



Cultural Heritage Agency  
Ministry of Education, Culture and Science

# Varnish Removal

*Paintings conservation*





# Varnish Removal

*Paintings conservation Part 2*

*“Many people still think that Dutch and Flemish art from the sixteenth and seventeenth century is intentionally brown. With exceptions, these paintings are the contrary, with the old varnish removed, they are bright and lively!” (Lia Gorter, Director Stichting Cultuur Inventarisatie/Dutch Masters Abroad, 2017)*

**SRAL**  
The  
conservation  
institute



## Colophon

Varnish Removal  
Paintings conservation part 2

Department: Cultural Heritage Agency of the Netherlands (RCE)  
Ministry of Education Culture and Science

Project name: (Shared cultural heritage) International heritage cooperation

Date: 2022

Contact: Klaas Jan van den Berg, Cultural Heritage Agency of the Netherlands

Authors: Julia M. van den Burg (MA PD. Res.; Private conservator),  
Kate Seymour (MA (Hons, MA; Head of Education and Senior Painting Conservator,  
Stichting Restauratie Atelier Limburg)

Editing: Klaas Jan van den Berg (RCE), Lia Gorter (Foundation for Cultural Inventory, SCI)

Photos: All photos are produced by Julia M. van den Burg, unless otherwise stated

Design and print: Xerox/Osage, the Netherlands

Photo cover: Detail of *Landscape with a windmill*, thought to be by Jacob Maris (1837-1899), viewed in daylight conditions with the varnish removed from the left part of the painting.

© Cultural Heritage Agency of the Netherlands, Amersfoort 2022

Cultural Heritage Agency of the Netherlands  
P.O. Box 1600  
3800 BP Amersfoort  
The Netherlands  
[www.cultureelerfgoed.nl](http://www.cultureelerfgoed.nl)

# Table of Contents

|  |           |
|--|-----------|
| <b>Foreword</b>  | <b>7</b>  |
| <b>Introduction</b>  | <b>9</b>  |
| <b>What is a varnish?</b>  | <b>11</b> |
| <b>Varnishing Practice and Approaches to Varnish Removal</b>       | <b>13</b> |
| <b>Solvents</b>  | <b>17</b> |
| Solvent Behaviour  | 17        |
| Solvents: Testing Solubility                                       | 19        |
| Testing Procedure:   | 21        |
| Solvent Kit  | 22        |
| <b>Solvent Gels</b>  | <b>27</b> |
| Clearance of the gels and gel residues                             | 27        |
| Types of Solvent Gels  | 27        |
| <b>Physical gels: Viscosity Modifiers</b>                          | <b>29</b> |
| Methyl cellulose and Hydroxy propyl cellulose                      | 29        |
| Carbopol® (straight chain high molecular weight poly acrylic acid) | 31        |
| Agar, Agarose and Gellan gum                                       | 33        |
| Xanthan gum  | 34        |
| <b>Emulsions</b>   | <b>37</b> |
| Pemulen™ TR-2  | 38        |
| Compress Tissue Cleaning with Solvent Gel:                         | 41        |
| Tissue Cleaning with Free Solvents:                                | 44        |
| <b>Current and Future Developments</b>                             | <b>45</b> |
| Chemical Rigid Gels  | 45        |
| Shin Etsu KSG® (Silicone Based Pickering emulsifier)               | 45        |
| <b>Conclusion</b>  | <b>47</b> |
| <b>Relevant Additional Literature</b>                              | <b>48</b> |
| <b>About the authors</b>   | <b>49</b> |



Before you lies one of six brochures created for conservators of paintings and panels wishing to keep up with and learn how to apply rapidly advancing techniques in their field. The brochures in this series are:

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

The brochures were compiled to serve as a reference, bringing together knowledge about new materials and methods for practical use.

Conservation practice has developed at an astounding pace. This knowledge is concentrated at a few large institutions with the capabilities to take major steps in the development and application of new methods. Smaller and medium-sized museums meanwhile do not have the resources to hire a permanent conservator for their collections, and often send paintings to be restored externally. For those not employed at large institutions, accessing such knowledge can be difficult. These brochures are designed to bridge this gap. They can also help conservators seeking to refresh and update their knowledge.

The need for this reference material became apparent during a series of masterclasses and conferences organized by the Foundation for Cultural Inventory (SCI) in India, the Russian Federation and elsewhere, in

association with SRAL - The Conservation Institute, the Cultural Heritage Agency of the Netherlands and Dutch embassies in the partner countries.

These gatherings, centring on mutual exchange and deepening knowledge in relation to the local contexts, were held under the auspices of the Shared Cultural Heritage programme.

This programme has since been succeeded by the International Heritage Cooperation programme, which more than ever emphasizes the comparable societal challenges countries face and the value of learning from each other to address them. The brochures show how much can be accomplished through cooperation and not only exchanging but also pooling and sharing knowledge.

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

We thank scientist René Peschar (University of Amsterdam) and paintings conservator Louise Wijnberg for valuable input.

Lia Gorter  
Director, SCI Cooperation Foundation for Cultural Inventory

Jinna Smit  
Programme Director, International Heritage Cooperation Cultural Heritage Agency of the Netherlands

Artist unknown, late 19th century town square scene.  
The painting is viewed in daylight with the varnish removed from the left part of the painting.

