Cultural Heritage Agency
Ministry of Education, Culture and Science

Filling Losses in Paint

Paintings conservation

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Paintings conservation Part 4

The job of the restorer is a most thankless one. In the best case, no one is aware of him... His mastery remains invisible, but his failing becomes evident... Max Friedländer

Filling is .... essential to get it right for the success of invisible inpainting. Helmut Ruheman

... through the interpretation of what is illegible, the original oneness of the work is sought, in order to make it legible again. Cesare Brandi[1]

[1] Restoration should aim to re-establish the potential oneness of the work of art, as long as this is possible without committing artistic or historical forgery, and without erasing every trace of the passage through time of the work of art (Brandi, 2005: 48-50). Brandi states that the work of art is a unique object derived from the unrepeatable singularity of its historical events (sum of the creative moment, the stages of transition in time and the moment of present reception). *https://www.iccrom.org/sites/default/files/publications/2020-05/conversaciones_07_04_madrid_eng.pdf*

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Colophon

Filling Losses in Paint

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Back cover:	Detail of: W. Hoving, *Landscape with Field*, 20th Century, 82 x 93 cm, oil on canvas, before filling a loss in the paint.

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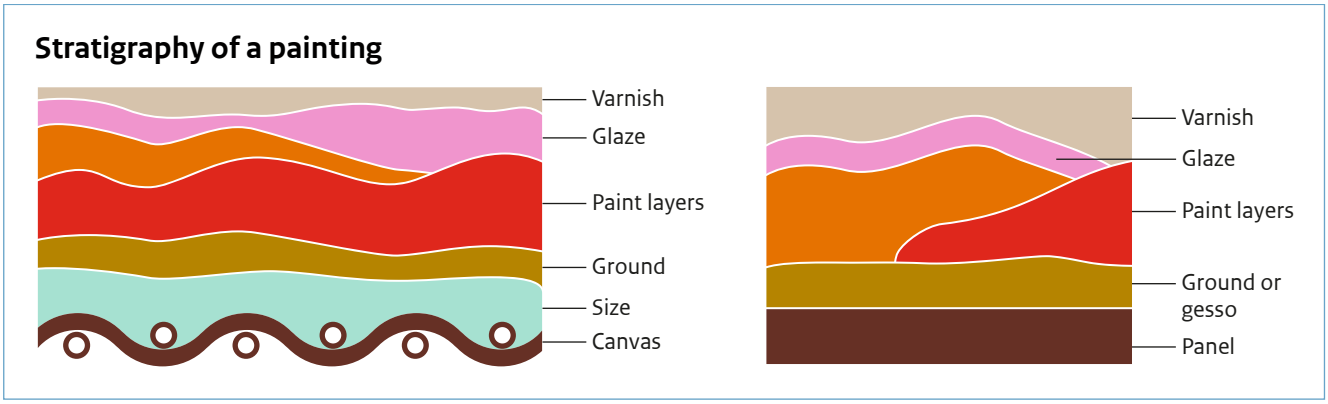
Missing sections in the pictorial image or surface can be disturbing to the viewer, as there is an interruption in the continuity of the image and a topographical discontinuation. Unknown artist, Portrait of a woman, 19th century.

Introduction

A painting is not merely an image on a flat plane, but a complex 3D structure composed of multiple layers of ground, paint and varnish, applied to a support. Damage to the ground and paint layers will invariably occur over time, often resulting in losses to these layers and a consequential textural alteration. Missing sections in the pictorial image or surface can be disturbing to the viewer, as there is an interruption in the continuity of the image and a topographical discontinuation. These disruptions detract from the original intention or context of the artist and greatly affect the viewer's perception of an illusionistic image. The conservator should, therefore, be able to stabilise and repair these losses, using an appropriate material and technique(s). This phase of treatment is part of the reintegration of the image.

Superficial damage to the decorative strata, including the ground layer, may result as an effect of mechanical forces imposed by the support. This leads to flaking and loss of either ground and paint, or paint layers.



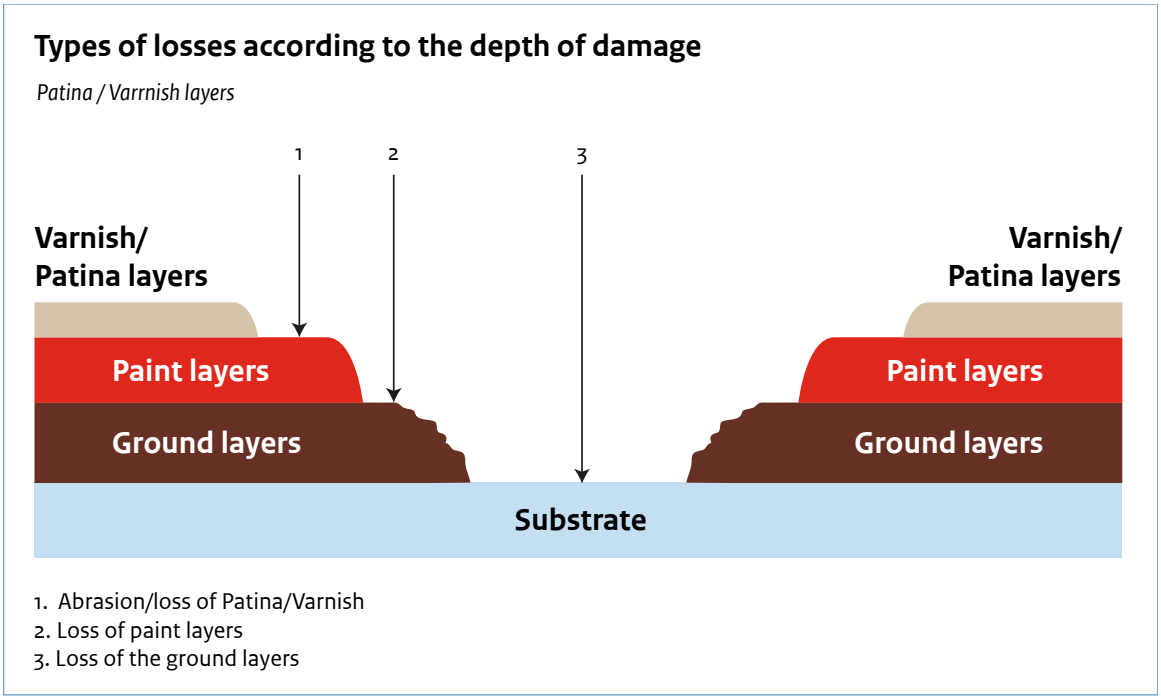
Stratigraphy of a painting

Small, superficial lacunae in paint and ground layers pull the eye of the viewer, distracting from the surrounding image.

Paint formulation defects may cause shear forces to develop, which also initiate in flaking and loss of the superficial layers. Painted surfaces may become knocked or scraped, which result in abrasion or loss to these layers. These damage manifestations may be caused by either natural degradation of the materials in the artwork, by accidental or intentional harm, from transport or from vandalism, improper handling and/or storage. Fills may be used to repair different types of damage found in different layers of the artwork. This brochure will cover the different types of losses found in ground and paint layers on different substrates, historical approaches to and materials for filling, methods for removing old fillings that are no longer suitable, modern types of fills and recipes, some techniques for fillings and applying texture to fillings, and recipes. Note that this brochure will only cover fills that can be applied to lacunae in paint and ground layers. Gaps in panel supports or structural losses to canvases require more robust materials, which are able to resist tensile and shear forces. These will be covered in the brochure on *The Structural Conservation of Canvas and Panels*.

Lacunae

Losses or lacunae in a pictorial image can distract completely from the reading of the image. From a psychological point of view, the loss pulls the eye of the viewer, distracting from the (parts of) the image that remains. This interruption of perception is not only figurative, but also structural. Lacunae result in a loss of structure, which can be perceived when viewed from oblique light angles. Even subtle depressions or disruptions in surface level can be easily discerned and will catch the attention of the viewer, especially as the viewer moves from one viewing position to another. On a figurative level, lacunae disrupt the pattern formed by the image. Lacunae transcend and extend beyond the borders of colour zones or design composition. This disruption in shape, depth and perception causes discord and confusion in the viewer's mind as the sense of illusion created by the artist is interrupted and therefore distorted. If extensive, losses in texture, colour and form can take on a pattern of their own. These patterns can dominate the viewer's experience, causing the viewer to register and remember the loss rather than the intact surface surrounding it. *From the moment that the lacuna is registered in our minds as a foreign element, it ceases to be part of the preparation and becomes a figure on the painting. In fact,*



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

Topographical deormations resulting from old (failed) fillings are visible in this unknown portrait from ca. 1750, drawing attention and distracting from the overall image. Left, the painting seen with raking light, right in daylight conditions. Unknown artist, *Portrait of a Gentleman*. 110 x 88.5 cm, oil on canvas. c. 1750. (Image credit: Kate Seymour)

what is registered is the figure and not the background. The new figure becomes the protagonist and distracts us from the painting, leading to devaluation, relegating it to a background role...[2] in modern art, the intention of the artist can be completely lost.

In order to make a damaged artwork legible again, these disruptions and distortions need to be visibly reduced or removed and integrated into the surrounding area. Filling losses, depressions or hollows, caused by the deficit of original strata, is the first step in reintegration of the image and recreating the illusion and meaning intended by the artist. Once the level and the quality of the surface of the loss is regained, a chromatic reintegration can conceal the filled loss, regaining the sense of continuation of image originally created by the artist.
The art of reintegration is to 'trick' the viewer's eye and sense of perception into believing that no damage or loss has occurred. In effect, the conservator, through reintegration, negates the psychological effect that lacunae impose on the artwork, though without trying to negate the effect of time.[3] The chromatic reintegration has to take into consideration any fading of pigment/paint when colour matching or traces of dirt/varnish left in the hollows of brushstrokes. There is a delicate, subjective balance that the conservator must achieve in order to make the restored artwork legible, but without imposing a sense of 'pristine', which may result from over-restoration.[4] Infrequently, cases are found where retouches are carried out directly without first filling the lacunae. In these instances, the damaged areas of the painting remain distinguishable, especially when viewed from an angle (*see image of the Justice Panel in Maastricht*). Of course, this effect can be intentional, and used to identify areas of inpainting, but if not, the result can be most disturbing.

Fillers

A surface fill, or filler, is essentially a mixture of an inert bulking material and an adhesive binding medium. The bulking agent may be white or pigmented depending on the resultant colour desired. The bulking agent tends to be an inexpensive mineral (powder) used by artists, such as chalk (whiting), gypsum (gesso), or earth pigments.

[2] Agulli, G., Silva, L., Treatment of lacunae, Gestalt psychology and Cesare Brandi. From theory to practice, Bailao, A., Henriques, F., Bidarra, A., (eds.) *International Meeting of Retouching of Cultural Heritage, 2015*, Postprints RECH3 (2015) pp 95-102

[3] A well-documented restoration treatment and study of eye-tracking with regard to losses and readability in a pictorial image has been conducted by the TATE London, for John Martin's *Destruction of Pompeii and Herculaneum* (1821) *https://www.theguardian.com/science/blog/2011/oct/03/vision-science-john-martin-destruction*
MAISEY, Sarah - The conservation of 'The Destruction of Pompeii and Herculaneum' In MYRONE Martin, ed. John Martin: Apocalypse, Tate, 2011 pp. 113-115
Maisey, S, Smithen, P, Vilaro-Soler, A, and Smith, TJ., Recovering from destruction: the conservation, reintegration and perceptual analysis of a flood-damaged painting by John Martin. In ICOM-CC 16th Triennial Conference Lisbon Portugal 19-23 September 2011 Janet Bridgland (ed). Paris: International Council of Museums. https://www.icom-cc-publications-online.org/1160/Recovering-From-Destruction---The-Conservation-of-a-Flood-Damaged-Painting-by-John-Martin

[4] In the brochure *Varnishing and Inpainting*, different types of inpainting materials, techniques and theories are discussed. Imitative inpainting is commonly employed by, for example, conservators in Northern Europe today, but there are also many examples when different techniques are used, such as *neutro*, *tratteggio* or *pointillism*. *https://english.cultureelerfgoed.nl/publications/publications/2022/01/01/varnishing-and-inpainting*

Detail of the *Dual Justice* Panel of the Town Hall in Maastricht, before treatment. Here, losses have been overpainted without prior filling (in the central shield), leaving the areas visible. In this case, they are disturbing, and draw the eye away from the overall depiction. Jan van Brussel, Dual Justice, oil on oak panel, 1475, collection Bonnefanten: long-term loan from the Municipality of Maastricht (image credit: Luuk Hoogstede/Kate Seymour, SRAL).

The binding medium, which may be a single fluid material or consist of a mixture, has the ability to cure into a solid either by solvent evaporation, by cooling, or through chemical reaction. Binders can be water-based adhesives, such as animal glues or gums, resinous materials used for varnishes, shellacs, drying oils, waxes or synthetic resins. Type of binder is dependent on the period of history in which it was used, the region or country, local traditions and type of painting and support. The filler needs to be fluid or paste-like for application, but forms a solid material on curing. The solid fill should be able to resist the mechanical-physical forces imposed by the original support and paint layers as they respond to environmental conditions. Thus, different types of additives can be added to a fill to adjust its working properties, colour, flexibility, strength, texture and so forth.

A fill is intended to raise the level of a loss, lacunae or void (a missing section of paint, paint-ground, or paint-ground-support), so as to permit the undisturbed continual visual observation of the depicted image by the viewer. Once filled, the section is retouched/inpainted.

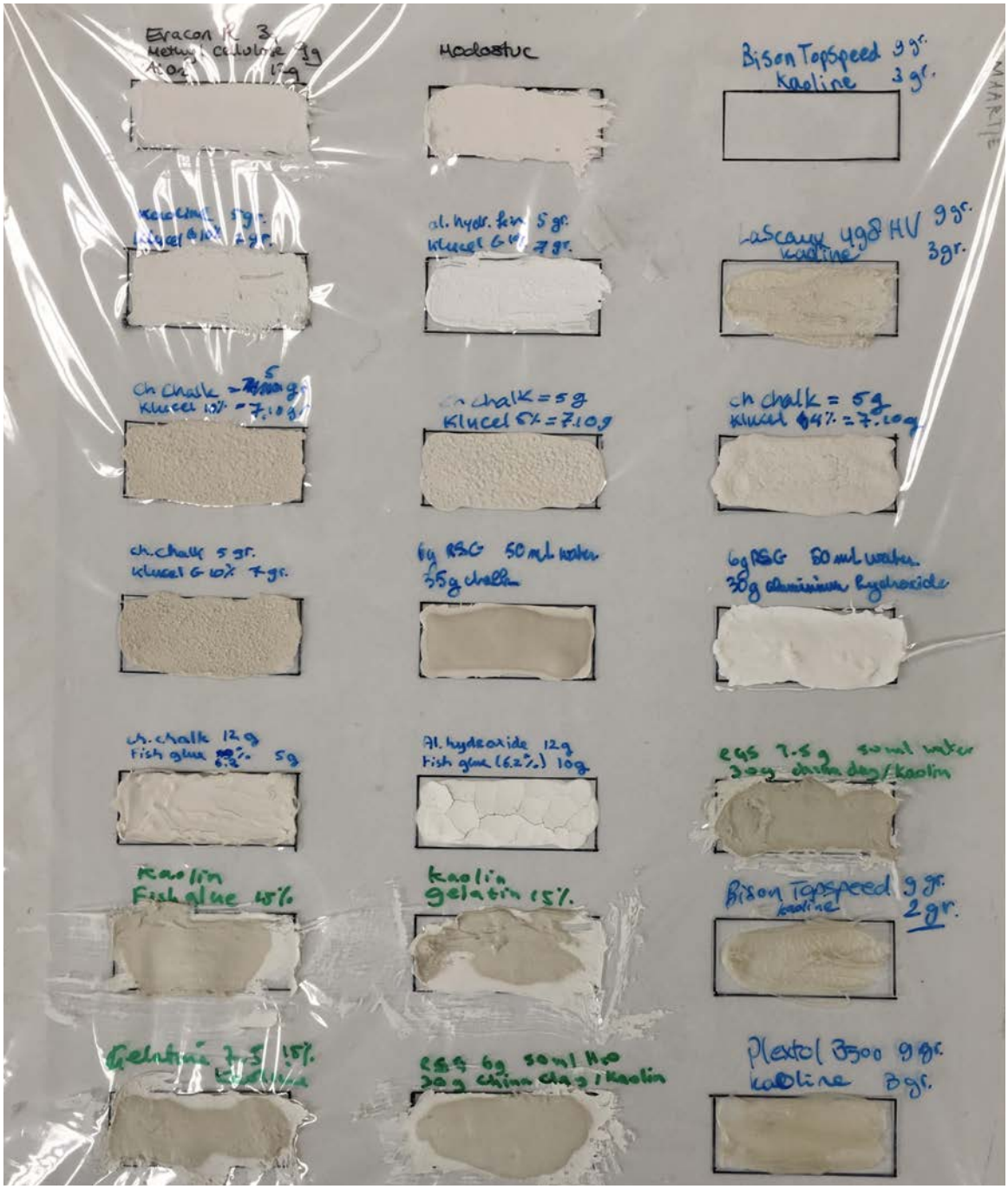
Fillers used for more superficial lacunae will need to be flexible and have good internal bond strength when applied in thin layers. These are often called 'surface fillers'.[5]

Although filling a loss in the paint and/or ground layers may seem quite simple, it can actually be rather tricky to get right**; a filling can make or break a retouching**. If a filling is in some way not 'right', whether it is the level of the fill, or the texture, or pattern in the surface of the fill, no amount of retouching will hide this fact, and the area of damage will always remain visible.[6] Conversely, the visibility of the fill may actually be a choice of the conservator (or the team in which the conservator operates), depending on the theoretical and ethical principles underpinning the conservation treatment. In these cases, as mentioned, the surface texture of the fill may be manipulated to allow for slight differences compared to the original texture. The losses will remain visible in raking light, allowing for an easily distinguishable, but non-disturbing continuation of the original image. This deliberate effect is very different from applying retouching directly on to the missing section, in which case the pattern of the support (canvas or panel) may be perceived more dominantly that the retouched area (*see image of the Equestrian portrait of the Rijksmuseum*).

The selection of the filling materials also needs take into consideration the stiffness of the support and the desired surface structure, which should match that of the original paint. Not all filler materials are able to resist the structural movement imposed by the support or form the desired surface texture. Oftentimes it is the filler that fails before the retouching or varnish discolour, making old repairs visible to the viewer as they crack differently than

[5] Where more structural repair is required, other materials need to be selected, as the fill will have a more mechanical-physical function. Damage may manifest as splits in wooden panels or tears in fabric supports. These types of damage require specialist treatment, as the function of the fill also involves the re-establishment of structural forces to maintain the integrity of the support. Structural repairs need to be robust enough, but flexible, in order to be able to accommodate any movement in the support and adhere with enough strength to all sides of the gap to keep joins aligned, without mechanical failure of the fill, such as tearing, cracking or splitting. These fillers are often called 'gap fillers', when used to repair a split in a panel support, or 'inserts' when used to repair canvas supports. Gap filers for panels and canvas inserts will be discussed in the brochure on *The Structural Conservation of Canvas and Panels* as they play a more mechanical-physical role in the reintegration of losses.

[6] "*The filling is a critical step and reconciles the need for structural and aesthetic characteristics. Just think of a perfect reintegration performed on a [filling] that has not been well-accomplished, in the end gives an aesthetically unsatisfactory result*. "Dr. Marco Ciatti, quoted in: Agulli, G., Silva, L., Treatment of lacunae, Gestalt psychology and Cesare Brandi. From theory to practice, Bailao, A., Henriques, F., Bidarra, A., (eds.) *International Meeting of Retouching of Cultural Heritage, 2015*, Postprints RECH3 (2015) pp 95-102



A variety of fills have been applied to a sheet of Melinex and are being tested for shrinkage during drying after being applied to Melinex. (Image credit: Kate Seymour, SRAL)

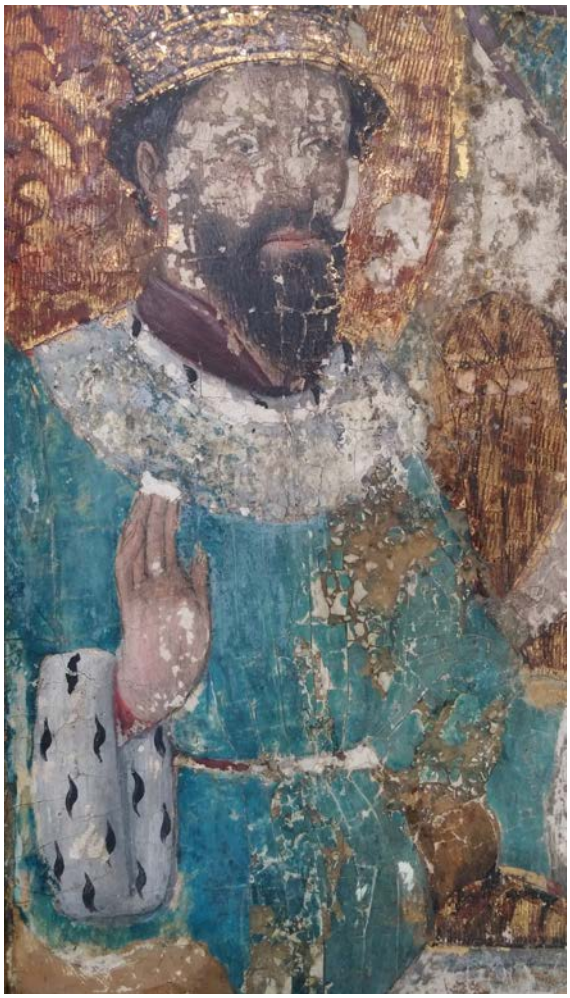
the the surrounding original paint (*see detail image of the King from the Suermondt-Ludwig Museum, Aachen, Germany*). It is, therefore, essential to have at one's fingertips (or in one's toolbox) the ability to make and manipulate a wide range of filling materials.

