focus is the study of formulations, techniques, material changes and surface cleaning in 20th Century oil paintings. Klaas Jan has written or co-authored over 140 scientific publications has been supervisor of a number of students of both science and conservation background. He organised the Issues in Contemporary Oil Paint symposium in 2013, and the Conference on Modern Oil Paints in 2018, and is editor of their Proceedings (Springer Nature, 2014 and 2019). He was project leader of the HERA-JPI EU project 'Cleaning of Modern Oil Paints'. Klaas Jan is currently leading the 20th Century Cultural Heritage research programme (2021-2023) at RCE.



Lia Gorter

Lia Gorter studied at the Textil Ingenieur Schule, Künstlerische Abteilung, Krefeld, and the University of Amsterdam. She is the director of the Foundation for Cultural Inventory (SCI), Amsterdam, since 1997. SCI digitizes and documents Dutch and Flemish cultural heritage in seldom known museum collections in non-western countries. SCI organizes exhibitions; publishes books and organizes international Masterclasses on preservation and conservation of paintings. The Masterclasses SCI organizes in co-operation with SRAL, the Conservation Institute and the Cultural Heritage Agency of the Netherlands. The SCI works in Russia in the Tretyakov Gallery, Moscow; Siberia with ten Siberian Museums in the Vrubel Museum in Omsk and in Mumbai, India in the Chhatrapati Shivaji Maharaj Vastu Sangrahalaya, CSMVS, the former Prince of Wales Museum.



This is one of a series of six brochures describing various aspects of conservation practice of works of painted art:
The brochures are intended for practicing conservators as well as other professionals involved in the field of painted cultural heritage.

The Cultural Heritage Agency of the Netherlands provides knowledge and advice to give the future a past.