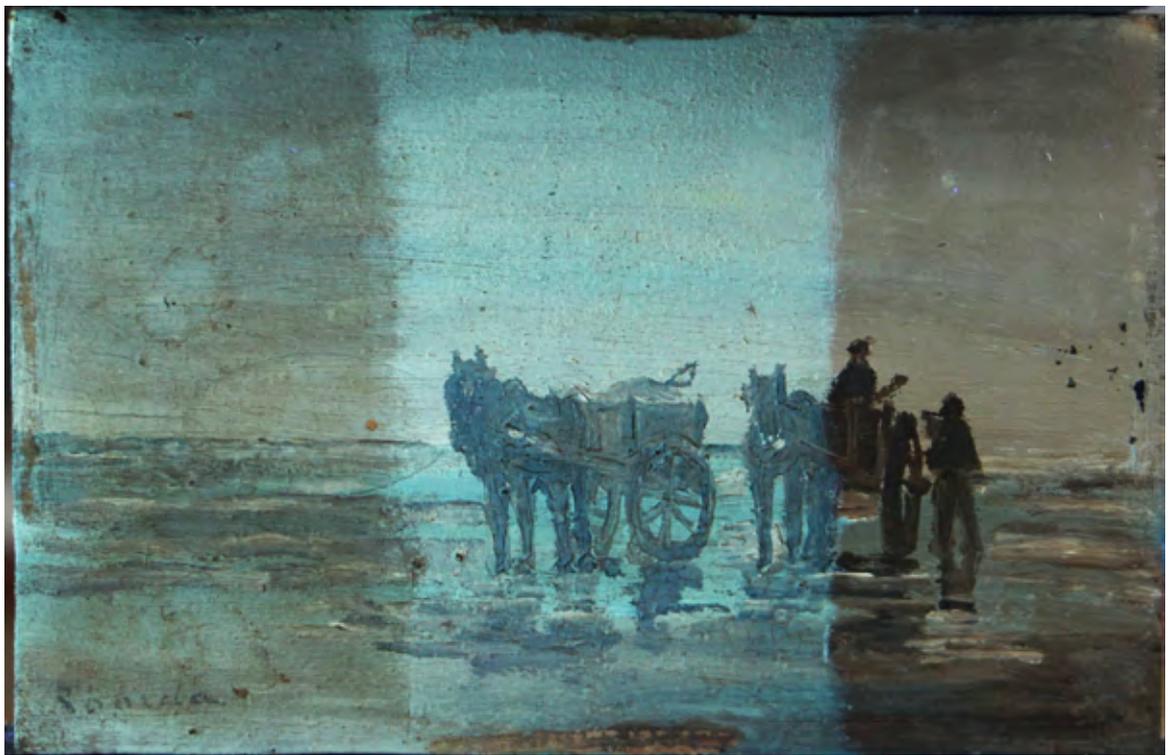


Varnish and overpaint removal can be a rather satisfying process. Layers of disfiguring overpaint and discoloured varnish are removed to reveal wonderful details, a more accurate tonality and bring back depth to a picture. Any material removed is permanent and cannot be replaced. At the same time, this process can be fraught with complications and can have the largest impact on the painting, both visually and chemically. Varnish removal can be time-consuming and requires a good

understanding of basic chemistry. The processes causing the degradation processes of varnishes, the aging of paint and the solubility parameters of paint, varnishes and solvents need to be fully grasped. This brochure will help practicing conservators gain a better comprehension of these complex theories and practices. It will also give advice and recipes for varnish removal, with an emphasis on older varnishes on traditional oil paint.



Detail of *Landscape with a windmill*, thought to be by Jacob Maris (1837-1899), with the yellowed varnish removed from the left part of the painting



G. Roorda, *Fishing for shrimp on the beach*, seen in daylight (above) and ultraviolet-induced visible fluorescence (below). The left part of the painting is untreated, the central part has the surface dirt removed, with the aged varnish fluorescing bluish-green and the right part of the painting has the varnish removed.

# What is a varnish?

Varnishes are clear coatings applied to the surface of a painting to protect it from light, dirt, humidity and abrasion, and to influence the appearance of the paint by unifying the gloss, saturating and darkening colours and enhancing tonal and colour contrasts. The most sought-after properties of varnish are pale, clear and colourless. Historical varnish coatings often consisted of a mixture of materials, such as tree resins, balsams and oils, with at times additives such as drying oil or natural waxes. These materials have in common a highly reactive chemical structure that is influenced by the ambient environment. Chemical changes are induced by exposure to light, moisture and heat, and especially to fluctuations in these conditions. Discolouration ensues and the varnish frequently becomes yellow, hazed, brittle and cloudy. In addition, the degradation results in a changed chemical structure of the varnish that will only dissolve in solvents that will potentially affect the original (aged) oil paint. Modern varnishes are solvent-resin mixtures, where the resin component is either a natural resin or a synthetic polymer or oligomer. When selecting a new varnish coating, the conservator should take into consideration the aging properties of the varnish polymer and the conditions in which the painting will be displayed, as well as the desired appearance of the painting (see brochure on *Varnishing and Retouching*).

Varnish deterioration is the reason that most aesthetic treatments are necessary. As mentioned, over time varnishes increase in polarity and become yellowed and brittle as they undergo a process of autoxidation.<sup>1</sup> The pronounced yellowing of thick layers of varnish can significantly change the appearance of a painting, hindering its readability. In addition, brittle cracking changes both the optical properties of the varnish and its protective function; and may also produce cracking in paint layers. Older varnishes must usually be removed with more polar solvents to match the changed (more polar) chemistry of the degraded resin, which has significant potential to damage the paint layers by the swelling and leaching of paint components.<sup>2</sup>

- <sup>1</sup> Dietemann P., Higgitt C., Kälin M., Edelmann M.J., Richard Knochenmusse R., Zenobi R., *Aging and yellowing of triterpenoid resin varnishes e Influence of aging conditions and resin composition*, Journal of Cultural Heritage 10 (2009) pp 30-40 [http://andbeyond.ch/Dissertation/Publications/J\\_Cult\\_Herit\\_2009\\_10\\_30-40.pdf](http://andbeyond.ch/Dissertation/Publications/J_Cult_Herit_2009_10_30-40.pdf)
- van der Doelen, G.A., *Molecular studies of fresh and aged triterpenoid varnishes (MoArt; 1)*, University of Amsterdam, 1999-03-25 <https://amol.f.nl/publications/molecular-studies-of-fresh-and-aged-triterpenoid-varnishes-moart-1>
- <sup>2</sup> Baij, L., Hermans, J., Ormsby, B. et al. *A review of solvent action on oil paint*. Heritage Science, vol. 8, 43 (2020). <https://doi.org/10.1186/s40494-020-00388-x> <https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-020-00388-x#ref-CR182>



Bottles of natural and synthetic resin varnishes, used in modern conservation studios



Unknown artist, ca. 1900, *Portrait of an elegant woman*, viewed in daylight. The varnish on the left part of the painting has been removed. Although not greatly discoloured, a number of scratches were present in the varnish, there were large overpaints integrated in the varnish in some areas, and the varnish had a thick, waxy appearance which gave a distorted image.

# Varnishing Practice and Approaches to Varnish Removal

Before attempting to remove the varnish layers from a painting, it is imperative to establish as much as possible about the painting: the medium and support, the technique used, the approximate date, the current condition of the artwork and any past restoration-conservation treatments. The existence of any non-original material should be noted: the number of layers of varnish present on the surface, areas of overpaint and their position to the layers of varnish and original paint layer, remains of past restorations (filling materials, tear repairs etc.). Note that artists from certain periods frequently used oiling out layers or varnish between paint applications as part of their painting technique, and these layers may be more reactive to solvents used to remove surface varnish layers than the paint.