While it may be common to use commercially available patented fillers, the conservator should be able to design their own filling system to accommodate all support types used for easel paintings (canvas, wooden panel, copper plates, plaster surfaces, or even stone) and all types of paint surface (oil, tempera, acrylic, encaustic,

Left: Overall image of a lifesize Equestrian Painting (Rijksmuseum Collection, Amsterdam), Right: Detail image of the painting (ca 5cm2). Due to the extensiveness and nature of the losses, the decision was made to apply retouches directly on the exposed canvas without a filler. In the detail image, the losses to the left of the orange line have been retouched, to the right of the line the bare canvas is visible where the paint and ground layers are missing (image credit: Kate Seymour, SRAL).

or even mixed media).[7] Fillers may need to be applied as a thin skim or to bulk out a deep crevasse; and thus different combinations of binder and inert bulking agent or different consistencies must be in the repertoire of the conservator. The conservator should be able to adjust binary mixtures of adhesive and mineral bulking compound to suit the needs of the painting. Experimenting with varying proportions of a range of combined adhesives and mineral compounds will provide the conservator with the ability to make the necessary adjustments.

Applied varnishes will also be absorbed differentially by different fill types, causing filled areas to sink in or become glossier after coating. This may mean that the 'perfect' filled and retouched damage still becomes apparent at the final stage of reintegration. Therefore, the use of one filler for all tasks should be avoided and the conservator should, when designing a reintegration plan, consider not only the filling phase of treatment, but also what materials will subsequently be used for inpainting and varnishing.



The section in the chest of King Herod was filled with a glue/chalk (or gypsum) filler but was re-damaged while transferring the painting to a new secondary support. The damage to the paint and to the fill was re-filled with wax-resin resin. The image shows partial removal of overpaint from the filled area which reveals the earlier (white) fill and the 1970s wax-resin filler. Detail image of: Unknown artist/Valencia workshop; St John the Baptist (Detail King Herod). After cleaning. Tempera on pine panel transferred to blackboard, 90 x 110 cm, c. 1470, Suermondt-Ludwig Museum, Aachen, GK 84b, (Image credit: Kate Seymour, SRAL Maastricht).

[7] Note that fills for paper-based supports require additional characteristics, and are not discussed in this brochure directly.

Historical Practices: Traditional Surface Fillers

Losses in painted surfaces have been filled for many centuries by artists or artist-restorers. Various recipes and formulations for filling losses have been used, altered, and passed down over the course of centuries. Artists knew well that most adhesives could be bulked out to be made denser by adding inert powders. Many diverse mineral powders or pigments, such as gypsum, chalk, clay, fine sand, glass powder and lime, added to a wide range of adhesives have been used. Powdered organic materials, such as coconut flour, paper and textile fibres, leather scraps, cork, and sawdust, have also been employed. Some materials were specifically used for certain types of artworks, for instance leather scraps were used to fill holes in leather, glass powder for glass repairs, clay for ceramics, etc. However, material usage crossed boundaries and the modern conservator may find different filler types when studying paintings, even within one painting if it has been filled multiple times.

Traditional fillers for easel paintings tend to consist of a mixture containing materials of a similar composition as the original ground, such as animal glue and chalk or gypsum for panel paintings, or drying oil combined with animal glue and pigment for canvas paintings. Presumably, those repairing painted artworks followed the advice laid down by master-craftsmen when selecting materials for filling. However, simple binary mixtures of binding medium and pigment were rarely employed in the past. Most filler mixtures containing multiple ingredients, sometimes even combining waxes, glues, resins and oils mixed together. The inclusion of some ingredients may not seem rational to the modern conservator, who has more knowledge of chemistry and longevity of materials. The long-term issues of stability and re-solubility presented by these fill types are questionable. Thus, the modern conservator is well advised to consider alternatives when formulating a filler mixture.

Nomenclature of filling materials is inconsistent. The terms *cement* or *stopper* are widely used in historical documents, as is *stucco* in Italian and *mastic* in French, to refer to fillers. Each name has specific connotations in its own language, which often do not translate fully. The term *cement* usually refers to a heavy-bodied compound, that is useful for filling wider voids. While the term *mastic* often refers, in English, to a thermoplastic filling compound, it is a generic term for fills in French. *Stucco* is used in Italian as both a verb and a noun, but in English refers more to applied plaster decorations. And *stopper* may refer to a plug or solid spigot that is used to tightly fill holes.

Traditional fillers contain materials such as animal glue and chalk or gypsum. A detail image of the edge of this panel shows different levels of fill: the white is gesso (containing gypsum) and the cream is putty cement and balsa. Unknown artist/Valencia workshop; St John the Baptist (Detail King Herod). Tempera on pine panel transferred to blackboard, 90 x 110 cm, c. 1470, Suermondt-Ludwig Museum, Aachen, GK 84b, (Image credit: Kate Seymour, SRAL Maastricht).

Early manuscripts on painting techniques, dating from the medieval period, quote recipes of such mixtures and provide advice on how to use them. Cennino Cennini mentions many glues and fillers in his 1397 treatise *Il Libro dell'Arte*.[8] He dedicates a chapter on how to prepare gesso for panel paintings.[9] He also mentions at least two fillers containing lead white (cerussite)[10] and a wax-resin based cement for mending stones, which could presumably be used for the repair of other artworks.[11] He gives the reader tips on how to prepare glues, such as fish glue, goat or parchment glue and a casein-based equivalent[12] and how to grind pigments to prepare paints and fillers with these adhesives. Furthermore, Cennini also provides

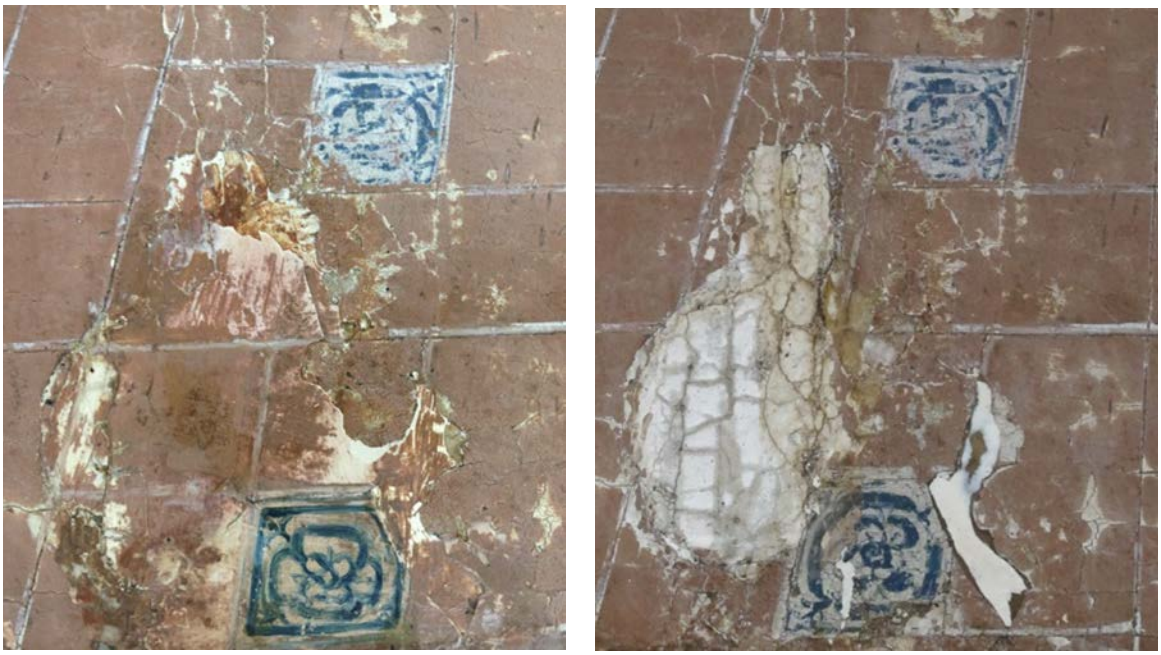
[8] Cennino Cennini, *Il Libro dell'Arte*. New Haven, Yale University Press; London, H. Milford, Oxford University Press. 1932. https://archive.org/details/illibrodellarte1933cenn/mode/1up

[9] See page 71 for the description of how to prepare *gesso grosso* and *sottile*. Gesso 'sottile' (di-hydrated calcium sulphate) is prepared from heating gesso 'grosso' (semi-hydrated calcium sulphate), crushing the product and slaking it in water for one month. The slurry is then dried in 'loaves'. These could be bought at an apothecary. This processed gesso product is mixed with warm diluted parchment glue to create the used material.

[10] *' ... and then take thoroughly powdered white-lead, and mix it with linseed oil until it comes out thin, while still preserving the white colour of the white-lead'*. Cennini, page 12. And secondly, *' ... take [two parts] gesso sottile, and the third, white lead, and the fourth, Armenian bole, and a little sugar. Grind all these things very fine with white of egg'*. Cennini, op cit. page 101.

[11] *' ... take mastic, fresh wax, sifted pounded stone; and then all melted up thoroughly together on the fire'*. Cennini, op. cit. page 105.

[12] *'There is a glue used by workers in wood; this is made of cheese. After putting it to soak in water, work it over with a little quicklime, using a little board with both hands. Put it between the boards; it joins them and fastens them together well. And let this suffice you for the making of various kinds of glue.'* Cennini, page 68.



Detail images of detail of the floor showing a large fill that was damaged and refilled with wax-resin filler. Detail image of: Unknown artist/Valencia workshop; St John the Baptist (Detail King Herod). Left: before overpaint removal, right:old fills after overpaint removal. Tempera on pine panel transferred to blackboard, 90 x 110 cm, c. 1470, Suermondt-Ludwig Museum, Aachen, GK 84b, (Image credit: Kate Seymour, SRAL Maastricht).

counsel on how to fill dents or knots in wooden supports using a glue and sawdust.[13]

One and a half centuries later in 1550, Giorgio Vasari provides, in *Vasari on Technique*, information to the reader on mixtures for the preparation of artworks and of materials that can be used to repair losses to the ground.[14] Vasari describes a '*paste [..] made of flour and walnut oil with two or three measures of white lead put into it*' as a ground for canvas paintings.[15] He also mentions cements and glues used to bind materials together. One recipe mentioned by Cennini echoes that used to bind stones.[16]
Thus, both authors mention (coloured) wax-resin based mixtures. These were likely to be used to repair losses for both panel and canvas paintings, as well as paintings on other rigid supports, such as copper. More frequently, these fill types were also used to repair polychrome sculptures. Sculptors were used to make preparatory models from mixtures of clay and wax. It is logical that these mixtures would also be used to repair damages to painted wooden or terracotta sculptures, and perhaps even other artworks. The wax-based pliable putties could be moulded and pushed into deeper gaps, smoothed and then retouched to match the surrounding colour.

Historically, early manuscripts with recipes for fills did not distinguish between recipes for different substrates, even though the structural and chemical requirements of canvas, wood or copper substrates are different.
The choice of materials and methods were a direct consequence of the availability and the traditions passed down from one generation to the next. Early artist-restorers tended to reintegrate losses by repainting or overpainting large sections of a painting, even if the damage was small, partially out of practicality or for financial reasons, and often without it necessarily being a conscious decision. This method of excessive coverage was often taken from the aesthetic and philosophical perspective, prior to the nineteenth century, that the unbroken image was the goal of the artist, and therefore the restorer. This method of covering large areas of original material also extended to filling, with very old fillings found on paintings sometimes extending to well over the area of loss. Fills were often smeared over the original surface in a more haphazard manner. Level differences in panel paintings between board joins were

[13] *'Take some strong leaf glue; heat up as much as a goblet or glass of water; and boil two leaves of glue, in a pipkin free from grease. Then have some sawdust wet down with this glue in a porringer. Fill the flaws of the nodes with it, and smooth down with a wooden slice, and let it stand. Then scrape with a knife point until it is even with the surrounding level.'* Cennini, op. cit. page 69.
[14] Giorgio Vasari, *Vasari on technique being the introduction to the three arts of design, architecture, sculpture and painting, prefixed to the Lives of the most excellent painters, sculptors and architects*. London J. M. Dent & co. 1907 *https://openlibrary.org/books/OL24528641M/Vasari_on_technique*
[15] Vasari, op. cit. page 236.
[16] *' ... It is made of travertine, lime, pounded brick, gum-tragacanth and white of egg'.* Vasari, op. cit. page 256.

frequently filled to create a smooth, non-stepped surface. Large sections of original paint have been uncovered at the board-join interface in the process of treating structural deformations. It is always an exciting endeavour re-discovering hidden untouched painted surfaces that have not seen the light of day for many decades or even centuries (*see images of the Adoration of the Magi*).

Many treatises discuss tear mending of canvas supports along with filling. This is because losses in the paint and ground layers often coincide with damage to the supports. Early restorations, prior to the nineteenth century, show patches that extended well beyond the area of damage, made of different types of cloth, paper or card, and on some occasions, fragments from other paintings.[17] Robert Dossi describes in his 1758 treatise *The Handmaid to the Arts* how to repair cloth '*worn out in parts, or destroyed by any accidents*'. He informs the reader to lay the picture on a '*flat board, cut out with a penknife, such jagged or damaged pieces, as cannot be brought to lie smooth and even*'. He advises to take a '*piece of canvas bigger than the whole intended to be covered; and plaster it over, with the [] fat oil and colours taken from the smush-pot, on the outside of the cloth*'. He recommends to '*fill afterwards the inequality, or sinking of that part of the picture where the patch lies, with the same matter from the smush-pot; raising it somewhat higher than the surface of the picture to allow for the drying; and if is risen too high, when dry, take it down with a penknife*'. Dossi finally advises that '*the part may be painted according to what the picture requires; and it will be found to be equally*

[17] One well-known example is the painting of *Saul and David* by Rembrandt, in the collection of the Mauritshuis (The Hague), which contains a large fragment of another painting, depicting a woman's hand. *https://jhna.org/articles/rembrandt-saul-and-david-mauritshuis-progress-report/*

Two old fills are seen in the above image: a hard, white fill, possibly compo or a lead-white based fill, and an older, brown fill which seemed to have a wax component (circled in red). Unknown artist, *Adoration of the Magi*, 95 x 124 cm, oil on panel, early 17th century Soeterbeek klooster, Nijmegen, Inv. Nr: 02.10.

Photo of composite X-radiography showing filled loses to paint layers and wooden support deriving from different conservation campaigns. Lead white containing fills can be clearly seen on the X-radiograph. Loses to wooden support were filled (c. 1800) from the reverse with a cement-like material containing lead white pigment. Loses to paint layers were filled (c. 1800) with a putty containing lead white pigment, then later (c. 1920) with calcium carbonate based filled, and later still (c. 1970s) with a pigmented wax-resin filler. Unknown artist/Valencia workshop; St John the Evangelist. Detail composite X-radiograph. Tempera on pine panel transferred to blackboard. 90 x 110 cm, c. 1470, Suermondt-Ludwig Museum, Aachen GK 84a (image credit: Kate Seymour, SRAL).

found and durable with any other part'.[18] It is clear that these types of patches could be attached with a wide variety of mixtures, consisting of animal glues, waxes and wax-resin mixtures, and even with (oil) paint. The incompatibility of some of these materials with the canvas support often caused distortions in the textile and thus even further cracks in the paint. Damage caused by the repairs, therefore, often further exacerbated losses and speed up the need for further treatment.

Fills consisting primarily of a heavily pigmented oil paint were common not only for 'gluing' canvas to the reverse of the damaged textile, but also to fill losses in paint

Another common early fill type was based on beeswax and resins from (coniferous) trees. This system was popular due to the availability of the ingredients. These mixtures were commonly pigmented. Here the beeswax fill can be clearly seen in the halo of the figure. Detail image of Unknown artist/Zaragosa workshop, Detail image of a monk in Last Judgement Tempera on pine panel, 90 x 110cm, ca. Suermondt-Ludwig Museum, Aachen GK 533.

layers. Fills composed of lead white (cerussite, lead carbonate) and oil, mixed with a small amount of litharge (lead monoxide) were probably the most frequently used materials for repairing damage to paint layers before the nineteenth century. As mentioned, this recipe is given as early as the fourteenth century, quoted by Cennino, who recommends its use for mending glass and ceramics, but it was obviously used ubiquitously. This type of fill was also mentioned by Vasari, and later in nineteenth century treatises. This mixture was used as a filler for losses on many types of artworks, including panel and canvas paintings, as well as wooden sculptures. These fillers fell into disuse in the late nineteenth century, due to their toxicity, the availability of alternative white pigments and the introduction of heavy-bodied, commercial fillers. Studio formulations, if preferred over commercially available fillers, were generally replaced by wax-based or water-based fills.[19] Lead-containing fills can easily be identified on x-radiographs as a highly contrasting white (*see image of the Spanish Panel*).

[18] Robert Dossi 'Of mending and cleaning pictures and paintings' *The Handmaid to the Arts* 1758 Volume 1 London J. Nourse, 1764. p. 217-218. In (eds.) David Bomford, Mark Leonard *Issues in the Conservation of Paintings*. Getty Conservation Institute, 2004.

[19] Fuster-López L., (2021) pp 607

Another common early fill type was based on beeswax and resins from (coniferous) trees. This system was popular due to the availability of the ingredients. Mastic, colophony or dammar powder was mixed into the heated wax to form the mass. Wax-resin mixtures were frequently pigmented. They were applied as a molten-heated mass to deep loses or crevasses. The coloured adhesive flowed well and conformed easily to the shape of the void, especially if not heavily pigmented. The fill mixture also had the added advantage of easily consolidating any flaking paint in the surrounding area as it flowed under the raised paint. Pigmented wax-resin mixtures gained in popularity due to their ease of use, availability and resistance to damp climates. They can be found on many artworks, especially panel paintings. They may be quite difficult to identify on canvas paintings subsequently lined with a wax-resin adhesive. However, the surface of wax-resin fills tended to remain relatively tacky and subject to thermal fluctuations. Filled areas may, therefore, show substantially more dust pick-up.

Composition filler (sometimes called compo) was developed toward the end of the eighteenth century. This is an oil-based putty that was used extensively for carved elements in frames, losses or voids in panel and canvas paintings and wooden sculptures. It consists of a mixture of animal glue, linseed oil, a natural resin such as colophony (rosin) and a calcium carbonate or sulphate filler. It is soft and malleable when warm. This mixture was considered useful as it could be easily manipulated and dried to a hard finish. Studying treatises and manuals, it is clear that the recipes are based on earlier press-moulded compositions that have been in use since the medieval period. Unfortunately, on aging it becomes extremely difficult to dissolve, or even remove mechanically. Composition fill was sold commercially by the late nineteenth century and well into the twentieth century. It is very similar in composition to window putty used to hold glazing in frames. It can be identified by its hard, rock-like structure and solid mass. If pigmented with lead containing colours, such as lead white, minium or vermilion, it will appear white in traditional x-radiographic images.