To ascertain these various aspects, observation of the artwork in good daylight conditions, raking/oblique light and ultraviolet light is required. This examination will highlight the presence of natural varnish layers and can aid in the identification and mapping of overpaints. If possible, images taken with infrared light can be used to further identify artistic practice or the presence of overpaints. Cross-sections<sup>3</sup> are also a possibility for understanding the build-up of layers; however, this is a destructive technique and should only be used when the above-mentioned non-invasive approaches do not give sufficient information. The technical information regarding the painting (method of production, condition and conservation history) can best be documented in a condition report.<sup>4</sup>

Once as much information as possible has been gathered about the artwork, a decision must be made regarding the removal of the varnish. Sometimes there are strong arguments against the removal of the varnish and overpaint layers. The coating may be original, and thus may warrant preservation. Such varnishes could be useful for research or because of the scarcity of varnishes from this period today. From later works (19th and 20th century), the argument against varnish removal may outweigh other factors if the varnish was applied by the artist, or if it is an integral part of the artwork. Varnish removal may not be an option when the paint layers beneath the varnish have the same solubility as the varnish itself, when intermediate layers of varnish are

present that are sensitive to the solvents required for varnish removal, or when past treatments have affected the sensitivity of the paint to solvents.<sup>5</sup>

Arguments for the removal of varnish include increasing the readability of the painting by removing yellowed, blanched, hazed, opaque layers of varnish and discoloured overpaint, and returning the image closer to the artist's aesthetic intent. Removing old, oxidised varnishes and overpaints, while the polarity differs enough from that of the paint beneath, reduces the chances of solubilising the paint layers and impacting future treatment options.

Once the decision has been made to remove the varnish and/or overpaint layers, a safe method to do this has to be established. Knowing where to start will be determined by the materials you want to keep (aged oil paint will be sensitive to different solvents than modern acrylics) and the materials you want to remove (aged natural resins will require different solvents than modern synthetic varnishes). The method of applying the chosen solvent will also need consideration. Solvents can be used in free fluid form applied with a swab or through a tissue, or in a more viscose form such as a gel or emulsion. Practical tips on how to undertake varnish removal will be given in this brochure.

Current cleaning practices can be categorised by Gerry Hedley's<sup>6</sup> three categories of cleaning described in 1985:

- *Total cleaning* (removal of all varnish layers and overpaint from the surface that has not been applied by the artist),
- *Selective cleaning* (the removal of varying amounts of varnish from different areas of the painting) and
- *Partial cleaning* (the preservation of a thin layer of varnish on the paint layer to maintain contact between the old varnish and the paint layer).

<sup>3</sup> Cross-sections are small samples of the painting removed and mounted so as to observe the stratigraphy and identify materials used by the artist or applied at a later time.

<sup>4</sup> The information can be written in a condition report, here is an example by the Canadian Conservation Institute: <https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/condition-reporting-paintings-examination-techniques.html>

<sup>5</sup> One method that may dramatically affect the sensitivity of the paint layers was a technique used in the late 19<sup>th</sup> century called 'The Pettenkofer method', which involved exposing paintings to ethanol vapours in a closed-off box to regenerate the varnish. Additions of copaiva balsam were often included. The long exposure to an environment saturated with solvents softened the paint layers frequently causing them to bleed into the varnish. Copaiva balsam is slow to dry and reacts strongly to moisture. As a result, paintings exposed to this method are highly sensitive to solvents and mechanical action. Schmitt, S., *Examination of Paintings Treated by Pettenkofer's Process*, Cleaning, Retouching and Coatings, IIC Preprints, Brussels (1990) pp 81-84

<sup>6</sup> Gerry Hedley was a conservator and educator of conservation teaching at the Courtauld Institute of Art, London in the 1990's. His writings on a variety of topics are esteemed. Hedley G., Villers C. 1993, *Measured opinions: collected papers on the conservation of paintings*, London: United Kingdom Institute for Conservation

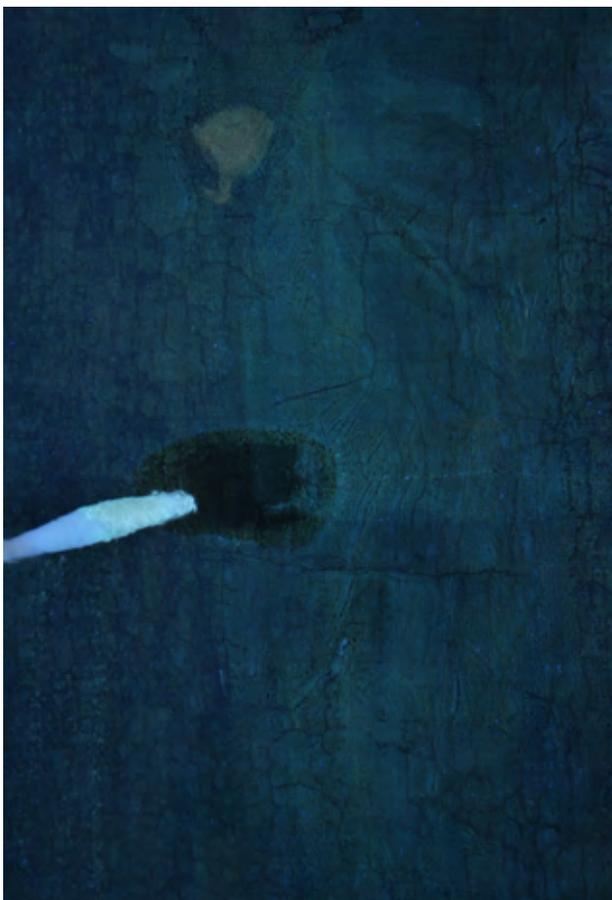
In this brochure we will also discuss a further category, *Targeted cleaning*. This refers to knowing what it is that you want to remove before commencing so that the right solvents/cleaning solution can be selected.

Prior to varnish removal, surface dirt should be removed (see Brochure on *Dirt and Dirt Removal (Dry and Aqueous Cleaning)*). Amongst other problems, dirt affects the polarity of the surface, and if it is not removed it can be impossible to remove the varnish!

Top right: Detail of a scratch in the yellowed varnish of *Portrait of an elegant woman* (Isaac Israëls? 1865-1934). Viewed in daylight.

Bottom left: detail of solvent testing for varnish removal in the area of the scratched varnish, viewed in ultraviolet-induced visible fluorescence.

Bottom right: detail of the result of the varnish removal test, viewed in daylight.





G.F. van Schagen *Dutch Landscape*, oil on canvas. Seen from top to bottom in daylight, Ultraviolet-induced visible fluorescence and raking light.



---

## Solvent Behaviour

---

Conservators traditionally use organic solvents (in free fluid form) and cotton swabs to remove varnish and overpaint from oil paintings. There are three parameters to consider when removing varnish:

- *Mechanical action*: the physical rolling or rubbing of the swab on the paint surface.
- *Time*: length of time required to remove a varnish and evaporation time of the solvents out of the painted surface.<sup>7</sup>
- *Solvent action*: solvent action encompasses the complex processes relating to solvent-solute interaction, including: diffusion, evaporation, capillary action, retention, softening, swelling, dissolution, leaching and chemical changes.

In order to fully consider these parameters, the following terms should be fully understood.

*Solvent diffusion*: the transport of solvent into the open spaces between polymer chains of the resin coating and subsequently into the paint film. Diffusion and swelling

---

<sup>7</sup> The evaporation rate of solvents will be impacted by the climate conditions in which the conservator is working. A warm, humid climate will affect the evaporation rate of solvents differently than 'ideal' museum conditions with a temperature of around 20-22 °C and a Relative Humidity (RH) of 50%.



Detail of a larger varnish removal test in the upper left corner of a painting. The swab has picked up the yellowed varnish, revealing the original colour palette.

are inextricably linked; the transport of solvents into the resin coating and paint film results in an expansion of the polymer network as the solvent molecules push apart the molecules of the coating or paint film. Strongly swelling solvents diffuse faster into the system than weakly swelling solvents. Solvents can be selected to interact faster with the varnish materials than the underlying paint film.

*Evaporation and retention*: during solvent action, some solvent molecules inevitably remain in the varnish coating or paint film for a certain period of time, the retention time. This is governed by the rate of solvent transport into the substrate (solvent diffusion) and the rate of evaporation of the solvent from the surface. Depending on the type of solvent, its presence may remain for up to several days in the underlying paint film. The paint will be partially swollen and thus soft and sensitive to mechanical action. Practically, this means that after removing the varnish and/or overpaints from a paint film, it is important to allow enough time for all the solvents to evaporate out before commencing to the next stage of treatment.

Solvent evaporation, retention and diffusion will be impacted by the thickness of the varnish, solvent application time, method of application and solvent or solvent mixture used. The temperature of the environment (climate conditions) will also impact solvent evaporation and retention, as will the thickness of the paint layer and substrate. Varnishes have been found to temporarily hinder solvent diffusion into the oil matrix of traditional oil paints.<sup>8</sup> Different methods of the application of solvents have shown different solvent diffusion and evaporation properties.<sup>9</sup>

*Capillary action*: the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity. The capillary penetration of a solvent into the paint film can lead to leaching and swelling of the film. Undercutting may also occur. This is when the underlying material dissolves prior to the overlying material. Solvents should be applied to heavily cracked paintings with caution.

---

<sup>8</sup> The oil matrix refers to the oil binding medium used to mix with the pigment to make the paint; in traditional paints this was commonly linseed oil or walnut oil. The binding medium hardens over several weeks as components of the oil polymerize to form an insoluble matrix. Driers can be added to accelerate this process.

<sup>9</sup> Baij, L., Hermans, J., Ormsby, B. et al. A review of solvent action on oil paint. *Heritage Science* 8, 43 (2020). pp 14 <https://doi.org/10.1186/s40494-020-00388-x> <https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-020-00388-x#ref-CR182>

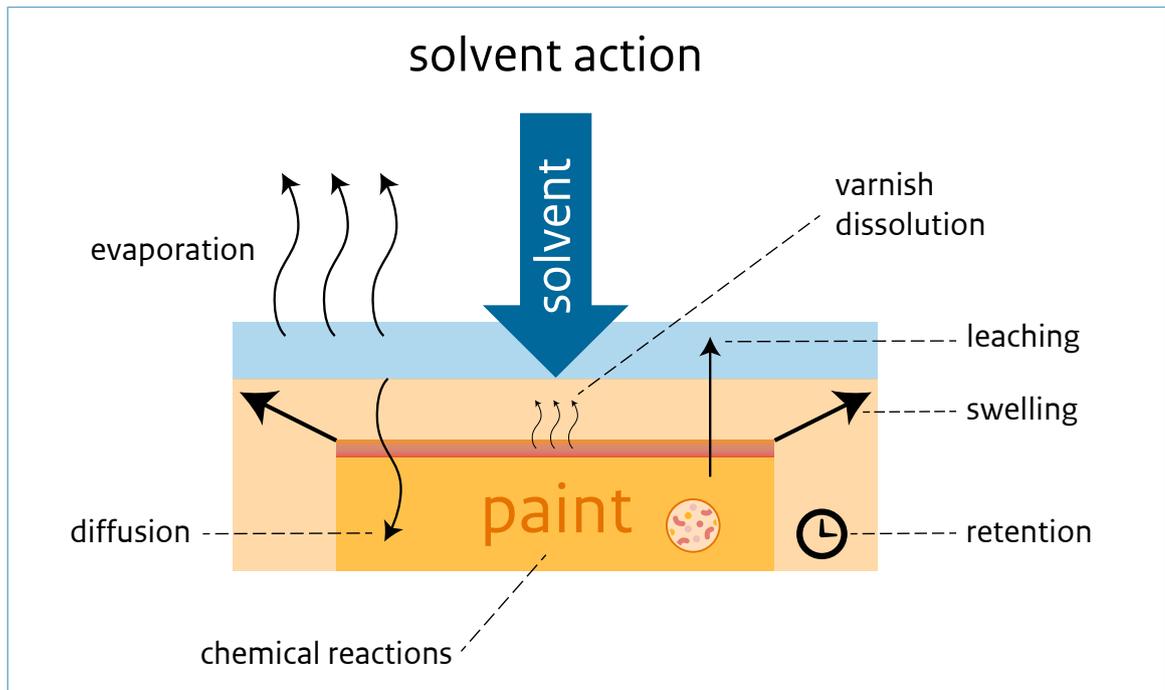
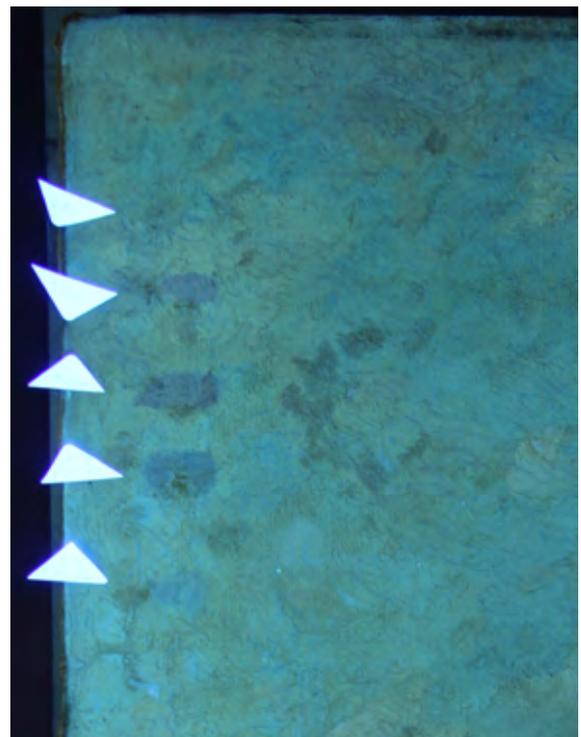