More comprehensive discussions on filling materials are found from the beginning of the nineteenth century onwards in treatises on treating easel paintings. These nineteenth century treatises often gave restorers tips as to what materials to use for fillers and how to apply them, taking inspiration from the practices of gilders and frame makers. Henry Fielding in 1847[20] mentions that *'cracks and damaged places are to be filled up, where hardness is required, with putty made of pipe-clay, or whiting crushed very fine, and paste or size. This putty should be made stiff and pressed well into the damaged places with a palette-knife, and where the broken parts are of any extent care must be used to obtain a true and even surface level with the surface of the picture; this, when dry, may be painted upon with oil colours ground exceedingly fine'. He goes on to mention that 'many prefer to use a putty made with drying oil and whiting, in which*

[20] Fielding, T.H. *The Knowledge and Restoration of Old Paintings: The Modes of judging between copies and originals and A Brief Life of the Principal Matters in the Different Schools of Painting.* Ackerman. London 1847 pp 67-68

Detail of a transferred panel in daylight (left) and ultraviolet fluorescence (UV) (right). The losses in the paint were filled with a glue/chalk (or gypsum) filler, but was re-damaged during the transfer to a new support. The damage to the paint and to the fill was re-filled with wax-resin resin. The image shows partial removal of overpaint from the filled area which reveals the earlier (white) fill and the 1970's wax-resin filler (which is yellowish and has a bluish tint in UV). The old retouches containing zinc white are a brighter green in UV. Detail of: Unknown artist/Valencia workshop; St John the Baptist (Detail King Herod). After cleaning. Tempera on pine panel transferred to blackboard, 90 x 110 cm, c. 1470, Suermondt-Ludwig Museum, Aachen, GK 84b, (Image credit: Kate Seymour, SRAL Maastricht).

colours are mixed, and thus matching the tints of the picture in some degree with the coloured putty: … [] … and if the tints so matched are carefully made lighter than the neighbouring tints of the painting much less trouble will be required in the retouching'. Henry Mogford, also writing in London, provides similar guidance to those practicing restoration. In his 1851 publication Handbook for the Preservation of Pictures, he states how to repair losses: '*…. it will be necessary to fill up, or in the language of the craft, to stop up all such damages. This is usually done by working in firmly, with a palette knife, a paste made of whiting and parchment size, of about the same consistence as putty; or instead of parchment size, good stiff glue may be used with the whiting. If the picture has been painted on an oil ground, it may be very carefully filled in with white lead made into a thick consistence with linseed oil'*. [21] It is clear that recipes reflected the same materials used in preparing grounds, though adapted for ease of use.

Practitioners tended to become comfortable with a favourite recipe and used specific formulations exclusively. At times it is even possible to identify the hand of the restorer through their use of filling material. In France, Jean-François Léonor Mérimée (1838)[22] and Simon Horsin-Déon (1851)[23] included chapters on preservation and restoration of paintings in their manuscripts on painting technique. Ulisse Forni (1866)[24] and Giovanni Secco-Suardo (1866 and 1894)[25] wrote treatises in Italy towards the end of the century directed specifically at the practicing restorer. Mérimée mentions '*a strong cement composed of ceruse, and very fat oil*' to be used to repair tears in canvases and to fill losses in paint layers.[26] He also recommends that '*the holes, if any, must be filled up with glue, or size, and white chalk, such as the gilders use*'.[27] He discusses how to texture the 'stopping' by impressing a piece of canvas with a similar weave before the material has set before the retouching is applied. Horsin-Déon provides a number of options for the practitioner to choose from, including a gilder's putty,

Animal glues used to make traditional fillers. These are mixed with gypsum and are known as 'Colletta'.

pure beeswax and a pigmented wax-resin.[28] Forni and Secco-Suardo both describe methodology and give detailed instructions for applying fillings in various circumstances. Forni provided tips on how to prepare losses for filling and how to flatten and texture the applied 'stucco' (a mixture of gilders gesso and animal glue) in a chapter dedicated to 'How to fill the parts missing in a painting'.[29] Secco-Suardo goes as far as to describe the patience needed by the restorer to achieve a good filling.[30] He advises to use the same gilders; a stucco recipe as mentioned by his contemporary and rival Forni, though Secco-Suardo recommends diluting the glue content slightly.[31] Both of these manuals are available (in Italian) online at *Archive.org*.

Water-based filling materials remain as popular as ever. Traditionally the inert material was the same component found in the ground layers. Thus, while southern restorers favoured calcium sulphate dihydrate (gypsum), those in the north were more inclined to use calcium

[21] Mogford, H. *Handbook for the preservation of pictures containing practical instructions for cleaning, lining, repairing, and restoring oil paintings, with remarks on the distribution of works of art in houses and galleries, their care and preservation*. Windsor & Newton. London. 1851.

[22] *Mérimée, J.F.L. (1839). The art of painting in oil and in fresco: Being a history of the various processes and materials employed (translated from the French by W. B. Sarsfield Taylor.* London: Whittaker & Co

[23] Simone Horsin-Déon, *De la conservation et de la restauration des tableaux*, Hector Bossange, Paris,1851. p 59.

[24] Ulisse Forni, *Manuale del Pittore Restauratore*, Successori, Le Monnier, 1866

[25] Giovanni Secco-Suardo, *Manuale ragionato per la parte meccanica dell'arte del ristauratore dei dipinti*, 2 vols. (Milan: Tipografia di P. Agnelli, 1866-1873) *https://archive.org/details/manualeragionatooosecc*

[26] Mérimée, op cit. page 232.

[27] Mérimée, op cit. page 23

[28] *'A few years ago, putties alone were used to fill in the damage of all kinds that the paintings had suffered. These putties are of three kinds: the one with glue which is composed of glue of skin and white of Spain. The second is nothing but natural virgin wax. The third is a compound of wax and resin dissolved together, to which ochre is added in order to colour it and give it body. The putty (mastic) with glue is, in all cases, preferable.'* Horsin-Déon, op cit. Chapter IV, page 51.

[29] Forni, op cit. Chapter XXXIII, page 76.

[30] *'Plugging a hole with putty only takes a few minutes; reducing that putty to the precise level and degree of smoothness or roughness of the remainder requires a great deal of time and patience, sometimes having to repeat the operation four or five times. Likewise, very little time is needed just to redo a piece, but a great deal of time is needed to restore it to its original appearance. And when the defect consists of small faults, while redoing the whole piece will take only a few hours, repairing the small defects and plugging all the small holes, sometimes very small, without going over and covering the preserved part, can take several days or even weeks.'* Secco-Suardo, op cit. page 42.

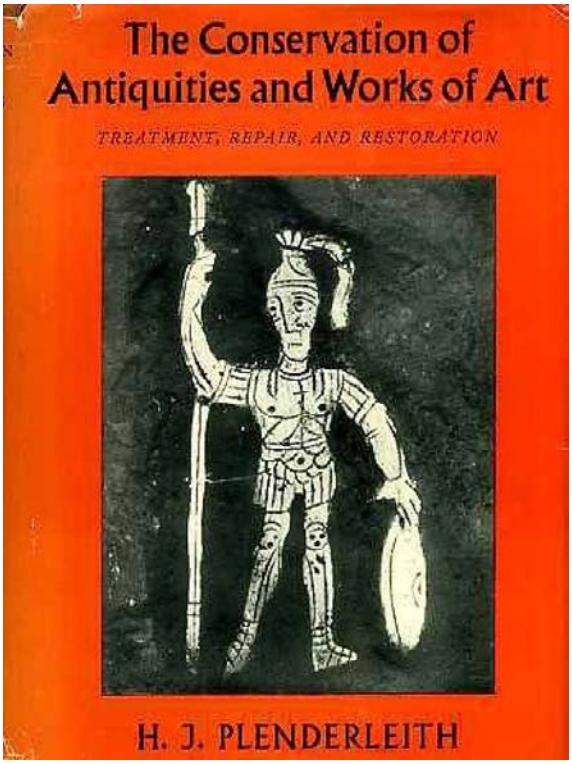
[31] *'… dilute it [stucco] with water, making a very homogeneous paste, and for that purpose grinding it or manipulating it while hot, so that the animal glue it contains dissolves, then, with the aid of a spatula compress it in the shortcomings [losses], making sure that the level of the paint is possibly preserved. And when it is dry, scrape it with the bistori [scalpel] then with a cloth, wrapped around the index finger or a cork, and moderately wet, lightly rub off the putty, especially around it, and immediately wipe it off with another dry cloth, so that it does not extend to the edges over the painting…'* Secco-Suardo, op cit. page 115.

Patented commercial fillers, such as Keene's cement, were sold at hardware stores in the 19th century, as fills for wooden panels. Image source: https://archive.org/details/TheBestBros.KeenesCementCompanyTheOriginalManufacturersOfKeenes

carbonate (chalk). Earth pigments became common additives so that the filler matched the colour of the original ground. The most common binding media used throughout Europe was animal glues, such as hide glues, fish glues, isinglass, or gelatine. Gesso putties were easy to make and cheap as materials were locally available. But they shrink on drying and cure to a relatively brittle material. Additives were therefore common to increase the flexibility. Oils were often added to animal glue fillers to increase resistance to water and reduce shrinkage. Many early recipes also mention inclusions of natural resins such as colophony, rosin, dammar or sandarac, dissolved in either hot drying oils (earlier recipes call for this), while later recipes called for solvents (spirit varnishes).[32] Anti-fungal agents, such as vinegar or alum, were used as a preservative against mould growth. Numerous other additives can be found in recipes, from molasses, Venetian turpentine, egg yolk, honey, and drying oils suggested to increase the plasticity of the fills and waxes (such as beeswax, carnauba wax, paraffin waxes or lanolin) and resins added to glue-based fills to increase resistance to water.[33] Venice turpentine and castor oil found their way into filler recipes, dissolved in ether and alcohol. As recipes became more complex, they also became commercialised. It seems that the developers of such recipes worked under the impression that if a few ingredients functioned well, then the addition of many more would improve performance.

Proprietary or commercial (pigmented) fillers became available at the end of the nineteenth century.[34] These were sold in tins, tubes or bottles by both artists colourmen, such as Rowney or Windsor & Newton (both in London, UK)[35] and at hardware stores often for filling (damaged) wooden structures. Commercial formulations were trademarked and subject to discontinuation and change. They were often called 'stoppers' or 'spackles' or 'putties'. Commercial oil-based fillers were selected for ease of use, as the practitioner did not have to buy the individual ingredients or make the filler in the studio. However, these fillers were not easy to dilute or alter and were therefore used directly from the container. Often the fillers cured to a hard and resistant material that now can be challenging to remove. Examples of early patent plaster fillers are based on gypsum that was heated to beyond the usual point for the production of plaster. By heating longer, all water molecules associated with the calcium sulphate crystals were driven off creating a 'dead burned' gypsum (anhydrite calcium sulphate). This, when mixed with a metal salt compound and water, would set – the metal salt would act as a catalyst, though the setting process was longer than with traditional gesso. This property was desirable when using as a filler as it increased the open time of the filler. Patented variants included Keene's cement made with alum, Martin's cement made with sodium sulphate (so-called Glauber's salt), Parian made with borax[36] and Keating's

[32] Fuster-López L., 'Filling' in: Hill Stoner, J., Rushfield, R., (eds.) *The Conservation of Easel Paintings*, 2021 (2nd ed.) pp 606-608
[33] Fuster-López L., (2021) pp 606-608
[34] Thornton, Jonathan. "A Brief History and Review of the Early Practice and Materials of Gap-Filling in the West." Journal of the American Institute for Conservation, vol. 37, no. 1, 1998, pp. 3–22. JSTOR, https://doi.org/10.2307/3179908. Accessed 26 Mar. 2023.
[35] A comprehensive list of British artists' suppliers, 1650-1950, along with a list of British Framemakers 1600-1950 and British Picture Restorers 1600-1950, is available on the website of the National Portrait Gallery, London: *https://www.npg.org.uk/collections/research/*
[36] *https://www.1902encyclopedia.com/C/CEM/cements.html*



Harold Plenderleith's 1956 book *Conservation of Antiquities and Works.* Image source: https://www.amazon.com/Conservation-Antiquities-Works-Art-Restoration/dp/B0000CHASI of Art.

made with borax and alum. All of these products could be found in the advertising pages of late nineteenth century trade journals. It is likely that some of these filler types can be found on art works treated in this period when these commercial products became popular. And still today, conservators frequently use commercial fillers as a multipurpose solution to resolve levelling issues.

A large number of natural waxes became available in the nineteenth century. These were of plant extracts (carnauba, candelilla, esparto, ouricuri), from insects (shellac wax, Chinese insect wax), whales (spermaceti) and sheep wool (lanolin).[37] These alternative waxes found their way into commercial patented fillers as plasticisers and to lower the melt temperature of the mixture. Waxes from crude oil became available after commercial drilling for oil became commercialised in the last quarter of the nineteenth century. However, beeswax (natural or bleached) has remained the most common wax component of wax-based fills.

By the twentieth century, restoration began to be carried out with more understanding and focus on the artist's intention and originality by those who were trained in the complexities of the profession. Advice given in the manuals to restrict fills to missing sections was followed by practitioners carrying out treatments. Those carrying out conservation-restoration treatments were no longer artist-restorers, but through their training could begin to be called conservator-restorers. Practice changed as more respect was given by art connoisseurs and restorers to the support and the three-dimensionality of the artwork. Restoration techniques evolved which aimed to preserve and restore the structural aspects of the artwork as well as the pictorial image. Repair systems that valued the original materials and their function within the laminate system became more common practice. For instance, fabric inserts that were cut to the size of the loss became a common procedure by the mid twentieth century. The fill material was applied from the front and extended only to the boundary of the loss. This reduced the thickness of the fill required and, therefore, avoided cracking and the need to re-restore within a short period of time. Fills were given texture to match the original surface texture of the paint layers, which facilitated pictorial integration. The practitioner's ethical view has shifted over the centuries and fills are today reserved for the loss of material and are not used to level other types of depression in the surface structure. Just as the approach to filling has evolved, so has the conservator's selection of material for implementing fillings.

However, manuals from the twentieth century continued to include recipes from at least a century earlier as many early formulations had good handling properties and, therefore, had a long history of use.[38] Harold Plenderleith in his 1956 book *Conservation of Antiquities and Works of Art* continued to recommend a traditional putty made from whiting (chalk) and linseed oil.[39] Another oil-based filler designed by Helmut Ruhemann (Chief Restorer at the National Gallery London from the 1950s until 1972) consists of calcium carbonate, stand oil, animal glue, zinc white and beeswax. This fill has a smooth texture, adheres well, does not shrink or expand upon drying and can easily be removed. Some conservators still use this

[37] Masschelein-Kleiner, Liliane. and International Centre for the Study of the Preservation and the Restoration of Cultural Property. *Ancient binding media, varnishes and adhesives / Liliane Masschelein-Kleiner; translated by Janet Bridgland, Sue Walston, A.E. Werner,* ICCROM Rome, 1985.

[38] Heinz Althöfer, in his 1985 text on restoring modern paintings, suggested three different fillers that had been advised by Horsin-Déon's 1851 treatise more than a century earlier (a hide glue filler, a wax filler and a wax-and-resin filler). Horsin-Déon in turn, had used a recipe from an earlier manuscript. Fuster-López L., 'Filling' in: Hill Stoner, J., Rushfield, R., (eds.) *The Conservation of Easel Paintings*, 2021 (2nd ed.) pp 604-605

[39] Harold James Plenderleith. The Conservation of Antiquities and Works of Art Treatment Repair and Restoration by H. J. Plenderleith. Oxford University Press 1957. pp 156-181. Especially pages 167 and 17

Polyfilla. Commercial fillers for repairing plaster and wooden surfaces are available from many suppliers, such as from Polyfilla from Polycell (United Kingdom) and Modostuc from Plasveroi (Italy) and are commonly used to fill surface losses or model three-dimensional losses.

Modostuc is a commercially-made filler for conservation that is based on polyvinyl acetate and an acryl ester binding media with kaolin and chalk as bulking agents.

recipe today.[40] Plenderleith does however provide information about synthetic adhesives that can be used in fills. This is one of the first major publications of the field in which synthetic polymers are advised.

Synthetic resins and polymers found their way into filler recipes as early as the 1850s. These were typically formulated for filling holes or narrow splits in wood surfaces. An early synthetic polymer that was sometimes used was cellulose nitrate (also known as Collodion, when dissolved in a solvent), which was available from 1855 to 1869 and sometimes plasticised with camphor, Venice turpentine and castor oil. Collodion was used as a binder in some early commercial fillers, and was the original composition of the popular proprietary filling compound called 'Plastic Wood'. Both vinyl and acrylic polymers were available from the 1930s onwards, though not as water-based dispersions until after the Second World War. The ease of use of water-based dispersion adhesives made these materials very popular as a binder for fillers in studio formulations. Today, these synthetic polymers are the typical basis of all commercial stoppers, spackles and fillers.

In the late 1950's, commercialised polyethylene glycols such as Polywax and Carbowax were suggested, as they had physical properties similar to waxes, were thought to adhere well to canvases and to old fills, were reversible with water, miscible with other wax-based and thermo-plastic fillers and resistant to environmental fluctuations.[41] These synthetic waxes were substituted for the traditional beeswax-colophony/dammar mixture, along with synthetic polymers used in the coating and adhesive industry.

In the late twentieth century, conservators began to experiment in the studio with formulations using synthetic adhesives, that imparted different properties to the cured result. Fillers were developed from acrylic, vinyl and other thermoplastic resins, with the aim of creating flexible materials that are less prone to crack when exposed to environmental fluctuations and dimensional changes in original layers.[42] [43] Vinyl binders, such as polyvinyl alcohol (e.g., Mowiol 04-M1, now Mowiol 4-88)[44], polyvinyl acetate (Mowilith DMC-2) acrylic emulsion and acrylic solution adhesives (e.g., Plextol B-500, Lascaux Medium for Consolidation, Paraloid B72) and BEVA 371 are widely used in conservation and also as binders for fills.

[40] Calcium carbonate (60 g) stand oil (15 g) animal glue in water (20 g) zinc white (10 g) beeswax (5 g). The putty is made on a hotplate, with all the ingredients combined and kneaded together. Jessell, B., *Helmut Ruhemann's Inpainting Techniques*, JAIC, 1977, vol 17 (nr. 1) pp 1-8

[41] Fuster-López L., (2021) pp 608

[42] Hulmer, Eric C. "Notes on the Formulation and Application of Acrylic Coatings." *Bulletin of the American Group. International Institute for Conservation of Historic and Artistic Works*, vol. 11, no. 2, 1971, pp. 132–39. *JSTOR*, https://doi.org/10.2307/3178905. Accessed 2 Apr. 2023.

[43] Hulmer, E. C. "Notes on the Formulation and Application of Adhesives and Supports." *Bulletin of the American Group. International Institute for Conservation of Historic and Artistic Works*, vol. 12, no. 1, 1971, pp. 46–54. *JSTOR*, https://doi.org/10.2307/3178994. Accessed 2 Apr. 2023.

[44] Note that Mowiol 04-M1 is now being sold as Mowiol 4-88.

Early experimentation using synthetic binding media for fillers was ongoing from the late 1960s on both sides of the Atlantic. In America, eminent conservation scientists and conservators, such as Robert Feller (National Gallery of Art, Smithsonian) and Richard Buck (Oberlin College, Ohio), collaborated to establish the properties and parameters of synthetic resins to be used as coatings, varnishes, and media. This early work ultimately led to the development of the BEVA formulations by Gustav Berger[45] and to the use of synthetic resins for varnishes (and retouching media) by René de la Rie. The inclusion of synthetic binders for fillers found more experimentation in Europe. In The Netherlands at the Central Research Laboratory for Objects of Art and Science (now incorporated into the Cultural Heritage Agency of the Netherlands) (RCE) conservators such as Diane Falvey and IJsbrand Hummelen trialled and tested a number of different synthetic resins. Falvey focussed on a chalk-based filler with Mowiol 04-M1 (a copolymer of polyvinyl alcohol with a small amount of polyvinyl acetate by Hoechst, West Germany) after testing a variety of adhesives, including Plextol B500 (ethyl acrylate methyl methacrylate by Rohm, West Germany) and Cryla (an acrylic primer by Rowney, UK), and comparing them with many traditional recipes based on linseed oil, casein, beeswax and gelatine.[46] The Mowiol 04-M1 formulation performed with the best results and became popular with conservators due to its ease of handling and solubility in water.

Vinyl and acrylic polymers, and formulated mixtures of these polymers, are also used in commercial brands of fillers as binders. Brands developed by multinationals are available in hardware stores and many are currently also distributed by conservation vendors. These include products developed by companies such as Alabastine, Polycell, Flügger, and Modostuc. These products often have one or two adhesives within the formulation and frequently contain cellulose ethers to bulk out the filler. As they are originally formulated for wooden surfaces, many brands are available in different wood colours, such as pine, beech, mahogany, oak, etc. Epoxy-based fillers have also found use for filling losses in stiffer surfaces, such as wood, ceramics or glass. These have been produced by companies such as Araldite and Milliput.

In current practice, traditional fill materials co-exist with synthetic and commercial formulations. However, fills are often still handmade by the conservator. Today, traditional hide glue fillers, both chalk and gypsum variants, are still made and used frequently. Formulations can be modified by adding synthetic adhesives, such as cellulose ethers (methyl cellulose) or Aquazol 200 or 500 (poly (2-ethyl-2-oxazoline)), to increase hardness and ease in smoothing very shallow fills. These adhesives have the added benefit that they can be dissolved in solvent rather than water, making them appropriate for use on moisture-sensitive surfaces.[47] Other synthetic polymers, such as PVA, have also been added to increase flexibility and improve adherence.

Chalk (whiting), kaolin (China clay), gypsum (gesso) and barytes (barium sulphate) may be utilised as the 'white' bulking compound, depending on the refractive index and absorbency in the chosen adhesive. Zinc white and titanium white pigments may also be exploited as ingredients due to their opacity when bound in many media. Aluminium hydroxide or tri-oxide powder (Portafil A40), typically added to house paints because of its opacity, may also be made use of. Any coloured pigment can be added to impart colour, but natural earth minerals are used more frequently. The same inert minerals can be added to other binding media to form fillers. Recipes that are based on starch, (Arabic) gum, cellulose ethers are still common. Other binders such as vinyl and acrylic dispersions have become standard formulations. Recipes for these fills, and a discussion of commercial fills available can be found below.