Diagram of the different types of solvent action occurring simultaneously. Diagram referenced from Baij, L., (2020) Fig. 1a.

**Softening:** varnish or paint films may become less firm due to the diffusion of solvents into the layer causing swelling. While softening of the varnish layer is desirable, softening of the paint binder is not. This can contribute to the vulnerability of paints during cleaning to pigment loss as a result of mechanical action by the swab rubbing over the affected surface. There is a relation between paint softening and solvent retention.<sup>10</sup>

**Swelling:** the varnish or paint film may increase in dimension as the solvent enters the coating or oil matrix by solvent diffusion, resulting in expansion of the material. The possibility for swelling will depend strongly on the degree of polymerisation of the oil matrix. Organic molecules contain functional groups within their chemical structures that can bind to other adjoining molecules permanently through chemical bonding, through hydrogen, dipole-dipole and dispersion forces. These cross-linked networks are more difficult to swell and disperse than adjoining molecules that are bonded through less strong intermolecular bonds such as hydrogen bonds, dipole-dipole interactions and

<sup>10</sup> Prati S, Sciutto G, Volpi F, Rehorn C, Vurro R, Blümich B, Mazzocchetti L, Giorgini L, Samori C, Galletti P, Tagliavini E, Mazzeo R. *Cleaning oil paintings: NMR relaxometry and SPME to evaluate the effects of green solvents and innovative green gels*. *New J Chem.* (2019) vol. 43(21) pp 8229–38 <https://doi.org/10.1039/C9NJ00186G>.



Detail of varnish removal tests using different solvents along the left edge of Jacob Maris (1837-1899), *Landscape with a windmill*. Left: viewed in daylight conditions, right: viewed in ultraviolet fluorescence.

dispersion forces. Aged oil paint is an example of a cross-linked polymer network, while aged natural resin varnish layers are typically an example of a polymer network bound by intermolecular forces. Naturally, this is a simplistic sketch of a very complex situation. Swelling is a tangible phenomenon because the mechanical and optical properties of the surface can change during the swelling process. Swelling will result in a different 'feel' of the surface during mechanical action; and will cause the desired removal of the varnish. But, if the solvent effects the underlying paint matrix, mechanical action may result in pigment loss during varnish removal. If this is noted by the conservator, treatment must halt immediately until a safer method is found.

*Leaching:* this refers to the extraction of soluble paint components out of the oil matrix. These components are typically soluble free fatty acids, which act as plasticisers in the oil matrix. Leaching results in the loss of binder matter, ensuing in the embrittlement and further densification of paint. This causes an alteration in the mechanical properties of the paint film. Strongly leaching solvents may have low(er) swelling power. Polar solvents such as ethanol or acetone may cause more embrittlement than apolar solvents such as cyclohexane. This can be explained by the fact that ethanol or acetone are much faster diffusing solvents than cyclohexane.

*Chemical reactions inside the paint:* these may occur for long periods of time after solvent exposure due to high diffusion rates and slow evaporation rates of the solvent out of the paint matrix. Solvent action may result in the migration and redistribution of soluble components between paint layers. This may enhance the rate of degradation reactions inside the paint film such as hydrolysis of the triacylglyceride ester bonds and metal soap formation.<sup>11</sup>

- Varnish dissolution: this describes the moment at which the solid varnish (film) dissolves in the solvent to form a solution.<sup>12</sup> Note that many varnishes need a little time to (fully) dissolve in a solvent as the polymer network is dense and inter-tangled. The solvent molecules need time to diffuse through the polymer network. Hindering the evaporation rate of the solvent

from the surface by gelling the solution will allow sufficient time for solvent action to take place. Dissolved varnish may also penetrate into cracks in the paint layer and be transported through to the underlying support. Canvas supports may suck up dissolved varnish causing discolouration, increased acidification and exacerbating degradation. Again, gelling solvents, and using compress systems, may hinder this undesired effect.

It should be noted that these solvent action processes all occur simultaneously. Solvent action depends strongly on the chemical and physical properties of the materials that will be exposed to solvents. The material composition, stratigraphy of the paint layers with their respective chemical differences and states of degradation will impact the reaction to solvents.

---

### Solvents: Testing Solubility

---

Testing for varnish removal should always start with the least invasive technique. You may want to compare results, so it is recommended to try more than one technique. Testing of several techniques will ensure that the most effective method is chosen: one where the solvent removes the varnish and overpaint safely in the shortest amount of time with the least mechanical action. Also note that the surface may not be homogeneous and reactions may differ across the surface as the varnish layer or underlying paint film may react differently. Special consideration to this issue must be given to paintings that have been partially cleaned previously.

Testing of solvents should occur in an area near the edge of the painting, preferably in a lighter area if possible. Tests should not be carried out at the extreme edge as this area may have been protected by the rebate of the frame and thus not respond in the same manner as varnish exposed to the ambient environment. It is easier to observe the effectiveness of solubility of the varnish in lighter areas as the colour change or tonal shift will be more evident. Lighter colours may also be safer areas to carry out initial tests, as in past centuries lead white was the most commonly used white pigment in oil paintings.<sup>13</sup> Lead white acts as a drier to oil paint by

<sup>11</sup> Hydrolysis occurs in the presence of water. This may be present from aqueous cleaning, or from fluctuations in relative humidity. Baij L, Hermans JJ, Keune K, Iedema P. Time-dependent ATR-FTIR spectroscopic studies on fatty acid diffusion and the formation of metal soaps in oil paint model systems. *Angew Chem Int Ed.* (2018) vol. 57(25) pp 7351-4 <https://doi.org/10.1002/anie.201712751>.

<sup>12</sup> [https://www.researchgate.net/profile/Stefan\\_Zumbuehl/publication/272140913\\_The\\_Kinetics\\_of\\_Dissolution\\_of\\_Varnishes\\_-\\_The\\_Influence\\_of\\_Vapour\\_Pressure\\_on\\_the\\_Rate\\_of\\_Solvent\\_Action/links/54db5b8docf2ba88a68feaca/The-Kinetics-of-Dissolution-of-Varnishes-The-Influence-of-Vapour-Pressure-on-the-Rate-of-Solvent-Action.pdf](https://www.researchgate.net/profile/Stefan_Zumbuehl/publication/272140913_The_Kinetics_of_Dissolution_of_Varnishes_-_The_Influence_of_Vapour_Pressure_on_the_Rate_of_Solvent_Action/links/54db5b8docf2ba88a68feaca/The-Kinetics-of-Dissolution-of-Varnishes-The-Influence-of-Vapour-Pressure-on-the-Rate-of-Solvent-Action.pdf)

<sup>13</sup> Darker paints may be more sensitive to solvents. For example, black is generally more sensitive than lead white, as it requires more binding medium to fully coat the pigment particles, glazes are also more sensitive due to the high ratio of binding medium to pigment particles, greens and organic dyes are also generally more sensitive to solvents than lighter colours and white.



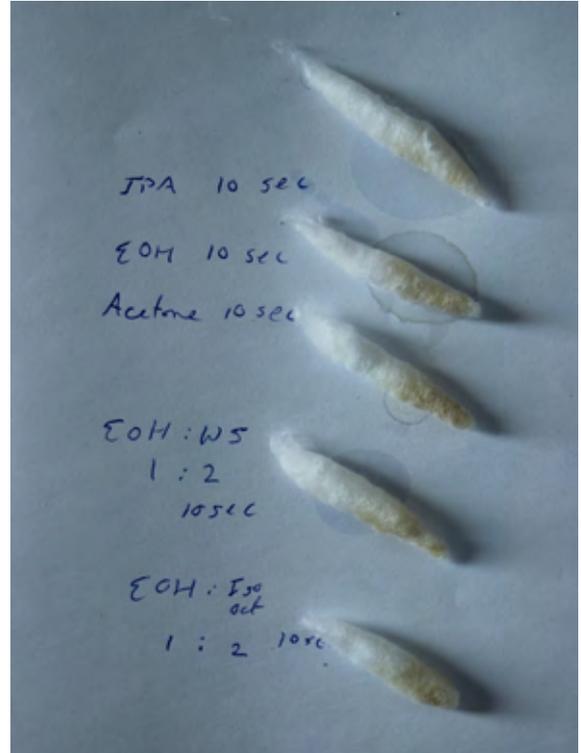
1.



2.



3.



4.



5.

1. The swab is dipped lightly in the solvent solution.
2. The swab is rolled on a small area of the surface, in a representative area of the painting.
3. The test area is labelled and the next solvent is trialled.
4. The swabs of each test location are kept and labelled, for comparison.
5. Once a solvent has been chosen, a larger area is tested for varnish removal. Other areas are also tested for sensitivity to the chosen solvent.

speeding up the oxidation and polymerisation processes resulting in a paint which is less sensitive to polar solvents. Testing should initially be done in an area where no overpaint is present; the presence and removal of overpaint will hinder you from seeing if the original paint layer is affected by the solvent or not.

Once the most effective technique has been selected, it is important to establish that all the colour zones are stable in the selected solvent. It may be necessary to adapt the solvent selection for individual or specific areas of the painting.

In general, when testing for the removal of varnish, it is wise to begin with the least polar solvent. It should be noted here that practically speaking, when the varnish and overpaint layers have yellowed substantially, low polarity solvents such as Low Aromatic Content White Spirits<sup>14</sup> will do little to remove varnish and overpaint. Use pure solvents to begin testing, but be aware that solvent mixtures may also function. Please note that some solvent mixtures (such as alcohols and Low Aromatic Content White Spirits) may cause the swelling of (young) oil paint films. These traditional mixtures of cleaning solutions should be avoided.<sup>15</sup>

Typically, when removing aged polar natural resin varnishes, it is beneficial to begin testing with pure solvents such as Isopropanol, Ethanol and Acetone. This order reflects the order in which they should be tested.

<sup>14</sup> [https://cool.culturalheritage.org/waac/wn/wn29/wn29-2/wn29-204.pdf?fbclid=IwARz1BJPzkNwkNzszVJG3ha\\_r3iMpEUce7\\_5EBLH\\_U5XqUcoCixrzCURyRfg](https://cool.culturalheritage.org/waac/wn/wn29/wn29-2/wn29-204.pdf?fbclid=IwARz1BJPzkNwkNzszVJG3ha_r3iMpEUce7_5EBLH_U5XqUcoCixrzCURyRfg)  
<sup>15</sup> Phenix A., *The swelling of artists' paints in organic solvents. Part 2, comparative swelling powers of selected organic solvents and solvent mixtures.* J Am Inst Conserv. (2002) vol. 41(1) pp 61 <https://doi.org/10.2307/3179897>.  
 Phenix A., Mar Parkin H., *The swelling of artists' paints by organic solvents and the cleaning of paintings: recent perspectives, future directions.* In: 2002 AIC paintings specialty group postprints, Miami, Florida, June 6–11, 2002. (2002) pp 71–86



A selection of solvents found in a solvent kit

---

### Testing Procedure:

---

The testing area should not be larger than 1 cm<sup>2</sup> for each solvent, as the aim is to test for the solubility of the specific solvent.