[45] Berger, Gustav A. "Application of Heat-Activated Adhesives for the Consolidation of Paintings." *Bulletin of the American Group. International Institute for Conservation of Historic and Artistic Works*, vol. 11, no. 2, 1971, pp. 124–28. *JSTOR*, https://doi.org/10.2307/3178903. Accessed 2 Apr. 2023.

[46] Falvey, D. "The advantages of Mowiol (polyvinyl alcohol): comparative studies of organic and synthetic binding media for fillers for paintings on canvas". In ICOM Committee for Conservation 7th Triennial Meeting Ottawa Canada 21-25 September 1981 81/2/13

[47] Fuster-López L., (2021) pp 609-610

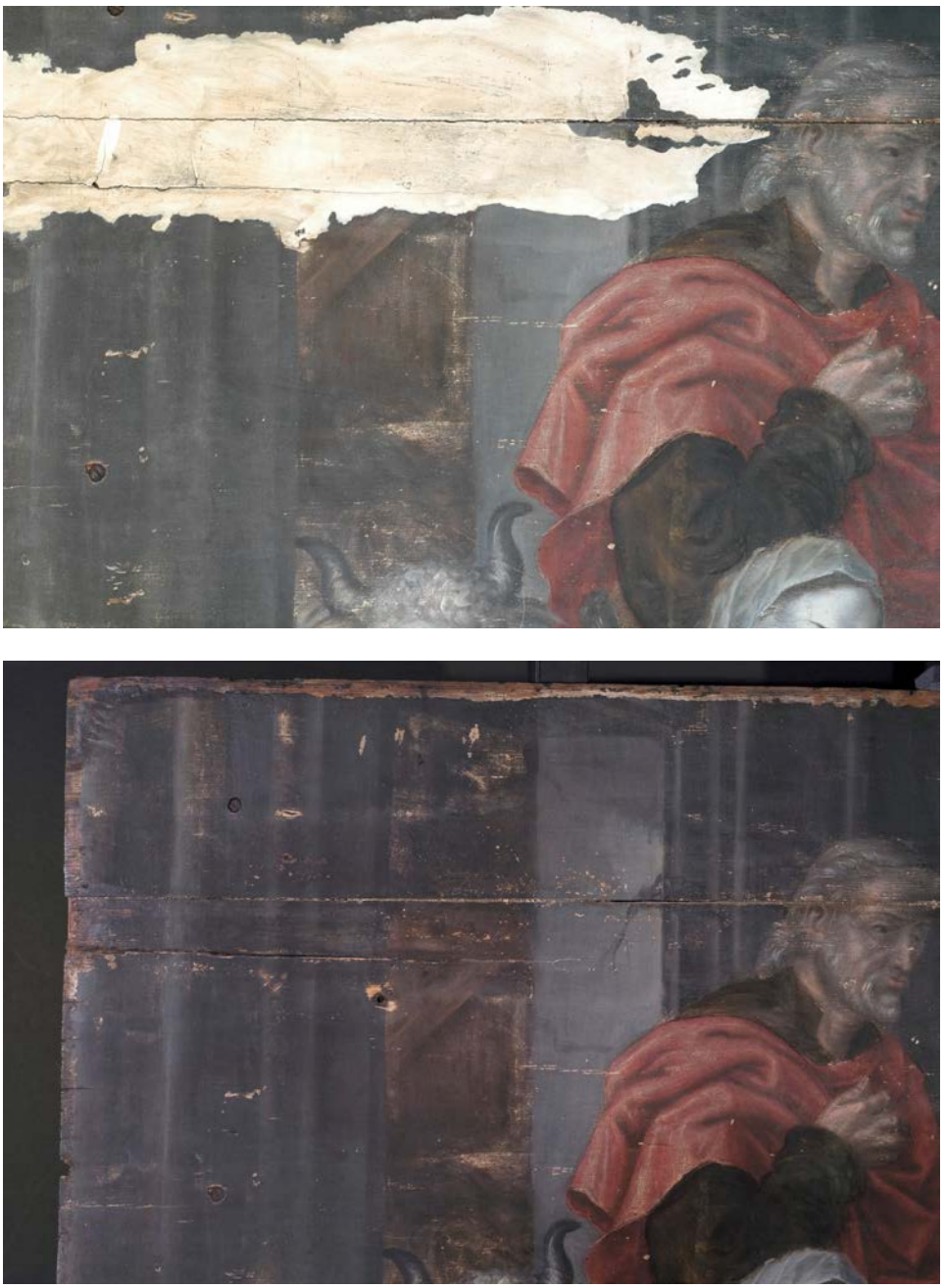
Removal of old fills

Part of the conservator's treatment of an artwork may require the removal of old filling material. This may be necessary for a number of different reasons. The filling material may have degraded over time, whether from aging or from reactions to the environmental conditions in which the artwork is held, with cracking, crumbling, pulling away from the support and surrounding paint or disintegration as a result. Filling material may also need to be removed if it extends over the edges of the loss and covers original material such as original paint layers. Often when the fill extends over original material, it is also slightly raised compared to the surrounding area, increasing its visibility and therefore potential for distraction from the aesthetic of the artwork. The texture of an old fill that deviates from the texture of the original material may also be distracting, whether the texture is too smooth (thus increasing the gloss of the filled area), or with a texture that differs to the original, resulting in a disturbing visibility and thus requiring its removal. Often old filling mixtures, especially when they present a different crack pattern to the original paint surface or are flaking, need to be replaced as part of the conservation process.

However, it may not be necessary to remove all old fills. Some may be kept if they continue to function adequately, it may be opportune to investigate if original surfaces can be recovered by removing excess material. It may be difficult to identify and distinguish the old fill from the original ground layer. In these cases, it is best to err on the side of caution and leave the fill in place.
The modern conservator often realises, when removing old fills, that the traditional materials used for filling losses may be stubborn and difficult to dissolve. Mechanical removal may be possible, however, if the fill has the consistency of 'cement', its hardness may prevent removal by this means. Thus, today the selection of materials for surface fillers is more refined and attune to the aging characteristics of the binding media.

In order to facilitate removal, it is important that the conservator can recognise these traditional fills. Often more than one filling campaign can be identified, especially if the loss of adhesion between the ground/paint and support is reoccurring. Identifying the number of fill campaigns may provide the conservator with an increased understanding of the biography of the painting. Therefore, an understanding of traditional filling practices and materials is useful to interpreting what is found on the artwork. Identifying the type of filler may aid in dating the execution of the repair. Certain

Detail image of an old fill and retouching before and after removal, with the area being cleared in preparation for a new fill and retouching. Anton van Rappard, *Workers at the brickworks Ruimzicht*, oil on canvas, 183 x 300 cm, 1885, Gemeentemuseum Helmond, on loan from Centraal Museum, Utrecht. (image credit: Kate Seymour, SRAL Maastricht).



Before and after removal of an old fill. The filler was in this case used to create a level flat surface hiding the out-of-plane deformation of the panel resulting from the split in the board. The structural repair of the support was not effectuated prior to filling during the previous restoration. Covering large areas of original material that is still intact was commonly undertaken in restorations in past centuries. This old fill may have been *Compo*, or a fill based on lead white, as it appeared bright white in the x-radiography and was extremely difficult to remove. Unknown artist, *Adoration of the Magi*, 95 x 124 cm, oil on panel, early 17th century, Soeterbeek klooster, Nijmegen, Inv. Nr: 02.10.

'historical' fills may even be of historical importance and context. Traditional fills can also be used as an indicator of the longevity and appropriateness of a particular material for conservation applications, and provide suggestions for the conservator in material selection.

If the fill is a glue-based fill, such as those mentioned above under historical fills, it may be removed by softening or dissolving it with an aqueous solution, enabling its removal with a scalpel (mechanical action) and cotton swabs. Those with oil and oil-based fills may require solvents for their softening and ease of removal. Some fills, such as the composition filler mentioned above, may not easily be dissolved with aqueous solutions, solvents or gels. In this case, careful removal mechanically (with a scalpel) will be necessary. It is always wise to first thin down the fill mechanically (if possible after softening) as much as possible during removal, as chipping larger or thicker portions of the fill away with a scalpel may inadvertently cause original material to be lost, if the fill is well-attached to the original surface. By thinning down a fill, it will also reveal material that may not have aged as severely as the surface of the fill, which was exposed to changes in environmental conditions. This means that it may be more readily reactive to solvents, and therefore more easily softened for removal.

Ethical Considerations and Criteria for Selecting Materials for Fills

Today, surface filling materials can generally be divided into two categories:

- those that cure by loss of solvent,
- those that are thermoplastic in nature.

Fills that cure by loss of solvent (often water) can be manipulated by carving into the fill or building up a textured surface. Thermoplastic fills can be manipulated by impressing a mould made from a similar surrounding surface into the heated fill material. This process of manipulation of the fill to aid the imitation of the original surface and diminish its visual disturbance is an essential phase in disguising the loss and often more time is spent carrying out this step than the subsequent inpainting/retouching of the loss. Note that fills should be strong and flexible, but if further stresses are applied to the artwork, it should be the fill that gives way and breaks/cracks, rather than the surrounding original materials! This brochure will discuss options for both types of surface fillers.

Fills are generally intended as long-term replacements of missing sections of original materials. It is preferable that the fill material does not bond strongly to the original material so that they can be more easily removed in the future. However, it should be noted that typically some of the filler components, especially if fluid, may permanently penetrate the substrate to which they are applied. It is unlikely that impregnated materials can be effectively removed and so the filler components should be selected carefully.

Successful fillings will depend on the proper selection, use and application of filling materials to prepare a surface for varnishing and retouching. The filling should fulfil a number of criteria.

Firstly, the fill must be reversible – or rather removable without causing damage to the painting. The ability to reverse – or remove – a material applied during a treatment campaign is one of the guiding principles of restoration, and this also applies to fillings. Ethically, any material applied to the artwork that would impede any future action or treatment should be avoided. Components of fills may degrade over time, or no longer suit the requirements of the loss in the paint and ground layers, and reversibility is therefore imperative to a successful fill.

The properties of both the artwork and filling material should be considered when choosing a suitable filling material. Image credit: Kate Seymour (SRAL).

Secondly, filling materials must also be compatible with the original materials of the artwork, and with other materials used in the conservation treatment. This applies to the chemical, physical and mechanical properties of both the binder and the inert material of the fill. It is important to choose the fill material dependent upon the retouching and varnishing materials selected, because not all materials are compatible. For example, it will be difficult to retouch with an aqueous medium over a fill containing wax or oil and a porous fill may result in the sinking in of the varnish applied.

Thirdly, filling materials should not be overly responsive to environmental changes or the strains in the laminate structure of the artwork, as this will cause premature damage to either the fill (through cracking or crumbling) or loss of adhesion to the surrounding area.

Therefore, when choosing a fill, the following properties should be considered:

- The viscosity and flow properties of the filling material, and the compatibility of the solvents required with the original materials to adjust these properties if needed;
- The drying or curing time;
- The flexibility, and whether this changes over time when exposed to environmental changes;
- The short- and long-term stability (its aging properties);
- The reversibility/ease of removal;
- The degree of shrinkage or expansion on drying/curing;
- The ease of surface manipulation (carving or imprinting);
- The ease of application;
- The colour (and ease of adjustment of the colour);
- The pH;
- The weight, and whether this can be adjusted;
- The compatibility of the fill with the original materials of the artwork, and with other conservation materials required;
- The surface gloss and texture (and ease of adjustment);
- The application temperature (if relevant);
- The Tg of the adhesive component;

Generally, the binding agents of a fill should be chosen for their strength, flexibility, reversibility, shrinkage and aging properties, whereas bulking agents are chosen for their availability, colour, particle size, hardness, cost and compatibility with the substrate.

As many fillers, both studio formulations and commercial variants, are applied fluid or semi-fluid, overfilling is inevitable. Excess can be removed with an appropriate solvent, which should not adversely influence the original material or stratigraphy of the artwork. Ghosting (the presence of a white haze around the fill) will result from the entrapment of particulate or bulking agents in the pores or cracks surrounding the loss. Fillers with bulking agents that have a similar refractive index as the subsequently applied varnish layer may be preferred. Alternatively, a coating (applied either locally or over the entire surface) may be utilised to reduce the effect of ghosting. Barrier coatings can be a varnish of low molecular weight that can be easily removed with an aliphatic hydrocarbon solvent once the filling campaign is completed. Alternatively, filling can take place after the application of a first varnish layer.

Modern Commercial Fills and Studio Formulations

Commercially manufactured fills

Commercially available fillers should be used with caution, as they may contain components such as foaming agents, emulsifiers, and biocides. Not all contents may be disclosed by the manufacturer for a variety of reasons. These commercial fillers have been developed for the construction industry, artistic market or commercial market, which have different requirements to the conservation field. Most commercial fillers are available in different grades (light, heavy or hard, water soluble etc.) and may be suitable for some fields of conservation (porcelain, glass, wood, furniture or frame) but not compatible with paintings. Commercial fillers can be found in the product list of conservation suppliers, although regional stockage limitations may mean finding a preferred commercial product can be challenging and expensive if it the standard manufacturing country is on the other side of the globe. Also note that although some commercial fillers have been tested by conservation institutions, this is not a guarantee that the recipes remain unchanged over time. Where possible, **studio formulations are preferred** as the conservator has complete control over the ingredients, formulation and any additives.

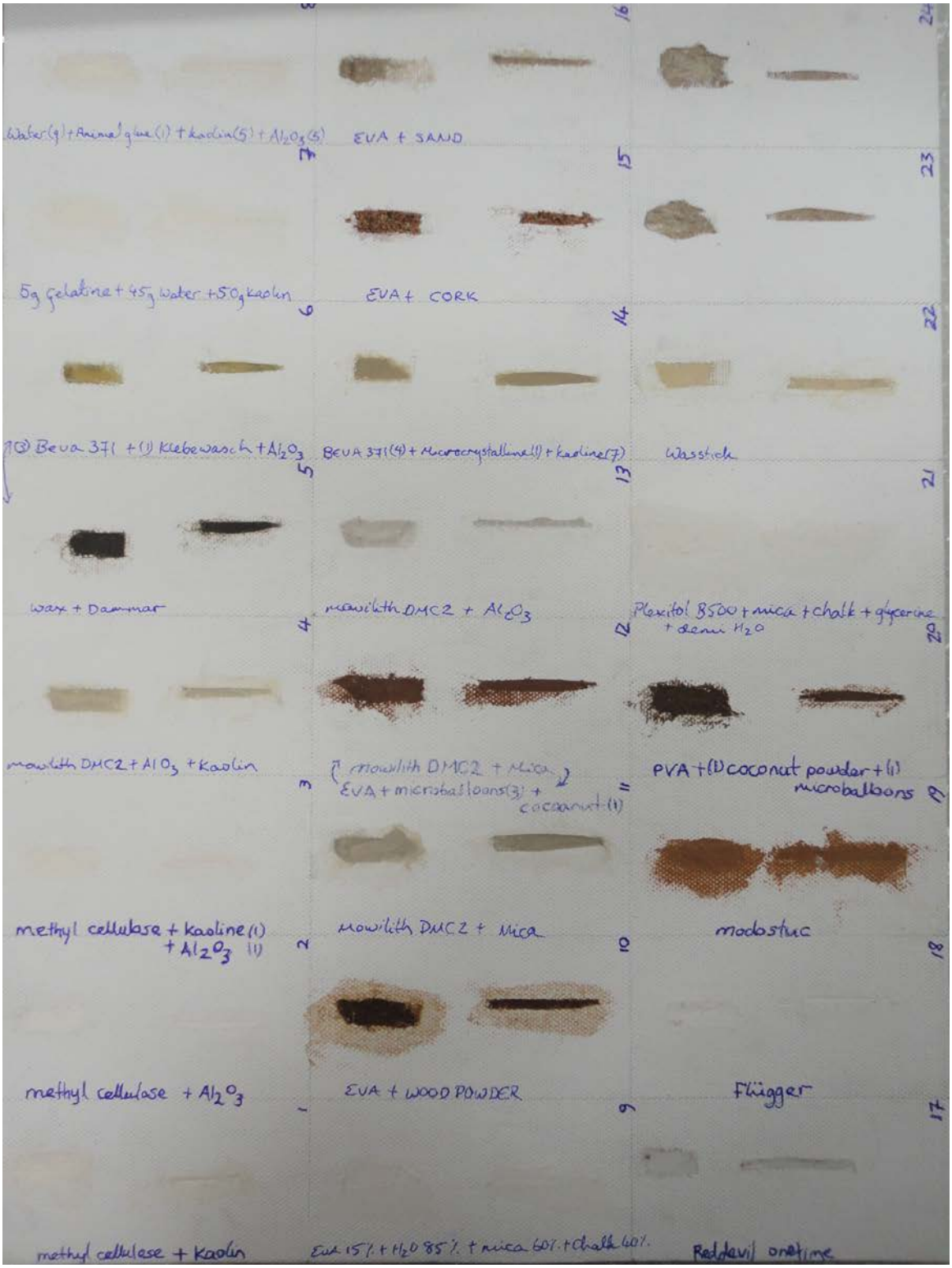
Commercially manufactured fillers are typically patented, and their formulations are trade secrets. The manufacturer may be required to list the main ingredients but will not provide information on all of the components of the fill – ingredients of a low percentage are not legally required to be declared. They are created for filling surfaces such as plaster, wood, ceramic, glass, plastic or even metal. Some are designed for the construction industry to repair holes in plaster walls or plaster board, others for filling dents and holes in wood or covering nail or screw heads. Fillers are also designed for the arts and crafts industry, which has a considerable crossover with conservation in terms of handling and practice. Many varieties of modelling pastes can be bought in art supply stores, and these are designed to mimic a variety of different structures, such as wood, clay, plaster, glass, and ceramic.

Commercial fillers cannot be categorised into one class, especially as many have been designed for use on a multitude of different surfaces and purposes. Frequently, a filler designed for one material type is used for other surfaces, particularly out of habit and ease of use. The appropriateness for use on different surfaces will depend on the filler's binding medium – which maybe more than one adhesive. Some commercial fillers maybe best suited for skim fills, others for deep crevasses. If commercial fillers are used, it is best to have a wide range of choice and to become conversant with many varieties.

The vehicle for modern commercial fillers is often based on vinyl or acrylic adhesive dispersion formulations.[48] These offer a greater convenience and flexibility in application than traditional gap- or surface-filler materials, including water-based animal glue systems (chalk or gesso), wax-resin fillers or oil-based putties. These ready-mixed fillers contain a balanced formulation of an adhesive and bulking agents. They are designed to be produced *en masse* and to have (un-opened) a considerable shelf-life. As such, they typically are not binary formulations, but contain additional agents, such as thickeners, foaming agents, emulsifiers, plasticisers, pigments and biocides. The bulking inert material many also not be a single species, but instead consist of a number of different mineral compounds or thickeners, which provide the desired opacity and (reduce) weight. These patented, undisclosed formulations are also subject to change as individual components are substituted – either through an improvement of the formulation or because of the discontinuation of the production of certain ingredients. Analysing the components of these fills has limited accuracy, as the results are only as correct as the duration of the formulation. Additionally, the exact balance of ingredients may shift according to the batch made.
On merit, the acrylic based commercial adhesives tend to have a better long-term performance than the vinyl equivalents. Therefore, the time-saving feature of using ready-made products must be balanced by the knowledge of the formulation and its ageing characteristics.

Most of these commercial fillers (both vinylic or acrylic) can be diluted with water to produce a thinner, more fluid application. Most of these fillers are designed so as to limit cracking on drying (of relatively thick films) and therefore are heavy-bodied, although at times it is advised to apply in multiple layers when the fill is deep, and diluting with water will encourage cracking on drying. Most of these fillers will be insoluble in water on curing, although they will swell and dissolve in acetone, ethanol or aromatic hydrocarbon solvents. Many of these commercial fillers are available in a range of different colours – though the range may be limited to the imitation of different wood types. Pigments can be added to some of the more fluid variants, although this may disrupt the balance between vehicle and mineral

[48] *Learner, Tom. "A review of synthetic binding media in twentieth"century paints." The Conservator 24 (2000): 103 - 96.*



Studio experimentations of different formulations and comparisons with commercial fillers tested on a canvas board for future use as reference.

compound resulting in an underbound fill. Some are easy to shape or model and others easier to carve.

Acrylic-based fillers

Acrylic-based fillers are often combinations of methyl, ethyl, butyl acrylate and methacrylate copolymers. The bulking agents are frequently combinations of calcium carbonate, calcium sulphate, barium sulphate, talc (French chalk), kaolin and other clays, as well as fumed silica, ground glass or (phenolic or glass) microballoons[49]. Additional ingredients may be ammonia or ammoniated compounds (as biocides), ethylene glycols (as thickeners), pigments (as colourants) and surfactants (as emulsifying or anti-foaming agents).