- Take a small cotton swab dipped lightly, but not saturated, in solvent and roll it over the surface of the test area. Roll for a designated number of times. Save the swab and label it. Some conservators prefer to roll for a designated number of seconds.
- Look carefully for changes in the surface of the painting and in the colour of the swab.
- If varnish remains, take another swab and repeat for the same number of designated rolls. Again, save the swab and observe any changes. Compare with the previously saved swab.
- Repeat with the same solvent until the desired outcome is achieved. It may be necessary to stop prior to this point, if the solvent action is deemed too aggressive.
- The same sequence should be repeated with the comparative set of solvents.
- Keep all of the swabs clearly labelled and compare results. Time of application should also be taken into consideration; a quick acting solvent may not be optimal because it can reduce the amount of control over the process.
- Select the most effective solvent and carry out a larger test area in a stable paint.
- Once a solvent has been selected that is effective in removing the varnish, it is necessary to test all the other colours in the painting to ensure that they are not adversely affected.

It is also useful to observe the surface with an ultraviolet light source to check for remains of varnish or overpaint. Check for unwanted effects such as blanching, whether the solvent has been effective in removing all the varnish or whether residues still remain on the surface.

If the results of solvent testing are not satisfactory, it may be necessary to test mixtures of different solvents, for example mixtures of ethanol (99%) with isooctane. Ethanol is a highly polar solvent and mixing it with different portions of isooctane will reduce the polarity. Ethanol and Isooctane should not be mixed in equal



*Landscape with a windmill*, thought to be by Jacob Maris (1837-1899), during varnish removal. Left: the painting viewed in daylight conditions, right in ultraviolet-induced visible fluorescence.

portions, however, as this may cause swelling of (young) oil paint.<sup>16</sup>

Note that the solvent that is most effective for varnish removal may not be efficient at removing aged (oil) overpaints. It may be necessary to test the solubility of overpaints in a second testing phase.

A new methodology for solvent testing and documentation has been recently developed at SRAL.<sup>17</sup>

<sup>16</sup> Theoretical models to predict the solubility of (aged) oil paints have been developed since the 1950's. The Hildebrand and Hansen models aim to predict the solubility behaviour of varnishes and oil paint films, with the aim of minimising swelling and leaching while removing unwanted materials from the surface. The Hildebrand parameter indicates the degree of interaction between molecules and can be a good indication of solubility. It is derived from the square root of the cohesive energy density. Hansen's solubility parameters  $\delta_d$ ,  $\delta_p$  and  $\delta_h$  are three separate values at megaPascal (MPa) scale that describe the dispersion, dipolar and hydrogen-bonding forces between molecules, respectively. The squares of Hildebrand parameter  $\delta_t$  and the Hansen parameters are related via  $(\delta_t)^2 = (\delta_d)^2 + (\delta_p)^2 + (\delta_h)^2$ . The Teas solubility parameters  $f_d$ ,  $f_p$  and  $f_h$  are based on the Hansen parameters with  $f_d = \delta_d / (\delta_d + \delta_p + \delta_h)$  and  $f_p$  and  $f_h$  are defined similarly from  $\delta_p$  and  $\delta_h$  respectively. The Teas parameters are usually depicted at the scale 0-100. The Hansen and Teas parameters can be both used as coordinates to plot in an independent three-axes graph. The Teas diagram has been the go-to model for predicting solubility in the conservation field since its introduction in the 1960's. While individual solvents and binary mixtures are easy to plot, complex mixtures of solvents, such as the hydrocarbon distillation products, have to be plotted as a zone. The solubility zone of polymers can also be plotted by marking their response to a series of solvents. This allows conservators to visualise the solubility of polymers in tested solvents and compare results. There are however many drawbacks. The pros and cons of this chart and its practical application has been discussed at length in other publications.

[https://cool.culturalheritage.org/byform/tutorials/consitut/teas\\_chart/index.html](https://cool.culturalheritage.org/byform/tutorials/consitut/teas_chart/index.html)  
<https://cool.culturalheritage.org/waac/wn24/wn24-2/wn24-205.html>

<sup>17</sup> Fife, G.R., *The solvent star: Accessing and documenting solvent selection*, The Picture Restorer, Issue 56 (spring 2020) pp 41-44 <http://sral.nl/nl/ateliers/onderzoek/>

The testing sequence is explained in an article available on the SRAL website, along with handouts that can be downloaded and short videos. The 'Solvent Star' provides a straightforward way in which to quantify, document and share varnish removal results using a spider diagram with axes that reflect mechanical action of the varnish compared with that of the paint film, toxicity of the solvent and ease of controllability. This tool is still in development but shows promise.

### Solvent Kit

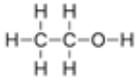
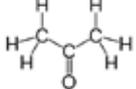
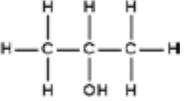
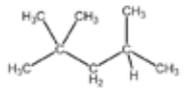
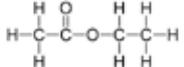
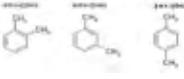
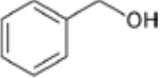
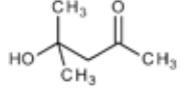
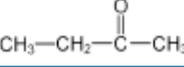
Traditional varnishes made from natural resin varnishes will typically dissolve in the following solvents, or mixtures thereof: ethanol, acetone or isopropanol. These solvents can be mixed with hydrocarbon solvents to lower the polarity. Typically, isooctane or a Low Aromatic Content White Spirits (aromatic content <20%) such as Stoddards Solvent, Shellsol D40® or Shellsol T®. The evaporation rate of the additive will determine if the mixture becomes more or less polar as the components evaporate. The conservator may also be able to add other solvents in small proportions to remove more aged or insoluble varnishes, or oil overpaints. These additional solvents include propylene glycol methyl ether (commonly known by its Dow Company trade name Dowanol™), benzyl alcohol and methyl ethyl ketone.



Detail of 'Crucifixion with Donors' during varnish removal in daylight. The left side of the painting still has the old, degraded varnish intact. Collection of Museum W (Weert, the Netherlands).

Image courtesy of Eva van Zuien and Kate Seymour, Stichting Restauratie Atelier Limburg (SRAL).