Flexibility of the dried acrylic-based film varies considerably. These modelling pastes are designed for indoor use only. They are available in many grades and are often labelled light, heavy or hard. The hard variants contain a higher proportion of inert material and are considered heavy-bodied. These are typically carvable, whereas the light bodied versions are intended to help build depth without adding additional weight. The relatively low Tg of the acrylic resin means that these fills, on hardening, are comparatively soft. These products should be kept above freezing during shipment and storage. The acrylic modelling pastes are typically semi-fluid and can be applied with a spatula, but can be thinned with water to allow for brush applications. Note that thinning may also be carried out using ethanol if appropriate, though this reduces the open time of the fill. While coloured versions are sold by most manufacturers, acrylic paints may be added to produce the desired colour. The shelf life of acrylic-based fills is reduced as soon as the container is opened. The films are formed through solvent (water) evaporation, which commences as soon as the container seal is broken. Once dry, the hard filler can be sanded or rubbed down with a solvent. However, if a lower molecular weight acrylic polymer is used, sanding may not be viable as the surface can be rubbery. These lower molecular weight variants are thermoplastic and the heated surface can be textured through impressing a mould. A wide variety of retouching systems can be applied over these fill types. Water-based retouching systems are suitable on top of the heavy-bodied fillers. However, varnishes may sink in when applied to these variants.

Examples[50] of acrylic modelling pastes or fillers are:

Liquitex Modelling Paste (Liquitex), introduced in 1958 and its production is continued today. This probably is the most widely used acrylic filler, especially with object

Golden Molding paste.

Liquitex modelling paste

[49] Note phenolic microballoons are brown in colour and may not be opportune due to their dark colour as an addition for surface fills. They are typically included in commercial wood putty formulations and as a bulking agent in Araldite two-component epoxy resins. Glass microballoons are available in different diameters and are added, amongst other purposes, as a bulking agent for lightweight fillers, along with fumed silica. These can also be added to studio formulations.

[50] The products mentioned in the section below, while not formulated for conservation practice, are used by conservators. Research has been carried out on many to determine the components. Though this may not be up-to-date, product information and references are given in CAMEO, a material database housed on the Museum of Fine Art, Boston's website: *https://cameo.mfa.org/wiki/Category:Materials_database*

conservators. It is a modelling paste that is used to build durable (stiff) textures and create three-dimensional forms. Acrylic paints (and other water-based paints) or dry pigments can be added to colour the substrate. Inert bulking agents, such as aluminium tri-oxide, chalk, barium sulphate or kaolin can also be added – note that the refractive index of the inert material will influence the colour of the dried film. It dries to a hard paste that can be sanded, carved or painted. High peaks, brushstrokes or low impasto can be replicated. Moulds of the original surface texture can be caste, filled with the modelling paste and subsequently adhered when dry using either an acrylic dispersion or a thin coating of the same paste. It has good stability and can be removed on aging with polar solvents or aromatic hydrocarbons. Other producers of acrylic paints such as Golden also manufacture similar modelling pastes.

Liquitex Acrylic Gesso (Liquitex). This product is available as a neutral colour or pigmented. It is a modified form of the Liquitex Modelling Paste. The formulation is pigmented with titanium white (likely also fumed silica) and, if desired, coloured pigments. It is formulated as a preparation material for artists to apply to paint supports. It dries to a non-absorbent surface. It can be made into a more 'putty-like' consistency by adding additional bulking component or pigments. While not disclosed, it is probable that both Liquitex products used Rhoplex AC-33 as a base polymer until 1963, at which point their acrylic paint formulation shifted to a thicker consistency. Similarly to modelling pastes, acrylic gessos are made by other manufacturers of painting materials such as Golden.

Flügger Acrylic Putty

Flügger Acrylspalter (Acrylic Putty) (Flügger Group A/S) is another commonly used filling material in paintings conservation. It is stabilised in water and composed of butyl methacrylate and calcium carbonate. It comes as a white paste in a tube. It is used in a number of fields in conservation: as a filler for small losses and chips on chinaware and porcelain, for fine surface finishing of archaeological ceramics and filling-in on acrylic paintings. Flügger® may be thinned or cleaned up during application using water, it may be polished to a very smooth finish, it takes a caste or moulded surface texture well, it may be tinted using acrylic paints or dry pigments, and it is quick drying. It is attractive to many conservators for its convenience and it shows less shrinkage than many other readily available fills (both commercial and homemade).[51] However, the film dries to a hard, rigid surface which may be prone to crack.

Polyfilla Fine Surface (Polycell products of ICI/AkzoNobel). This is available in all UK hardware stores and is sold by some leading conservation suppliers. It is available in both a tub and tube container. The tube container has a longer lifespan as it is less prone to drying out. Analysis of early formulations indicates the presence of multiple ingredients: the binder is a mixture of acrylic and vinylic polymers. The inert content is calcium carbonate with a fine particle size, though some formulations are based on gypsum. The binder is currently reported as a styrene-acrylate based polymer. Ghosting is inevitable, but the films dry with minimal shrinkage. Note while this is a trademark product, the name Polyfilla has become synonymous with many other surface fillers which are produced by competitors.

Vinylic-based fillers

Vinyl-based commercial fillers are produced for the building trade and are available at hardware stores. The adhesive is a polyvinyl acetate dispersion or emulsion, though often the desired film hardness and durability is achieved by using a combination with polyvinyl alcohol. The bulking agents are similar to those used in acrylic-based fillers and include (combinations of) calcium carbonate, calcium sulphate, barium sulphate, talc (French chalk), kaolin and other clays, as well as fumed silica, ground glass or (glass) microballoons.

[51] *https://cool.culturalheritage.org/byform/mailing-lists/cdl/2009/0674.html*
One study showed that Flügger® showed slightly inferior properties in ageing tests to Polycell Fine Surface Polyfilla®: *https://www.iiconservation.org/congress/sites/iiconservation.org.congress/files/IIC%202010%20Istanbul%20Congress/student-posters/student-poster-479.pdf*

Pigments can also be added to colour the product – again typically a wide range of 'wood' colours are available, though most are kept unpigmented as this is similar to the colour of plaster. Additional ingredients will include biocides and thickeners (such as cellulose ethers).

Most of the vinyl-based commercial fillers are thicker and more viscous than the acrylic counterparts. They can easily be applied with a spatula. Thinning with water to make a brushable fluid application is also possible, but will result in increased shrinkage and cracking. Most vinyl-based fillers will remain partially soluble in water, though those intended for outdoor usage will be water resistant. As most vinyl-based fillers are heavy-bodied, they can be easily sanded or carved. The resultant films may be stiffer and more prone to cracking than acrylic-based moulding pastes.

Examples of vinylic spackles or fillers are:

DAP Vinyl Spackling Paste (DAP Global), introduced in the late 1970s and still in continuous production, although this product has lately fallen out of favour as its formulation constantly changes. However, this material is widely available in all hardware stores in the USA, and has found constant use. It is formulated as an all-purpose filler for household repairs. Films formed are relatively brittle and prone to cracking. Dried surfaces can be sanded easily and excess can be removed before curing with water.

Modostuc (Plasvero International). This is an Italian brand which has become very popular with conservators worldwide. The inert content is a combination of calcium carbonate and a small amount of barium sulphate. The binder is a polyvinyl acetate and an acryl ester. It is likely that almond oil is added during manufacturing as a preservative.[52] The formulation is subject to periodic change. The product is designed for filling of plaster, wood and ceramic surfaces. It comes in a wide range of 'wood' and 'stone' colours. It is available in both tub and tube format. The tube variant has a longer shelf-life. It has optimal handling properties, can be applied straight from the container using a spatula or thinned with water and applied with a brush. Some conservators add a drop of adhesive to increase its flexibility, and it can be thinned with water, if application with a brush (for example to create texture) is required.[53] There is very little shrinkage on drying. Hardened films can be carved or sanded. The dry film remains reversible in water, as well as acetone and ethanol, and is compatible with aqueous media. Modostuc is also relatively cheap and be found through many conservation suppliers.

Quick Drying Wall Filler (Alabastine; Akzo/Nobel). This is a Dutch brand which is finding popularity in the BENELUX area. The filler is designed for filling small holes in wall plaster, and attaches well to stone, concrete, gypsum plaster, and wood. It claims to dry, crack free, within 15 minutes and can be sanded and cleared with water. On drying it forms a hard film which can be drilled. It takes all types of paint well. It is available also in a tub or tube, and as a powder that can be dissolved in water prior to application. Akzo/Nobel produces a wide range of other fillers for different purposes. The *All Purpose Filler* is light weight, likely to contain glass microballoons. It is crack free on drying and can be used for filling deeper gaps.

Epoxy-based fillers

Epoxy-based fillers are often used within the conservation field for harder surfaces such as metal, stone, ceramic or glass. However, at times, these commercial may also be appropriate for painting conservation, especially modern art with mixed media. Epoxy adhesives cure by chemical reaction. Typically, these are sold as a two-component adhesive – one container holds the active ingredient, which can be bulked out with a filler or pigment, while the other holds a catalyst, that starts the chemical reaction on contact with the active ingredient. These adhesives barely shrink on curing as no solvent component is included in the formulation. Different polymer chain lengths of epoxy and different functional groups lend a wide range of stiffnesses to the cured film. Contrary to belief, the cured film can be solvent sensitive, but typically only to high polarity solvents. Many can be carved or sanded on drying. Most removal is however achieved by mechanical means and aged epoxy resins, especially if a higher molecular weight variant was utilised, are harder, stiffer materials than their acrylic or vinyl counterparts. Epoxy-based fillers are therefore more useful as a structural fill for panel paintings.

Milliput (Milliput, United Kingdom), was introduced in the late 1960s. It is a two-part epoxy putty that is sold in a dual stick form. It is prepared by kneading equal portions of each stick together until homogenously mixed. Once mixed it has an open time of around 1 hour (depending on ambient temperature). It shapes readily and can be packed into deep crevasses or used to form edges of missing sections. The surface can be smoothed with

[52] Information obtained from James Bernstein as provided in his workshop manual 2017.
[53] Note that this will impact its drying and shrinkage properties.

Milliput epoxy putty.

acetone before drying. Excess can be cleared with water (before curing). Curing takes between 2-3 hours. The hardened film is resistant to most solvents but will swell in acetone if poulticed. It can be sanded, drilled, cut or filed when hard. It adheres well to wood, metal, plastic, glass and porcelain. It is available in pure white, yellow-grey, silver grey, black and terracotta colours and can be tinted with dry pigments. Most paint binders attach well to the surface though it is a little porous. It has found common use for repair of household goods, but in the conservation field it is particularly liked by frame and porcelain conservators as it can be used in casting of mouldings which can be attached with PVA or other adhesives as desired. The unmixed sticks will remain un-altered for considerable time.

Araldite 2020 Adhesive Core Range (Araldite/Huntsman) has been on the market for the past 40 years. It is designed for a wide range of bonding purposes, but has specific use for bonding glass and ceramics. It is a two-part system with the resin (2020/A) and hardener (2020/B) mixing in non-equal parts – ratio 10:3 weight/weight. It is transparent, has a low viscosity and is slow setting. The cure time is about one hour. It can be cast into silicon moulds and used to replace solid sections of missing materials. This makes it more suitable for structural conservation and frames.

Araldite 2020

Fillers designed for the conservation field

Very few commercial fillers are designed specifically for the conservation field and, in particular, for paintings conservation. Typically, the conservation discipline borrows from other fields.

Examples of conservation grade commercial fillers are:

Berger's BEVA Gesso (Conservator's Products Company CPC) comes in two forms, Gesso-V and Gesso-P, both of which were introduced in the late 1990s in the USA. They are manufactured by the company who holds the patent from Gustav Berger in the USA. Today, they are also sold in Europe, but their use is not widespread. The Gesso-P binder is a combination of vinyl copolymers – the formula is undisclosed but likely to be hydrogenated hydrocarbon resins and an (dispersion) ethylene-vinyl acetate copolymer (EVA). The formula includes a chemically inert mineral powder, a pH buffer, oxidation inhibitors, UV stabilizers, as well as the vinyl resin. The formula is similar to but not identical to BEVA 371 which does not contain a dispersion EVA. BEVA Gesso-P can be used to fill shallow losses, and its consistency manipulated for thicker or thinner applications. It can be shaped or textured while wet, or when dry with heat (65-75°C) and pressure. BEVA Gesso-P is translucent when wet, but will dry white. The inert component is likely to be chalk. Pigments can be added to the mixture to tint it.[54] BEVA Gesso-V has a rougher more granular consistency similar to sand, with mica powder content. Films formed are highly elastic and will adhere well to wood, cardboard, canvas, mosaics, plastics, metal, paint, etc. All paint media can be applied over these fills and it can be easily burnished and gilded, but also sanded and textured to a rougher finish. Films can be removed with aromatic hydrocarbon solvents and it will swell slightly in low-aromatic petroleum solvents. It is

[54] See Raquel Marques and Leslie Carlyle, Further developments on the use of BEVA® Gesso-P infills and solutions for reintegration of a large loss in Conference Proceedings from 3rd International Meeting on Retouching of Cultural Heritage (RECH3). 2015

BEVA Gesso-P.

thermoplastic (65-75°C) and films can be manipulated with heat. Thus, silicon moulds can be impressed with heat and pressure to texture surfaces. Some concerns arise around BEVA products, due to the necessity of aromatic solvents for removal.

Pigmented Wax/Resin sticks (Gamblin, Gamblin Colors, Portland), introduced in the 2010s. This material (PW/R) is gaining popularity as it is easy to apply. The formula was developed (for the conservation field to enable conservators to fill losses in paintings) at Buffalo State College Art Conservation Department under the leadership of James Hamm and research carried out by Christina MacIntyre.[55] Videos are available on Vimeo giving detailed instruction on use.[56] The wax/resin sticks can be easily handled and applied using relatively low temperatures (c. 40°C). The edge of the stick is placed adjacent to the loss and gently heated. The melted wax/resin pours into the loss filling the crevasse. A narrow tip and small shovel-shaped heated spatula make the best instruments to apply the filler sticks. Gamblin recommend using the Whipmix Wax Carving Pencil[57], however, dental tools can be self-heated on a hot plate or USB-coffee warmer. The warmed dental tool is used to compress the cooling wax/resin and spread across the desired area. The texture of the surface can be manipulated on application by carving or imprinting with a silicon mould taken from an appropriate surface. Cracks

[55] *https://gamblincolors.wpenginepowered.com/wp-content/uploads/2016/01/McIntyre_695_To_Gamblin_2014.pdf*

[56] Gamblin Pigmented Wax/Resin Sticks: *https://vimeo.com/120828910 https://vimeo.com/120827683 https://vimeo.com/120389040*

[57] *https://www.whipmix.com/products/digital-dental-wax-carving-pencil/*

Gamblin pigmented wax sticks

and other physical irregularities are easily replicated using dental tools. Application can be quite accurate, so little clearance is required. The fill remains soluble in low-aromatic hydrocarbon solvents. There is little ghosting. The pigmented wax/resin sticks come in a series of 12 colours and can also be bought in a neutral tone to which pigments can be added. However, some pigmented sticks do develop bloom over time due to the beeswax component.

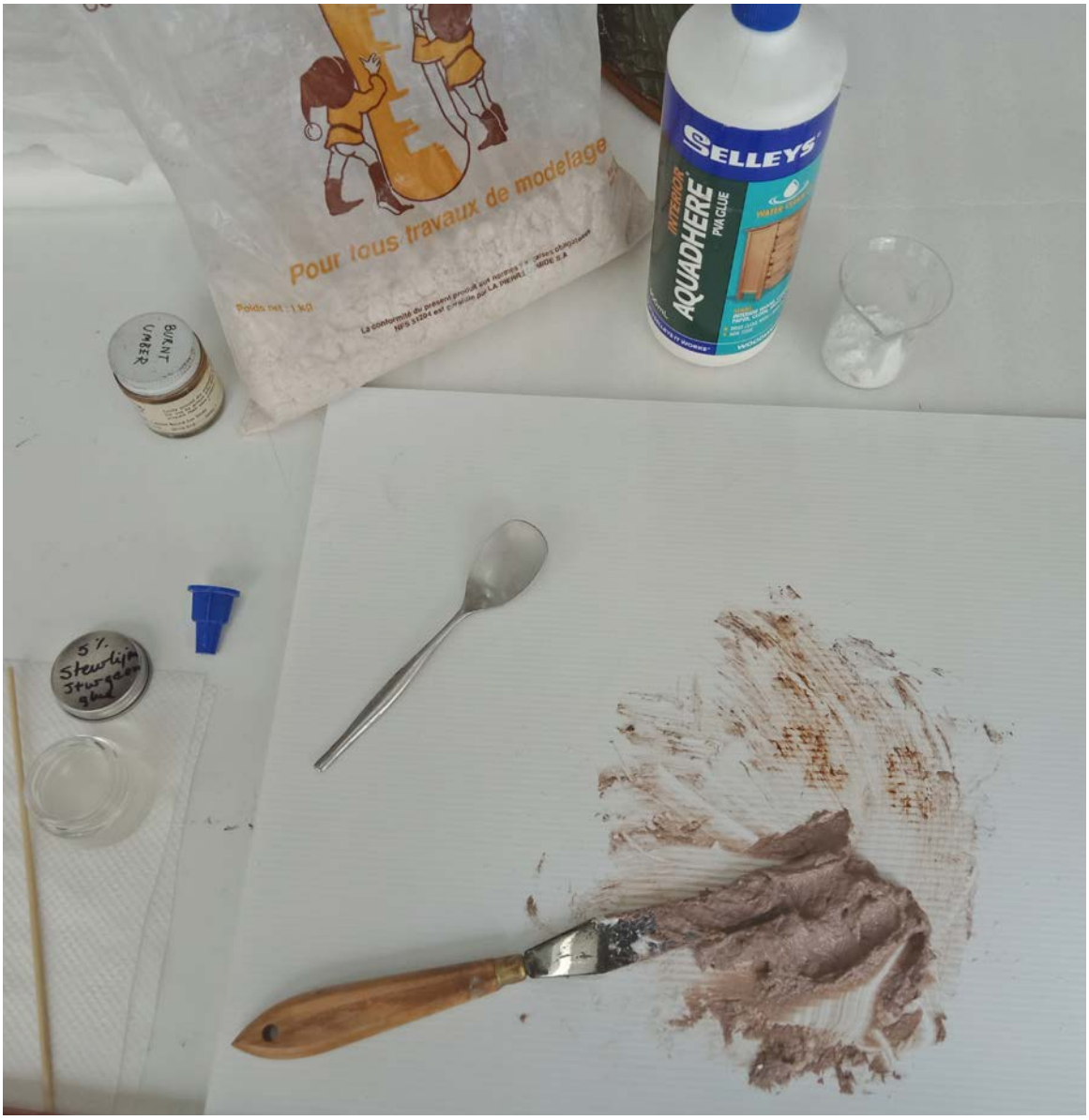
Studio Formulation Fills

Many conservators continue to create their own fills. The benefits of this include the ability to control exactly the ingredients and proportions of the various fill materials, and to create the desired amount required, minimising waste. Many conservators are therefore able to adapt traditional fill recipes to comply to the ethical considerations stated earlier. Typically, today studio formulations often combine traditional inert compounds with modern, synthetic polymers to create fillers. However, simple traditional formulations of simple binary combinations are still widely used.

The following ingredients are commonly used in fillings for paintings:

Bulking Agents

Chalk: calcium carbonate ($CaCO_3$) or whiting/Champagne chalk: this can be bought as a powder and is made of chalk/ground marine shells/ground eggshells, limestone dust, marble dust etc. Its refractive index is between *n* 1.50–1.64, which is relatively higher than that of animal glue (*n* 1.348) or acrylic dispersions (*n* 1.465-1.491) or vinyl emulsions (*n* 1.467).



The benefits of homemade fills include the ability to control the exact proportion, and therefore properties, of the fill, and to create the desired amount required, minimising waste.

Gypsum: calcium sulphate ($CaSO_4.2H_2O$) or gesso/alabaster: this product can also be bought readymade as a bulking agent, and is known as calcium sulphate dihydrate, or plaster of Paris. It may have impurities, such as quartz or selenite, according to the source. It has a refractive index of *n* 1.558-1.586. It can be bought in powdered form, and when mixed with water it reconverts to hydrated calcium sulphate and sets in the process. This mixture does not shrink upon setting, in fact it expands slightly, meaning its use should be avoided for closed or limited voids.

Note that Bologna Chalk is a natural mixture of calcium carbonate and calcium sulphate.

Kaolin: hydrated aluminium silicate ($Al_2H_4O_9Si_2$): this is a type of clay, sometimes known as China clay. It is white in colour and has a very fine particle size. Its refractive index is between *n* 1.549-1.565. Its relatively low refractive index results in off-white mixtures with most binders and a slight translucency. Other types of clay that can be used include pipe clay and bole (a terracotta coloured, very refined, fine clay). Bole is used for water gilding and can be obtained wet or dry.

Calcium Carbonate.

White Kaolin clay powder is available from many health food and beauty shops and websites.

Aluminium oxide powder

Table with refractive indices and oil absorption ratio of inert bulking media

Bulking media	Refractive Index	Oil absorption (mL/100 g)
Chalk (whiting)	1.59	16-18
Kaolin (China clay)	1.47-1.6	55-70
Gypsum (gesso)	1.52-1.53	38
Barytes (Barium sulphate)	1.64	15-20
Zinc white (zinc oxide)	1.929	15
Titanium white (titanium oxide)	2.614	20
Aluminium oxide	1.77	30

Barytes/Barite: barium sulphate ($BaSO_4$): this product can also be sourced as a powder. It was commonly added to grounds and paints as a bulking agent. It is heavier than chalk and has a refractive index in the range of *n* 1.636-1.648. As the refractive index is higher, it often has good opacity in paints or bound in a medium, and thus has good hiding power.

Alumina: Aluminium(III) oxide / hydroxide (Al_2O_3): this fine white powder which is inert and lightweight that can be used as a bulking agent for fills. It has a refractive index of *n* 1.7598. This high RI means it retains its pure white colour when bound in most vehicles. It is sold under the tradename Portafil A40, and as such finds its way into many latex (acrylic) house paints.

Silica/quartz: silicon dioxide (SiO_2): this white powder often contains mineral impurities. Its refractive index is *n* 1.543–1.545. It has a semi-translucent colour, especially when bound in media. Quartz can be found in grounds as a natural impurity of calcium minerals, but it can also be added to increase transparency or alter properties of the ground. It can also be added to fillers for the same reasons.

Glass microballoons/bubbles (borosilicate glass): these glass hollow microspheres or beads are very light, with an average grain size of 46 µ, and largest particle bubbles of 200 µ. They can be added to fillers at high volumes to reduce weight. Soda lime glass beads are solid and heavy. These may be added to gesso's or primers for surfaces. Glass microballoons can also be added to fillers as a finely ground powder. Different grades are available. Glass fillers are often found in commercial light weight fills which shrink less on drying. Note that handling glass can be hazardous, precautions should be taken.

Arbocel: cellulose fibres: this fluffy, powdered cellulose can be purchased in different fibre lengths. It is hydrophilic and will partially swell in water without dissolving. It is used as an inert filler for bulking fills. Fills containing this material may shrink on drying. It is sold by conservation suppliers in a number of grades: Arbocel BC

Ingredients for Arbocel filler (Image credit: Kate Seymour, SRAL).

1000 (0.7 mm), Arbocel PWC 500 (0.5 mm), Arbocel BC 200 (0.3 mm), and Arbocel BWW 40 (0.2 mm). Some variants can be bought already pre-mixed with calcium carbonate. Arbocel fibres can be added to fills to create a lightweight filler but this will mean that the fill retains a certain hygroscopicity.

Cellulose ethers: are available in many different grades as white powders. Each has different properties according to their specific functional group. Typical brands available are Tylose MH 300 P2 (methyl hydroxyethyl cellulose), Tylose MH 1000 P2 (methyl hydroxyethyl cellulose), Methocel A4M (methyl cellulose), Benecel A4C (methyl cellulose), Klucel E (hydroxypropyl cellulose), Klucel G (hydroxypropyl cellulose), Klucel H (hydroxypropyl cellulose), Culminal MHPC 20000 (methyl hydroxypropyl cellulose), Ethyl cellulose ET200 (ethyl cellulose) or Cellulose Thickener C6000 (sodium (Na)-carboxymethylcellulose). Each product has a different viscosity and purity, and thus price. The level of viscosity is determined by the degree of polymerisation. Viscosity will also depend on the solvent used and concentration. Only ethyl cellulose will swell in hydrocarbon solvents. Many will dissolve in alcohols.

While these materials are mostly known as binders or (low) adhesives, they can also act as a bulking agent when added to formulations and may assist in maintaining water solubility. Many dispersion adhesives, both vinylic and acrylic formulations contain a cellulose ether as a thickening agent. This includes the low molecular weight ethylene vinyl acetate emulsion, EVACON R, which was formulated for the conservation field.

Pigments: a multitude of pigments can be added or used exclusively or as a mixture to provide a desired tint or colour to the filler mixture. Note that pigments will 'absorb' media differently and some are excessively hydroscopic. Raw umber for instance will 'dry' out water-based fills and recipes may need to be adjusted accordingly.

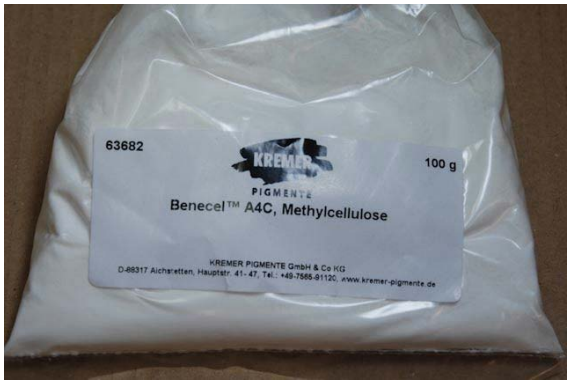
***Note** that some conservators use recipes that contain sand or silica as bulking agents for the filling material. This is advised against as both are abrasive materials, and even the action of clearing excess filing material containing these materials can result in abrasion and damage to the painted surface.*

Binding Media

Collagen glues: The most commonly used animal glues used in paintings conservation are gelatine, fish glue and sturgeon (isinglass) glue.

Paraloid B72: this resin is a copolymer mix of 70% ethyl methacrylate and 30% methyl acrylate. It is a relatively stable resin and has many different uses in paintings conservation.

Cellulose ethers: see above. These materials are commonly used in conservation as thickeners (when mixed with a solvent such as water or ethanol) and can be used as a weak binding medium for fills.



Methocel A4M and MHPC (methyl hydroxy propyl cellulose)

Animal glue (hide glue) and sturgeon glue are traditional binders used in conservation.

Vinyl dispersions: conservation suppliers worldwide provide a wide range of these dispersions. Conservators may resort to buying these adhesives as wood glues from local hardware stores. Typically, these are relatively viscous dispersions and not suitable for fillers as they produce mixtures with short curing times. Conservation suppliers do sell products that are slightly more refined such as Lineco Neutral pH adhesive, Jade 403, BEVA D8, EVACON R and Lascaux Medium for Retouching (Mowilith 30). While Mowilith DMC2 went out of production some 10 years ago, it has been replaced with Mowilith DC (Celanese) as a binder for PVA paints and can also be used as a binder for fillers. The Mowilith tradename is patented to Celanese Emulsions (Germany).

- *Lineco Neutral pH adhesive* (Lineco): this is an acid free adhesive which has excellent lay-flat properties and dries to a clear film. This is fast setting and re-moistenable with water. It is specifically formulated for the conservation field and is now being used in thread-by-thread tear mending. It does not become brittle on age and will bind to most porous or fibrous surfaces.
- *Jade 403(N)* (Jade Adhesives, USA). This is a common PVAc adhesive that is resold by numerous conservation suppliers with their own labelling though maintaining the product name. It is composed of an 80/20 vinyl acetate/ethylene copolymer with a 50% solids content. It is pH neutral but has been found to be a low acid emitter. It is used in bookbinding and paper conservation fields as an adhesive, but can be used also as a paint or filler binder.
- *BEVA D8* (Conservator's Products Company CPC): this is an aqueous, non-ionic dispersion based on ethylene vinyl acetate emulsified by a volatile solvent material. It is a viscous material that produces a film of a greater flexibility than the better-known BEVA 371. It requires an aromatic hydrocarbon solvent to dissolve once the original solvent content has evaporated. It dries to a colourless film which is not soluble in water. It is typically used for lining or striplining but can be added to filler formulations.
- *EVACON R* (Conservation by Design, UK): this product was also specially formulated in 1983 for the conservation field. It has a neutral pH, non-plasticised, and remains water soluble on drying. It is an ethylene vinyl acetate which contains no surfactant additives and is resistant to hydrolysis. A small amount of calcium carbonate is added, which assists stability and acidic production.
- *Lascaux's Medium for Retouching* (Mowilith 30) is sold dissolved in a solution of ethanol and acetone (7:3 volume:volume). On drying, films can also be dissolved using aliphatic hydrocarbons. The primary purpose of this solution is for binding pigments, but it can be used as a binder for fillers, though different inert compounds will need a different proportion of adhesive to create a good workable mixture.

Jade 403N is a common PvAc adhesive.

Evacon R

- *Mowilith DC* (Celanese) is not sold by any conservation suppliers but is the industry replacement for Mowilith DMC2. It is a vinyl acetate homopolymer dispersion available as white liquid. Mowilith DC is used in paper and packaging and heat seal adhesives.

Many commercial PVAc's are available as white dispersion glues. Not all commercial companies declare fully the ingredients. It is wise to carry out some home experiments, such as exposing brushouts to sunlight for a few months to determine their stability, before selecting these readily available products.

Other vinyl adhesives: Vinyl polymers can also be dissolved in solvents and used in studio formulations. PVAc adhesives come in a variety of grades according to their molecular weight. These are often combined to produce a more polydisperse mixture which gives improved handling and film forming properties.

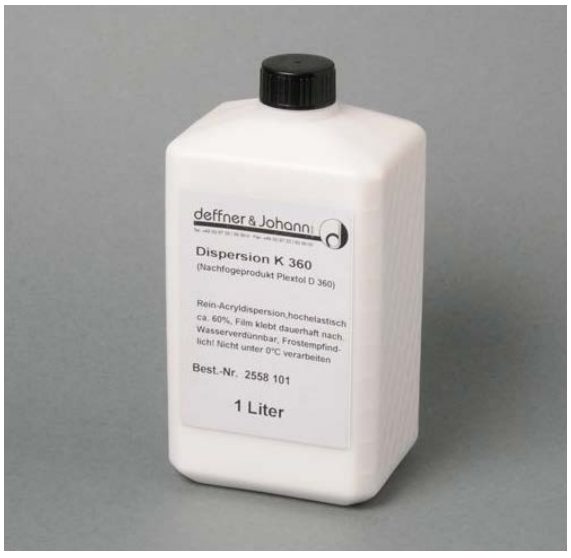
- *Mowilith 20, 30, 50* (Lascaux, Switzerland): these solid vinyl acetate polymers are used for binding paper and fabrics. They can be dissolved in ethanol (>95%), ethyl acetate, acetone, methyl isobutyl ketone and toluene. These, when dissolved in the appropriate solvent, make a good binding media for retouching paints which are resistant to most solvents used for varnishing (except for Paraloid B72). They function best when mixed to form a polydisperse solution. Inert bulking agents can be added to create a putty, but the handling properties can be challenging to master.
- *BEVA 371b* (whose formula is now based on a mixture of Laropal A81 and ethylene vinyl acetate copolymers) can be melted and mixed with kaolin. Additional micro-crystalline wax can be added to lower the melt temperature and make the resultant film more susceptible to texturing.

Acrylic dispersions: conservation suppliers worldwide provide a wide range of these dispersions. The viscosity of these tends to be less than their vinyl cousins. These are also typically lower in molecular weight than vinyl polymers and thus remain more flexible on curing but are less resistant to forces. They are greener to produce than vinyl-based adhesives. However, formulations are much more susceptible to change and discontinuation. These products are formulated for coatings and as binders for paints. Examples include Plextol B500, Plextol D 512, Dispersion K360, Dispersion K498 and Lascaux Medium for Consolidation. Solid polymers that can be dissolved in solvents are also available, such as Paraloid B72 and Plexisol P550. Certain well known Plextol variants (Plextol D360, D541, D540) are now discontinued. The Plextol brands are a patented trademark of Synthomer (Germany).

- *Plextol B500* is an acrylic copolymer consisting of ethyl acrylate/methyl methacrylate. It is typically used as a dispersant, thickening agent and sizing agent for inks, paints and used as an adhesive for textiles and paper-making. It can also be found as a cast thin film used as a heat set adhesive for backing paper. Films formed are no longer soluble in water, but can be swollen in alcohols or aromatic hydrocarbons. Other variants, such as Dispersion K 500, exist and produced by other manufacturers. Less content information is known for these alternative acrylics. Plextol B500 can be used as a

Plextol B500

Lascaux Medium for Consolidation



Dispersion K360

binder for fills, but dependant on the inert compound can produce a putty that is difficult to handle as it dries relatively swiftly.

- *Lascaux 498-M, Lascaux 498-HV, Lascaux 303-HV* are three acrylic adhesives produced by Lascaux Colours (Switzerland) as binders for paints. All of which are dispersion acrylic copolymers. The latter two products are thickened with acrylic acid ester. All are pH stabilised around 8-9 and have preservatives added which increase their shelf life. Alternative variants are produced by other manufacturers and sold by conservation suppliers. These include Dispersion K498, which is unthickened. Again, due to the pigment-binder ratio needed to achieve a workable putty, these materials may not be very suitable for filler components.
- *Dispersion K360* is a low molecular weight acrylic dispersion that remains elastic and tacky. It is good to combine this adhesive with others in the acrylic dispersion range to increase stiffness and reduce tackiness.

As with their vinyl equivalents, many commercial products are available on the market designed for the paint or coating industry. It is best to select a known brand paint medium if you are unable to obtain any of the above-mentioned brands. Most artist acrylic paint manufacturers will have one or two versions in their product range. It is recommended to test these before use, by for instance exposing a brush out to sunlight for a few months to determine the product's stability.

Other acrylic polymers are sold in pellet form or pre-dissolved ready for use. This includes organic solvent solutions of Plexisol P550 (now called Degalan or Acrylic Resin P55). This is a copolymer based on butyl methacrylate. This product can be used as an alternative to acrylic dispersions if water is undesired. Paraloid B72 can also be used as a binder or co-binder for fillers though again its molecular weight is too high to make it useful for this purpose.

Vinyl and acrylic polymer mixtures are also produced by the coatings and adhesive industry. These products have also found their way into the conservation field.

- *Dispersion Acronal 500D* is produced by BASF, Germany as a binder for paper and board. This is an aqueous, anionic dispersions of a copolymer of n-butylacrylate and vinyl acetate. Its Tg is slightly higher than an equivocal acrylic dispersion and thus films formed are slightly stiffer and more resistant to forces.
- *BEVA 371*: In 1975, Gustav Berger introduced BEVA 371 to the field of conservation. BEVA 371 is a mixture based on ethylene vinyl acetate (EVA) and is soluble in aromatic hydrocarbons, which makes it potentially suitable for paintings that are water sensitive. BEVA 371 is a very versatile product, it was created as a synthetic lining adhesive for use on vacuum hot tables, and is also used as a consolidant. Since 2010, Laropal A81 (an aldehyde resin) replaced Laropal K80 (Ketone resin 'N'), which was used in the original formula.[58] BEVA 371

[58] Ploeger, R., Rene de la Rie, E., McGlinchey, C.W., Palmer, M., Maines, C.A., Chiantore O. The long-term stability of a popular heat-seal adhesive for the conservation of painted cultural objects. *Polymer Degradation and Stability*, (2014), vol. 107 pp 307-313.

comes in a number of forms: in dry pellets, pre-dissolved in solvents and as a thin film.

Waxes: Microcrystalline waxes or beeswax can be added to other resins and used in thermoplastic fills. Some microcrystalline waxes may be too soft to use independently as a binder and may be better suited as a co-binder or minor additive in a studio formulation.

- *Microwax* (Kremer Pigmente, Germany): this product is designed for use in the wax decorating industry. The product sticks well at 35°C and is solvent free. It takes up pigment well and can be added to resin-based formulations to lower the melt temperature.
- *Cosmoloid H80* is an acid free wax used for metal preservation. It is colourless and easily dissolved in aliphatic solvents. It can be pigmented. It is best used as an additive for resin coatings or to drop the melt temperature of formulations. It is one of the main components of the NOVA Pigmented Wax-Resin formulation. It has a melt temperature around 70°C.
- *Lascaux-Klebewach* (adhesive wax) 443-95 (Lascaux Colours, Switzerland). This is a mixture of a micro-crystalline wax and a synthetic polyterpenoid resin developed as an alternative to traditional wax-resin adhesives for lining paintings. It can be added to thermoplastic formulations to lower the melt temperature. It has a melting point of 68°C.

Lascaux microcrystalline wax

Other resins typically used as coatings, varnishes or binders for retouching pigments can also be used as a binder for fill materials.

- *Laropal A81* (BASF, Germany) is an aldehyde resin which is soluble in circa 40% aromatic content as well as alcohols. It has found widespread use as the retouching medium for *Gamblin Retouching Colours*. It has a softening range of around 90°C.
- *Regalrez 1094 and 1126* (Hercules, USA) is a low molecular weight hydrogenated hydrocarbon resin which has found popularity as a coating. The higher molecular weight variant is commonly used by furniture conservators while the lower molecular weight resin is more popular with painting conservators. Regalrez 1126 is the main component of the NOVA Pigmented Wax-Resin formulation.

Additives

Pigments can be added to colour the fill. Choosing a colour that is similar to the original ground colour gives the added benefit that subsequent retouching can optically imitate the original paint layers. A small amount of pigment can be added to the fill, or a thin coating of gouache, watercolour or synthetic retouching paint can be used to tone a white fill. Only small amounts of pigment should be used, as pigments with a high siccative working can embrittle the fill material and increase its absorbency. If the original artwork has dark cracking, this can be imitated by using a dark toned fill, with a cracking pattern etched through the final retouching layer(s) with a needle, scalpel or other sharp instrument.

Filling Recipes

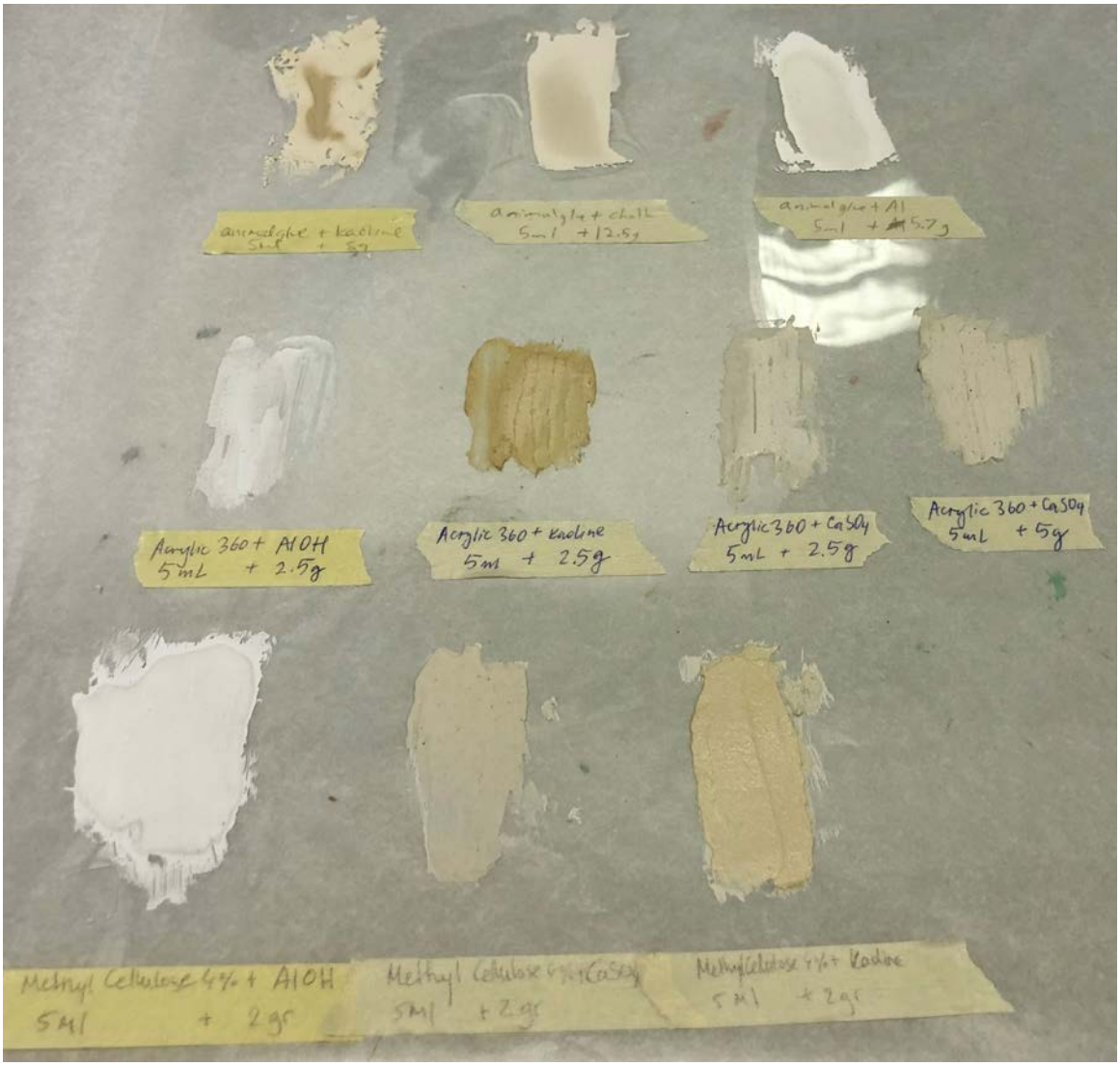
This section includes a number of recipes that can be used to make studio formulations. The ingredients and proportions can be adjusted as required. Even subtle shifts in the recipe can have an effect on the workability and long-term behaviour of the fill. It is worthwhile experimenting with recipes and making minor adjustments to master the potential of each fill type. Sample batches of fillers can be made, with modifications to the ingredient proportions. These can be applied to different surfaces, such as wood, textile, paper, Melinex etc, to explore and monitor behavioural tendencies and as a reference for future use.

None of the recipes provided are structural fillers – all should be used to fill superficial losses. Gap-filling systems for structural repair of canvases and panels is described in the brochure on *The Structural Conservation of Canvases and Panels*.

Water-based Fillers

- Water based fills can be applied either as a fluid with a brush or as a paste with a spatula. Considerable shrinkage is to be expected of the fluid versions and cracking may occur in the pastes.
- Water based fills can be carved using dental tools to give texture, or surface texture can be built up by moulding or applying layers of the diluted filler.
- Excess fill material can be removed using water and a cotton swab. A damp chamois leather cloth stretched over a cork or piece of balsa wood can be useful for removing excess filler.
- It is best to apply these water-based fills after varnishing to prevent ghosting. Ghosting occurs as the small (white) particles are pushed and trapped in cracks surrounding the loss.
- Many water-based fillers will need isolation with a resin (varnish) to modify the porosity and prevent the retouching medium or varnish from sinking in.

A commercially-made (Modostuc) fill is being thinned with water before being applied to the loss.



It is worthwhile experimenting with recipes and making minor adjustments to master the potential of each fill type. Here various types of fills are being tested for their drying and handling properties.

Recipe for Traditional 'Colletta' filler:

10 g (rabbit) skin glue
180 g water (tap water is suitable)
Calcium carbonate ($CaCO_3$)

To prepare the 1:18 solution of 'colletta', take 10 g of skin glue and swell in 180 g cold water overnight. Once the glue has swollen, the container can be suspended in *au baine marie* water-bath. Be careful not to let the solution boil as this will denature the animal glue. The temperature should not exceed 60°C. The glue will dissolve creating the 'colletta'. A preservative can be added if desired at this time.

Some recipes also call for plasticisers, such as molasses, though this will affect the mechanical behaviour of the 'gesso' (and may attract insects or other undesired pests/fungi under the right atmospheric conditions). Pre-sieve the calcium carbonate or Bolognese chalk (a natural mixture of calcium sulphate and calcium carbonate). Add the fine powder to the 'colletta', while the solution is still warm, until no more powder can be dissolved into the liquid. Mix carefully periodically with a wooden stick. Be careful not to allow air bubbles to be formed in the mixture. If a denser version is required, continue to add the inert powder until a putty consistency is reached.

Recipe for filling losses on a panel painting:

This recipe is suitable for filling shallow losses in panel paintings (not structural losses). The filling material is easy to manipulate and has the flexibility to move with the panel as it responds to environmental fluctuations. It has minimal shrinkage on drying.

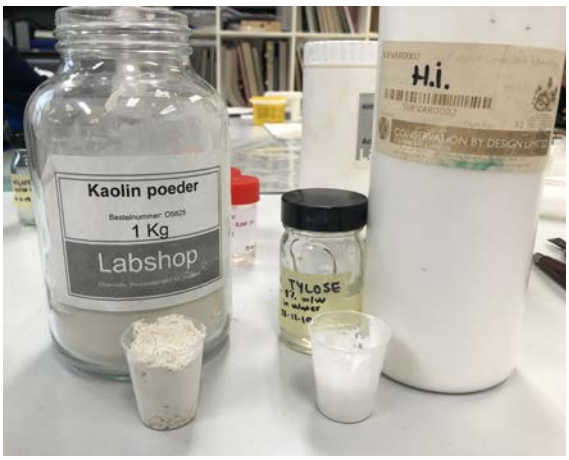
1 g sturgeon glue (or 1 g gelatine can also be used)
9 mL water (tap water is suitable)
1 pea drop size amount of PVA glue
59 heaped teaspoon of chalk (calcium carbonate) ($CaCO_3$)
Pigment (if required)

Warm the water in a small beaker and dissolve the sturgeon glue in it. Add the drop of PVA glue and stir until mixed. Add the chalk and a small amount of pigment (if required) and kneed to a ball (stiff but still pliable). The consistency is right when the ball can bounce. Keep this in clingfilm or plastic film, and warm with your hands (to help pliability) when needed. The chalk content can be replaced with kaolin or aluminum hydroxide (Portafil A40) (Al_2O_3). Note that the consistency of the finished result will be different due to the divergent absorbency (pigment volume concentration) of the different mineral content.

Recipe for filling larger losses on a canvas painting:

25 g Tylose C300 (cellulose ether) (using a 4% solution in water)60
5 g EVACON R (EVA)
60 g Aluminium hydroxide (Portafil A40) (Al_2O_3)
Pigment (if required)

This recipe is also useful to fill larger losses in a painting. Prepare the Tylose C300 in cold tap water (4% solution). Leave the mixture overnight to ensure that the cellulose powder is fully swollen in water. Weigh 25 g of the prepared solution of Tylose C300 and place in a larger beaker. Place the container with Tylose C300 on the scale and add 5 g of the liquid Evacon R. Stir the two adhesives until an even consistency is achieved. Weigh the Portafil A40 separately and place the powder on a grinding slab (marble or glass). Mix in the adhesive into the powder, first with a small pallet knife and then more vigorously with a larger flat-edged putty knife until there are no lumps of powder left and each pigment particle is encapsulated by the adhesive. Add pigment if necessary. Note that the amount of the Aluminium hydroxide may need to be adjusted slightly if you want a densely coloured filler. Place in a lidded container. To keep the prepared filler longer, you can place a wet tissue directly on the surface leaving no air gaps. Store in a cold environment.
The mixture can be used for a number of days if kept damp. Watch out for mould growth if kept damp! Use clean tools to remove the amount of filler needed from the stock to ensure a longer shelf life.



Ingredients for Evacon R filler. (Image credit: Kate Seymour, SRAL).

An alternative recipe:

15 mL EVACON R (EVA)
85 mL Water
60 g Mica (Phyllosilicates)
40 g Chalk: calcium carbonate ($CaCO_3$)

Mix the EVACON R and water together. Then mix the Mica powder and the chalk. Mix all the ingredients together until a stiff consistency is obtained. Note that this filler will be slightly more brittle than the above mixture as it has a higher portion of inert fill ingredients.

[59] We recommend using a well-known brand of PVA glue, such as Lineco Neutral pH adhesive (Lineco), Jade 403(N) (Jade Adhesives, USA), Mowilith DC30
[60] Note that cellulose ethers such as Klucel G, Tylose MH300 or Methocel A4M can be used instead of Tylose C30.

Lightweight fillers for deeper small losses:
Deeper losses in panels and canvasses may require a filling material that has minimal shrinkage. The following filling recipes can be used as a bulk filler for deeper losses, with another type of fill applied superficially, as required.

Klucel-based light-weight putty:

This filler has minimal shrinkage and can be used for deeper losses. Ethanol is used instead of water, allowing this filler to be used on water sensitive surfaces (though we recommend testing before application to such paintings). Alternatively, water can be used.

7% Klucel G, hydroxypropyl cellulose, in ethanol
1 part 3M Scotchlite glass microballoons (volume)
1 part cellulose fibres (volume)

Prepare a 7% weight to volume solution of Klucel G in (99.9%) ethanol. In a separate container mix 1 part 3M Scotchlite Microballoons with 1 part cellulose fibres (use either Whatman CF11 cellulose fibers or Arbocel 500). Add the microballoon/cellulose fibre mixture to the adhesive until a putty-like consistency is reached. Prior to application, the surrounding area can be isolated with a temporary varnish coating such as Regalrez 1094 or application can take place after the initial varnish coat. Lacunae can be filled to a slightly lower level than the surface, and a skim surface filler of choice can be applied on top of the dried bulk filler. Variations using other types of cellulose ethers or fibres can produce stiffer or more dense fillers.

EVA light-weight putty[61]:

ca. 25 g Methocel A4M: methylcellulose, 3% in water
ca. 5 g EVACON R (EVA)
Arbocel 500, cellulose fibres
Aluminium hydroxide (Portafil A40) (Al2O3)

Prepare the 3% weight: volume Methocel A4M solution in water overnight to ensure that the cellulose powder has fully swollen in the water.

Place 25 g of the Methocel A4M in a container and place on a scale. Add in the EVACON R to the Methocel A4M and stir until an even consistency is achieved. Different proportions of Arbocel 500 / Aluminium hydroxide can be formulated depending on the depth of the loss. For deeper losses, we recommend more Arbocel 500, for shallow losses this ingredient can be left out entirely. Bulk out the adhesive until the desired consistency is reached. Again, depending on the loss, a putty-like mixture may be beneficial for filling small deep losses (such as nail holes or wormholes). Other loss types may require a more liquid version that will flow into the void. Some shrinkage may occur on drying so it may be beneficial to apply this filler in multiple layers. The aluminium hydroxide can be substituted by kaolin and/or chalk.

Ingredients needed for a lightweight filling with methylcellulose, Evacon-R, Arbocel 500, Aluminium hydroxide and pigment.

Liquid ingredients are measured and mixed thoroughly before adding the dry components. Liquid ingredients are methyl-cellulose (Methocel A4M) and Evacon R (Preservation Equipment)

[61] Vicente M., Alapont B., Molenaar C., Seymour K., Innovative approaches for the re-integration of fifteenth-century Spanish panel paintings, *RECH6 - 6th International Meeting on Retouching of Cultural Heritage*, Valencia, Spain | 4th-6th November, 2021 Doi: https://doi.org/10.4995/RECH6.2021.13516

Dry ingredients are measured: Arbocel 500 ($CaCO_3$) and pigment (burnt umber). These are mixed with the wet ingredients.

Mix the ingredients well.

The filling (dark brown in this image) is ready. After testing on a small location, it can be adjusted as necessary. with additional arbocel or pigment. (Image credits: Kate Seymour, SRAL).

Aquazol 'light-weight gesso' recipes[62]:

28 g Aquazol 200 (15% in water)
0.8 g Alpha Cellulose (Sigma Chemicals) or Arbocel 500
3 g 3M Scotchlite glass microballoons
0.6 g Cabosil (fumed silica)
2 g Kaolin

This is a quick filler to make and is useful for filling deep losses in wooden substrates such as frames. Dissolve 15 g Aquazol 200 in 100 g cold water. Weigh out 28 g of the solution. Add 0.8 g of the cellulose fibres to the adhesive solution and allow to swell. Pre-mix 3 g of the glass microballoons with 0.6 g of the fumed silica and 2 g of kaolin. Add the inert solids to the fluid adhesive until the consistency desired is achieved. Use all of the solid content to reduce the tendency of the filler to shrink on drying. Overfill the loss, then burnish with an agate burnisher to achieve the desired level (preferably a burnisher that is no longer good enough for gilding because this will ruin it.) There is no sanding needed, and no dust.

An alternative recipe:

10% Aquazol 200 in water + small amount of (96%) ethanol
Calcium carbonate ($CaCO_3$)

This is a simpler variant on the above recipe that can be used for fills on paintings. It is nice and smooth with excellent working properties. Dissolve 10 g of Aquazol 200 in 100 g water and add a few drops of ethanol. Sieve the calcium carbonate before adding to the adhesive solution. Add sufficient solid content to achieve a putty with the desired consistency. To check that you have the right consistency, brush or smear the filler mixture onto a glass plate or Melinex sheet and allow to dry. Check the dried film for cracking. To preserve this fill, keep in a lidded container.

[62] Glover H., McGinn M., Two Aquazol 'Gesso' Recipes. Technical Exchange, *WAAC Newsletter*, September 2000 Vol. 21 (Nr. 3) *https://cool.culturalheritage.org/waac/wn/wn21/wn21-3/wn21-305.html*

Adding stiffness to a filler

Increased rigidity and strength can be added to the water-based fills, especially the commercial ones, by using Japanese paper interleafs. This can also be a useful way to create larger fills for more structural losses.
Thin layers of the filler are spread over the surface and a thin sheet of Japanese paper is applied before the filler is dry. A second layer of filler is applied over the Japanese paper. The process can be repeated a number of times to achieve the depth of fill required. These fills can be prepared in-situ but they can also be prepared away from the object and cut to the shape of the loss. They can be adhered in position with an appropriate adhesive.
The Japanese paper acts as a reinforcement and provides strength and increases stiffness, the potential for the laminate to resist the movement of the original support is enhanced and the potential to crack is reduced.

Increased rigidity and strength can be added to the water-based fills, especially the commercial ones, by using Japanese paper interleafs.

Pigmented Wax-Resin Fills

Recipe for filling larger losses on a painting which can be imprinted with texture:

3 parts BEVA 371b (volume)
1 part Kremer microcrystalline wax 62620 (volume)
2 parts Aluminium hydroxide (Portafil A40) (Al2O3)
or 7 parts Kaolin (volume)
1 part pigment for colouring (volume)

Fills with BEVA 371 as a component are thermoplastic and can be manipulated with heat to imprint a mould. They can also be adjusted with different colours.

An alternative to this recipe is:

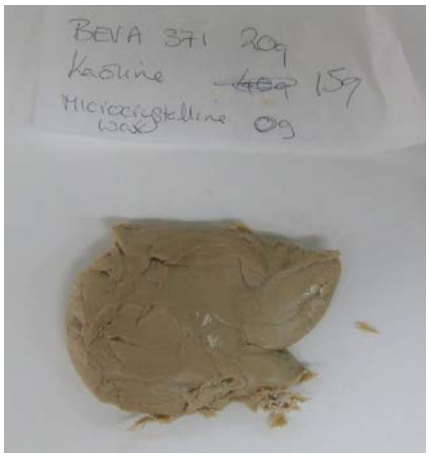
90 g BEVA 371b
60 g Kremer microcrystalline wax 62620
60 g Kaolin
4 g Titanium white
26 g Chalk, calcium carbonate ($CaCO_3$)

This is a thermoplastic filler which can be easily pigmented to match the surrounding area. In the right circumstances little to no retouching is required. Measure out the BEVA 371b and allow the solvents to evaporate out overnight. Warm the BEVA 371b on a hot plate in a metal dish and add the wax until both are melted (this is at around 90° C). Mix thoroughly but do not let the mixture bubble. Sieve in the inert filler materials gradually until a thick paste is obtained. The mixture can be placed between silicon paper sheets or Melinex and pressed when hot (90° C) to achieve a flat sheet. This is best done using a hot press, however if one is not available two metal sheets of aluminium can be used in combination with a hot plate and a heated iron. The filler is best applied using a small tipped heated spatula. The spatula is used to melt the filler in close proximity to the loss. The filler flows when melted into the loss. A larger heated spatula can be used to flatten and smoothen the surface. Final smoothing can be done at the same time as removing any excess fill with an appropriate solvent (a low aromatic content hydrocarbon solvent). The flattened thin filler can be applied directly to an insert canvas support and cut to shape, for placing in an insert.

Measure out the BEVA 371b and allow the solvents to evaporate out overnight for (for health and safety). Warm the BEVA 371b on a hot plate in a metal dish and add the wax until both are melted (this is at around 90° C).

Sieve in the inert filler materials gradually.

Mix in the inert bulking materials until a thick paste is obtained.



The mixture can be placed between silicon paper sheets or Melinex and pressed when hot (90° C) to achieve a flat sheet. (Image credits: Kate Seymour, SRAL).

Filling can take place either before or after varnishing. The solvent used for removing the excess fill should not be able to dissolve the surrounding varnish if this coating is maintained. Silicon moulds can be placed and pressed onto a warmed surface after the fill has been inserted into the desired location. Pressure must be applied when the filler is heated so that the mould imprints. The surface can become burnished and glossy, but can be easily made less glossy by placing a sheet of baking paper over the surface and warming it slightly (Note that this action is best carried out before any texture is imprinted into the surface). Most water-based retouches cannot be applied over this fill, though acrylic colours do bind well to the surface. All synthetic retouching resins will adhere well to this surface.

An alternative pigmented wax-based recipe:

1 part (weight) 'Be Square 195' (Petrolite white microcrystalline wax, melting point 91°C)
1 part (weight) Polywax 500 (white polyethylene Carnauba wax, melting point 85°C)
Pigment, as required

This filling recipe is often used for filling losses in wooden objects such as frames. Measure out equal weights of the two microcrystalline waxes. Place in a metal dish and heat to the highest melt temperature (ca. 95°C). Mix the two molten waxes thoroughly. Add the pigment(s) to obtain the colour desired. Allow to cool in sticks. Other waxes, such as Cosmoloid H80 can replace one or both wax contents to adapt the stiffness of the resulting filler.

The fill can be applied using a heated spatula or needle. The heated wax filler will flow into losses. A heated wax pen can be used to apply delicate texture. The surface can be finished off and flattened or sculpted with a small tipped heated spatula. Excess fill can be removed with a low-aromatic content hydrocarbon solvent. All synthetic retouching resins can be applied on top of these fills.

Another alternative pigmented wax-based filler:

95 g Multiwax W-445 (Witco)
185 g 'Be Square 195' (Petrolite white microcrystalline wax, melting point 91°C)
Chalk (Calcium carbonate, $CaCO_3$)
Pigments, as required

This wax-based filler can be prepared in the same manner as above, by melting the wax, mixing them when they are molten, and adding the chalk and pigment.

Gamblin Formulated Wax-Resin Retouching Sticks[63]:

This is a commercial adaptation of a formulation used predominantly in the USA as a pigmented wax resin. The original formula consists of:

3 parts Beeswax (weight)
1 part 'Be Square 195' (Petrolite white microcrystalline wax, melting point 91°C) (weight)
1 part Laropal A81
5 parts pigment (weight)
(Total parts: 10)

Laropal K80 (a ketone resin) was originally used, but is now discontinued. It has been replaced with Laropal A81 (a urea aldehyde resin).

Gamblin produce the reformulated filler in twelve different shades and as a series of greys. This recipe can also be formulated in the studio. The resin content should be crushed into a powder before adding to the melted wax. Pigments can be sifted in, to colour as desired. Heated small tipped spatulas or hot needles can be used to apply the fill. Excess fill can be removed mechanically or with a low aromatic content hydrocarbon solvent. Textures can be built up or carved in to the surface. All synthetic resin retouching media will bind well to the surface. Note that the beeswax content may bloom, especially when combined with some of the heavy metal-containing pigments.

[63] *https://gamblincolors.com/conservation-colors/pigmented-wax-resin/* **Technical research paper:** McIntyre C., *DEVELOPMENT OF A PIGMENTED WAX/RESIN FILL FORMULATION FOR THE CONSERVATION OF PAINTINGS*, May 13, 201

NOVA Pigmented Wax-Resin Filler[64]:

This formulation was designed as an alternative to the Gamblin pigmented wax-resin sticks. The materials selected have not shown any degradation phenomenon after rigorous testing. The filler has been field-trialled and reported, but has little use (as yet) in the conservation field.

1 portion (weight) Cosmoloid H80 wax
1 portion Regalrez 1126
Champagne chalk/ kaolin/ aluminium hydroxide (Portafill® A40)
Pigments

Place the weighed portion of Cosmoloid H80 in a glass beaker and heat on a hot plate to ~70°C-75°C. Grind the Regalrez® 1126 to a fine powder in a ceramic mortar and pestle (powdering accelerated mixing and melting). Add the weighed portion gradually to the molten wax. To facilitate incorporation, increase temperature to 85°-90°C and maintain for 20-25 minutes. Use a magnetic stirrer at this stage to ensure even distribution. Add the weighed pigments and/or fillers and incorporated gradually while stirring the heated mass. Sieve the inert materials as necessary. Application is by melting the filler into the loss area and allowing to cool. Excess is removed using aliphatic hydrocarbon solvent.

White filling materials can be adjusted by mixing in coloured pigments. This can aide the retouching/inpainting process, as less time and layers of inpainting material is required to integrate the loss. Here, a new pigmented wax-resin filler that was developed by NOVA students. Pigments were added according to desired colour. Application is by melting the filler into the loss area and allowing to cool. Excess is removed using aliphatic hydrocarbon solvent. No retouching required (in this case). Unknown artist, *Vision of H. Lutgard of Tongeren*, Oil on canvas, 79.0cm x 63.0cm, 1700-1799, Catharijneconvent Museum, Utrecht (image credit: Nikita Shah/Kate Seymour, SRAL Maastricht).

[64] Rocha Pires C., Carlyle, L., Seymour, K., Pombo Cardoso, I., França De Sá, S., An Investigation into the Suitability and Stability of a New Pigmented Wax-Resin Formulation for Infilling and Reintegration of Losses in Paintings, Journal of the American Institute for Conservation, DOI: 10.1080/01971360.2023.2172130Rocha Pires C.N.A., An investigation on the suitability and stability of a new pigmented wax-resin infill formulation to be used in the conservation of painting. *Master Dissertation. NOVA School of Science and Technology, NOVA University of Lisbon*, 2021, http://hdl.handle.net/10362/144895

Bulked Coloured Paints

Full bodied paints can be cast as sheets and used as thermoplastic fills, either heat set or solvent regenerated to fix into position. These fill types can be useful for modern surfaces or to replace lacquer layers. Many paint manufactures produce full bodied media which can be added to paints consisting of the same media. Studio formulations can also be made.

Bodied Aquazol:
1:1:1 (volume) Aquazol 50, 200 and 500 (all at 40% (w:w) in water)
Pigment

This formulation can be used with or without pigments as a filler in superficial losses. The pigment volume can be increased to form a stiffer putty-like material that can be pushed into voids. Surfaces can be sculpted, moulded or carved. The water content can be substituted with 99.9% ethanol for water sensitive surfaces. The formulation can be pigmented as desired which reduces the need for retouching. This filler dries to a semi-matt surface which can be coated with Aquazol (or most other desired coatings) to increase gloss.

A variety of Golden Modelling pastes and gels are available.

Bodied gel mediums (Golden)[65]*:*
Regular Gel Medium Matte (Golden)
Pigments

The Golden Paints manufacturer produces a series of bodied acrylic gels which can be used by artists to build texture into their acrylic paints. These can be pigmented and cast as sheets which can be heat or solvent activated for application into losses. The gels come in five consistencies varying in density and viscosity. Some dry to a glossier surface than others. The most effective gel for use as a bodied filler is the Regular Gel Medium Matt. The gel is essentially a colourless paint with a high solid content, which results in less shrinkage on the formation of a film. The Gel is bought prepared and pigment is added and mixed thoroughly to avoid any lumps of unbound particles. The mixture can be cast as a sheet and then cut into the shape of the loss prior to activating a bond. If the sheets are cast on Melinex the resulting surface will be smoother and glossier. Alternatively, sheets can be cast on baking paper which will produce a matter surface. Sheets can also be cast into silicon moulds taken of the surface of the original. Thin sheets are possible. The sheet can be activated for bonding by heating or by brush coating a solvent (alcohol or aromatic hydrocarbon) to the bonding face prior to insertion into the loss. The coloured heavy-bodied sheets can be applied on top of other fillers. Alternatively, the mixture can be applied to losses with a brush or spatula as any other filler. These materials can be varnished, though resins dissolved in high aromatic solvents will disturb and may even dissolve the Gel component when brushed on to the surface.

Texture can also be applied using transparent acrylic gels. These are applied on to the top of the fill to create texture and imitate irregularities. Acrylic gels can also be dabbed onto the fill through a piece of fabric (with the fabric then removed) to create an imitation of the fabric weave.

Application methods and texture of fills

Preparation of the loss
The successful filling of a loss involves two stages, the preparation of the loss, and the selection and application of the filling material.

[65] *https://www.goldenpaints.com/products/medium-gels-pastes/gel; https://www.goldenpaints.com/technicalinfo/technicalinfo_gelsmeds* and *http://faic.wpenginepowered.com/osg-postprints/wp-content/uploads/sites/8/2015/05/osg022-14.pdf*

When there is a large loss in the canvas, the use of a fabric insert is required, even if the painting is to be lined. Inserts help improve the adhesion of filling materials and reduce the thickness of the fill necessary, minimising later cracking. Here an insert has been added into a large loss, prior to adding a thin layer of fill.

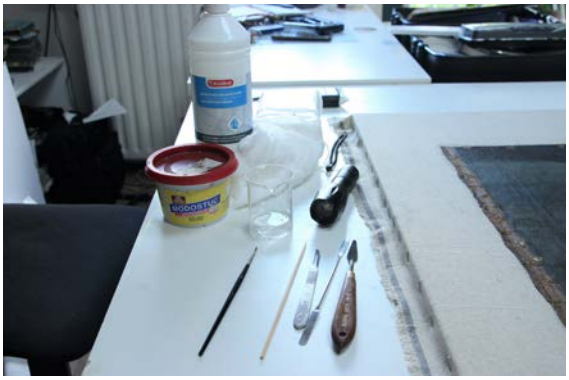
The proper preparation of a loss involves pre-treating the damaged area around the loss by consolidating any loose or flaking paint (discussed in the brochure on *Consolidation of Paint*) and treatment of the underlying support. Ideally, the original support should be clean and free from unwanted material such as previous fillings or adhesives from previous treatments (such as excess wax from a wax-resin lining), as these could inhibit the potential adherence of the new fill to the original material. It may be necessary to apply an isolating layer or priming layer to the area of loss (either a collagen glue, gelatine solution or synthetic resin), to avoid excessive absorbency of the binding component of the filling material by the underlying support, which would weaken the filler and reduce the cohesive and adhesive properties of the fill.

For panel paintings, if there is a large loss to fill, scratching the exposed wood slightly with a scalpel will help create a new 'tooth' that will enhance the adhesion of the filling material. In these cases, however, it may be best to pre-treat the exposed surface with a thin coating of an adhesive to help bond the filler to the substrate.

Application of Filling Materials

In most cases, the application of filling materials takes place after any desired cleaning treatments and before pictorial reintegration. If more intensive structural work needs to be carried out, such as lining, filling can take place either before or after this action. The decision is at times dictated by the needs of the painting and in other cases the decision is influenced by more practical time dependant reasons. It is logical however that the whole surface, if feasible, is filled in one campaign before pictorial reintegration takes place. Typically, artworks are photographically documented after filling is complete and before reintegration takes place. This allows a 'state of affairs' to be quantified, as the filled areas are typically easily visualised and this image can be used to establish the amount of loss present, also at a later date.

Prior to the application of a filling material, the conservator should also envision the retouching or inpainting required to integrate the loss, to better determine the appropriate level of the fill for each loss in the painting and select the appropriate materials for retouching. Whether the retouching will only require one or two thin glazes, or if it will require several thicker layers of paint to integrate the loss, will impact the level of fill and texture



Some equipment that can be used to apply a filling.

Water-based or solvent-based fills can be applied directly with a spatula. Care should be taken with metal spatulas not to scratch the paint surface.

that may be required. Some fills will need to be flush (level) with the surrounding original material, and others may need to be slightly lower than the original material, to compensate for the later application of layers of paint and varnish. Precision in the application of the fill material in the losses is crucial to a successful fill, and cracks and fissures around the area of loss should not be obstructed.

Filling can take place with the original canvas mounted on its auxiliary support (strainer or stretcher) or if the canvas has been removed from the auxiliary support. In both cases, the reverse of the canvas should be in full contact with a hard and ridged surface, especially if pressure will be exerted during the filling process. Panel board inserts can be constructed to fit in between stretcher bars. It is wise to use a release layer between the reverse of the painting and the support surface.

Water- and solvent-based fills: film forming via evaporation

Water- and solvent-based fills that set through evaporation of the water or solvent dry from the outside in. These include commercially made fills such as Flügger and Modostuc, which can be used straight from the pot or tube, as well as studio formulations.

Application with a Spatula:

- Water- and solvent-based fills that have the consistency of putty or paste can be applied with spatulas made of metal, bamboo, bone, Teflon or agate. Care must be taken when using metal spatulas, as they can easily scratch and damage surrounding paint layers.
- Putty or paste fills can be left a little higher in the centre of the fill, if possible, as it will contract a little on shrinking.
- Excess bulk fill material should be removed immediately with a spatula. Residues should be removed after the fill has dried and set, using damp soft cotton swabs and cloths. The filling material (the inert bulk) is abrasive, so change the swabs and cloths often, to prevent abrasion of the paint film. To flatten larger fills, a damp cloth or chamois can be wrapped around a flat cork or piece of balsa wood and rubbed over the surface. This should be avoided if the surrounding paint is severely cupped.
- A small amount of kaolin (ca. 10%, but no more than 15%) can be added to the filling material (if it does not already contain it). Only a small amount should be used, as kaolin expands up to 15% when in contact with water. The addition of kaolin helps when smoothing the fill after drying, by compacting the fill material and making it less absorbent and porous.
- Fills with kaolin as the main bulking agent tend to 'ghost' less than other white inert compounds. This is because the refractive index of kaolin (RI = 1.56) is very close to the refractive indices of many of the retouching media or synthetic resins used as surface coatings or varnishes. The remaining particles of kaolin are fully saturated by the resin and appear translucent. The refractive indices of other minerals used as inert compounds for bulking fillers differ considerably from the retouching media and therefore will appear opaque.

Brush application:

When the filling material is thinned a little with a solvent (including water), it can be applied with a brush in layers. As a general rule, the wetter and thinner the filling material, the more shrinkage upon drying!

Traditional 'colletta' gessos are typically applied as a fluid. Losses are overfilled to compensate for the shrinkage and scraped back when dry. Using a putty that presents minimal shrinkage can be time saving. It is worthwhile exploring and experimenting with a variety of putty formulations to expand your repertoire of fill materials.

- Fill materials should be built up in thin layers, one at a time, and allowed to dry thoroughly between each application, to avoid excessive shrinkage after moisture or solvent evaporation.

Extra layers of fill are applied with a brush, after thinning the filling mixture slightly. In this way texture can be re-created by building up the fill in layers.

Excess fill material from water-based fills can be removed with a cotton swab dampened with water.

- The benefit of brush application is that brushstrokes and impastos can be more easily reproduced.
- Another benefit is that less overfill/excess/ or waste is created, and therefore less clean-up of the surrounding area, and potential damage to the paint layer is reduced.
- One of the downfalls of this method is that there is much more shrinkage during drying due to the higher proportion of solvent/aqueous medium. This means a higher concentration of binding medium is required to maintain the strength and flexibility of the fill.
- Another downside to this method is that each layer of fill must be completely dry before the next layer of fill can be applied. Each layer should also be burnished when dry, to avoid porosity of the filling layers and to help level out the final fill.
- The texture required in the fill can be created in the final layer(s) with a brush.

Once these types of fills have dried, they can be smoothed or sanded down using cotton swabs or slightly moistened cloth or chamois leather wrapped around balsa wood or cork. Alternatively, a soft cotton fabric (such as an old white cotton t-shirt) wrapped around a finger, can be used in the same way. When the fill uses a solvent, a piece of synthetic textile such as nylon or polyester, dampened with mineral spirits can be used in the same way as cotton fabric.

Smoothing the surface with these materials helps to compact the fill into the loss and to create a smoother, less absorbent surface. Agate stones are commonly used to burnish the surface of fills. This helps compress the particles of the fill, making it less absorbent and porous.

Fine sandpaper can be used if appropriate, however care must be taken not to damage or scratch the surrounding original surfaces. A scalpel can be used for the removal of excess fill on an uneven surface (such as in paint brushstrokes or impasto).

Thermoplastic Fills (Wax-based Fills and BEVA 371b)
Wax-based fills are useful, due to their flexibility and very little shrinkage upon drying. The wax can be manipulated with a warm spatula to imitate brushstrokes and to create texture. One of the benefits of wax-based fills is that any corrections or changes to the final surface can be easily applied due to the thermoplastic nature of these filling materials.

- A small amount of pigment can be added to thermoplastic fills to create a similar colour to the original ground layers. This can aide retouching in the later phase of restoration.
- Thermoplastic fills can be warmed and applied with heated metal spatulas, metal or wooden pens, or stiff tools. Cold metal tools are not recommended, as the metal draws the heat out too quickly from the wax (or other thermoplastic material), making it difficult to manipulate.
- Thermoplastic fills can be textured by using heated tools, applied through a silicone release sheet, or if the tip of the heated tool is covered with a silicon coating.

Note that the solvents in thermoplastic fills should be completely evaporated first, prior to applying a texture (recommended is to wait at least 24 hours), to prevent the mould sticking to the fill and damaging it! A release sheet should also be placed underneath the fill area to avoid the reverse of the painting sticking to the table surface. The reverse of the painting should always be in contact with a hard, rigid surface when impressing texture into the surface.

A commercial fill has been applied to the loss. Excess fill is being removed with a damp swab. 'Ghosting' (a white haze around the fill), can be difficult to remove completely, but saturation of the area with a varnish can remove the visibility of any filling particles remaining around the fill.

Raking light can be used to ascertain the level of the fill, and if extra fill material is needed to create a flat surface, or whether excess filling material needs to be removed.

Note that when imprinting a synthetic textile onto a wax-based fill, the temperature must be very controlled, to prevent the fill from spreading into surrounding cracks and crevices (and to avoid melting the synthetic textile!).

Imprinting Fills and Creating Texture

Most paintings have a textured surface. This can include the artist's brush strokes, impasto, and various craquelure patterns. The surface of the fills can therefore be levelled and textured to blend with the surrounding substrate. Imprinting the texture of a fabric onto a fill can be a good way to imitate the texture of the surface of the artwork, and reduce the smoothness, and therefore the visibility, of the fill. Both water-based and wax-based fills can be given texture by imprinting with a piece of fabric. A piece of canvas or fabric should be chosen with approximately the same thread count in the warp and weft direction as the original canvas. Care should be taken to correctly align the threads with the original canvas and paint. Note that using this method will give a negative imprint! Often this is fine, depending on the size and location of the fill or loss. When imprinting on a water-based fill, the fabric can be dampened first and pressed gently onto the fill with a hot spatula, or using light pressure. When imprinting onto a wax fill, the canvas is used dry. Generally, it is recommended to use synthetic fabrics for wax moulds.

Spatulas with metal tacking iron tips shaped with a canvas imprint are available but expensive, and often the designed 'thread' count does not match the original. These can be purchased from various conservation suppliers.

Silicone Moulds

There are a wide variety of silicone moulds available for casting. Two-component silicone mould kits are used in many different areas of everyday life such as the dental or food industries. The set time is usually between 5 and 20 minutes, and as this is a chemical reaction there is minimal shrinkage.

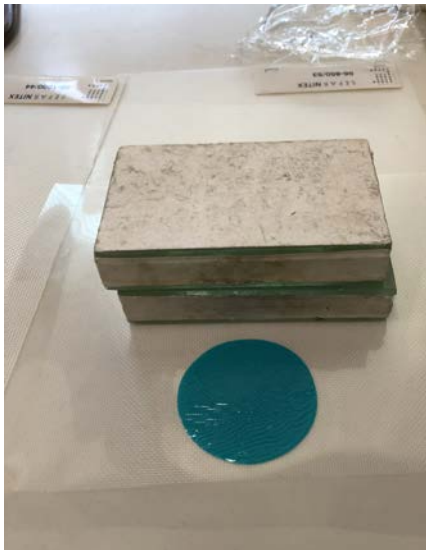
These moulds can be used to take an impression from fabric in the tacking margins of the original artwork, or from the painted area to reproduce any type of texture or surface desired. These moulds are useful when the surface pattern is generic but less useful when specific brushstrokes or impasto patterns have to be replicated.

In order to best make use of the silicone mould for surface textures on filling materials there are some tips in how to make the mould.

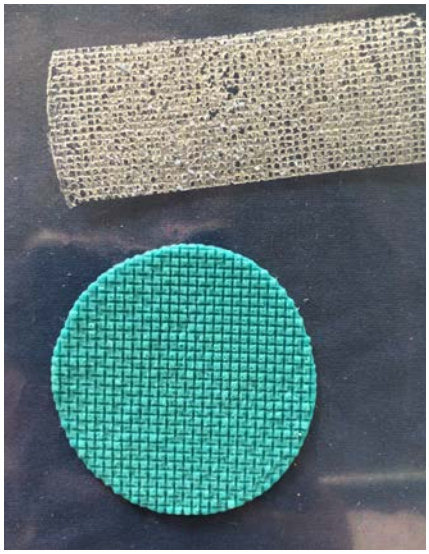
- Apply the mould to a representative area of the original surface or to a representative surrogate material with similar surface texture.
- If the mould is applied to the original surface, apply over a (temporary) coating to ensure there is not staining or transfer of materials to the original.
- Ensure that the mould created is as thin as possible. To do this, after the mould material is applied to the surface, cover the area with a thick piece of Melinex and place a flat weight, such as a glass block, over the surface. The block weight will spread out the silicone mould creating a flat and thin surface. Flat surfaces are also easier to heat evenly. If silicone coated Melinex is used, the silicone mould will bond to that material – not a disaster and can be quite useful.
- Mark a directional indication on the Melinex or the silicon mould before removing it from the surface. This will assist placing the mould over the filler in the right orientation.
- Make the mould larger than the area of loss it will be used to texture.

Aquasil silicone gun for the application of a silicone mould to recreate texture. (Image credit: Kate Seymour, SRAL)

The mould is put in the gun and the two-part components are mixed and applied to a textured surface. (Image credit: Kate Seymour, SRAL)



The mould should be spread to cover an area larger than the area requiring filling, and flattened (under a weight and Melinex) and left to set. (Image credit: Kate Seymour, SRAL)



Once the mould has set, it can be used to apply texture to a fill. (Image credit: Kate Seymour, SRAL)

Here a silicone mould has been applied to the surface of a painting to obtain a texture. Note that a negative imprint will be obtained. It is also always wise to apply a temporary coating to the painted surface before taking a mould imprint, as the silicone oils could stain the original surface.

Neosil two-component system.

Coltène silicone two-component system.

The most commonly used two-component silicone mould materials in conservation are:

- *Optosil / Xantopren* (Heraeus Kulzer)[66]: This is a dental silicone two-component system which comes in three different product ranges. The Xantopren C-Silicone range is available with a different stiffness (L=light, H=heavy, M=medium, VL=very light). The Optosil Comfort putty system allows for a good impression to be taken of a raised and rigid material. The Xantopren Comfort Light can be used for low relief impressions. This version comes with a cartridge delivery system.
- *Aquasil* (Dentsply/Sirona)[67]: This is a dental silicone two-component system which comes in different stiffnesses (LV=light body, XLV=heavy body) and as a putty. This can be purchased in larger or smaller pre-dosed cartridges. The smaller versions are very handy sized. Cartridges are available for easy delivery system.
- *Peakosil* (Neosil Corporation)[68]: This is a dental silicone two-component system which comes in two consistencies: heavy body and light body. There is also a putty version which can be used for taking impressions of frame elements. Cartridges are available for easy delivery system.
- *Rebound 25 Silicone Rubber* (Smooth On):[69] This is a two-component system which must be mixed together in equal portions. Both components come as a fluid which can be mixed to the volume as desired. This system is useful for taking of impressions of larger surfaces.

These resulting moulds can then be imprinted directly onto the fill. Generally, it is a good idea to isolate the surface that will be cast, as some silicones for moulds are very oily and leave residues that can be very difficult to remove. In this case, a varnish such as Paraloid B72 or Regalrez 1094 will not act as an effective barrier, as after its removal with solvents, silicone residues can still remain on the surface of the artwork, due to the affinity of oily silicone for organic solvable varnishes. A better barrier between the artwork and a silicone mould is a high molecular weight Methyl cellulose buffer (such as Methocel).

There are a number of benefits to cast moulds:

- They produce an accurate reproduction of generic surface texture (fissures, cracks, impasto, canvas etc).
- They can be used on almost all types of filling materials. Water- or glue-based fills should be imprinted before fully dry or dampened slightly first to take up the imprint. A warm spatula or light pressure is required to apply the texture of the silicone mould to thermoplastic fills.
- The reverse of the area receiving the texture should be well supported so that the pressure exerted does not deform the original support.

Flexible cast moulds are better than rigid cast moulds, as their removal is easier and therefore, they are less likely to damage the original surface. They also adapt more readily to irregular surfaces.

66 https://kulzer.nl/nl-b/nl-b/products/optosil-xantopren.html
67 https://www.dentsplysirona.com/nl-bx/shop/restorative/indirect-restoration.html/Restorative/Indirect-Restoration/Impression-Taking/Silicones-VPS/c/1000679.html
68 http://www.neosil.co.kr/?lang=e&ckattempt=1
69 https://www.smooth-on.com/products/rebound-25/?pk_campaign=dynamicsearch&pk_kwd=

Conclusion

The filling of losses in panel and canvas paintings is a complex task, that, when done well will provide a good base for the visual reintegration of these losses. Commercial filling materials are available off the shelf, but few are designed with the conservation of fine art field in mind. Studio formulations are not complex to make and can also be tailored to suite the specific requirements of an artwork and its losses. Before a filling material is chosen, the final aim of the conservation treatment should already be clear, as the choice of filling material will affect the varnishing and retouching materials that can be used, and vice versa. Filling materials may comprise of traditional materials or modern synthetic materials, or a mix of both, but should be compatible with the original materials of the artwork. The final surface effect of a filling can be adjusted to suit the outcomes of the treatment and to further integrate the filling into the surrounding area. Various techniques and tools are available to help integrate the surface structure and the filling material into the surrounding area.

About the authors

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.cultureelerfgoed.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.