Table 1 Comparison of BP/Evaporation rate<sup>1,2,3</sup>

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

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

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

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

Table 1 Comparison of BP/Evaporation rate<sup>1,2,3</sup>

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

Useful websites:

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

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

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

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

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

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

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

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

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

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

[https://www.merckmillipore.com/NL/en/product/msds/MDA\\_CHEM-808691?Origin=PDP](https://www.merckmillipore.com/NL/en/product/msds/MDA_CHEM-808691?Origin=PDP)

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

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

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

<sup>2</sup> When handling solvents appropriate gloves should be worn. See: <https://www.osha.gov/sites/default/files/publications/osh3151.pdf>

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

The full solvents kit is as follows:

- Ethanol (both 99% and 96%\*) (ethyl alcohol)
- Acetone (propanone)
- Isopropanol (propan-2-ol or 2-propanol)
- Propylene glycol methyl ether (1-methoxy-2-propanol) common trade name: DowanolTM\*\*
- Benzyl alcohol (phenylmethanol)\*\*
- Methyl ethyl ketone (MEK) (butanone)\*\*
- Low Aromatic Content White Spirits (17-25% aromatic content) or Odourless Mineral Spirits
- Shellsol D40® (1% aromatic content)\*\*\*
- Shellsol T® (1% aromatic content)
- Shellsol A100® (100% aromatic content)
- Isooctane (2,2,4-trimethylpentane)
- (Xylene)\*\*\*\*

\* The percentiles refer to the purity of ethanol which easily absorbs water from the atmosphere creating an azeotropic mixture. Note that the purity will affect miscibility with other solvents. In some countries Industrial Methylated Sprits (IMS) or modified ethanol may be more readily available.

\*\* These are highly retentive solvents and should not be used pure for varnish removal. They should only be used as additives to solvent gels.

\*\*\* Shellsol® products are produced by Shell. If it is not possible to buy locally these products, the boiling point ranges should be noted and used to select similar solvents.<sup>18</sup>

\*\*\*\* This is not used often today due to health hazards. Benzyl alcohol can be mixed with mineral spirits to approximate the solubility parameters of xylene.

The purity of various solvents is important to consider. Solvents can be bought from specialised suppliers of chemicals in different grades.

ACS (American Chemical Society) grade solvents are a very pure grade of solvent, whereas technical grade solvents are less pure (these are produced for commercial and industrial purposes). These purer solvents may be more costly and difficult to source, but will produce better cleaning results. Solvents bought from local drugstores or building merchants will be of lesser quality and should be avoided.

The purity of a solvent will have an impact on factors such as the Boiling Point (range) and Evaporation Rate of solvents, but also on their effectiveness at diffusing into a coating and thus removing varnish layers. Some solvents have properties that affect their purity, and thus may be difficult to source in unaltered form. For example, ethanol is very reactive to moisture contained in the atmosphere and will easily form an azeotrope (stable mixture) with water molecules absorbed from the surrounding air.<sup>19</sup> It can be bought at 99% purity at a higher cost. A stable azeotrope with water at 96% purity is cheaper but may affect the efficiency of the solvent (sometimes ethanol which is 96% pure will cause blanching of the paint surface, whereas a 99% pure ethanol will remove varnish without leaving a blanched surface).<sup>20</sup> Other stabilisers are often added such as methanol (up to 2%), in addition to colourants (to avoid using ethanol for alcohol production). These mixtures are called Industrial Methylated Spirits (IMS).

<sup>18</sup> <https://www.shell.com/business-customers/chemicals/our-products/solvents-hydrocarbon/isoparaffins.html>

<sup>19</sup> An azeotrope is a mixture that has a Constant Boiling Point. An ethanol-water azeotrope will form at a 95.63% volume ethanol 4.37% water (96% ethanol). Once this composition has been achieved, the two components will evaporate out at the same rate. The Boiling Point of this mixture is 78.2 °C.

<sup>20</sup> Note that the working properties of 99% ethanol are very different to 96% ethanol. When possible, 99% ethanol is preferred.

Since the 1990's, focus has shifted to the development of increasingly controlled methods of solvent cleaning, aiming to reduce the exposure of paint layers to solvents by enhancing the viscosity of the cleaning solution. Solvents confined in gels and emulsions are part of this trend. A gel is defined as a non-fluid colloidal network or polymer network that is expanded or swollen throughout its whole volume by a fluid (In other words, a fluid such as a solvent that is thickened with a polymer). Gels are often called retentive as they retain the solvent in the gel system more than a swab with a free solution. By confining the solvents in a gel, the rate of solvent diffusion into the varnish and paint is reduced, limiting solvent action on the paint and the substrate.

Thickened solvents and gelled systems aim to reduce the fluid penetration of a solvent into a substrate while still allowing diffusion in the gaseous phase to occur. The solvent vapours can act on the surface allowing dissolution to occur but are retarded from accessing lower substrates. Less solvent can be utilised and the conservator can have better control of the cleaning process. Additionally, less mechanical action is necessary in picking up the swollen or dissolved varnish.<sup>21</sup> Furthermore, as solvent application times can be extended, less reactive solvents can be utilised, lessening the risk to underlying paint areas. Penetration and transfer of dissolved material through cracks in the paint layer to the (canvas) support is reduced, although gel residues can become trapped in wider craquelure.

---

## Clearance of the gels and gel residues

---

A disadvantage of physical gels (but not rigid gels) is that it is always necessary to rinse the surface after the use of a gel to avoid gel residues. Typically, free solvents and cotton swabs or (dry) sponges are used. The introduction of gels for the removal of surface dirt and varnish removal from paintings in the late 1990's, sparked much debate and discussion regarding clearance of the gels

and the effects of any residues left on the surface. The Getty's solvent gel residues research project found that residues can be left on surfaces if not cleared carefully.<sup>22</sup> The results from this project have been published in 'Solvent Gels for the Cleaning of Works of Art: The Residue Question' (2004).<sup>23</sup> Clearance for gelled systems should be considered specific for the individual gel used. In general, a slightly less polar solvent can be used than the solvents in the gel system. Clearance should occur once the gel has optically been completely removed from the painting surface and some time has passed for the evaporation of any solvents that may have penetrated the surface of the paint film. A final clearance of the gels can be achieved using a 1:1 mixture of demineralised water and ethanol. However, any use of water should be avoided for Carbopol®-Ethomeen® gels (see below). Some conservators apply solvent gels through a barrier layer to help mitigate the problem of residues (see also the Tissue Cleaning section below).

---

## Types of Solvent Gels

---

Gels are commonly divided into two classes:

- *Physical gels*, which use hydrogen-bonding between monomers and can either be mixed with the solvent and applied to the surface of the painting, or come as powders that need to be mixed or heated to form a gel.
- *Chemical rigid gels*, which are made by reactions between polymers to create covalent chemical bonds between the polymers. These gels are synthesised in specialised chemical labs and can only be bought pre-made. They only need to be soaked in the solvent of choice before application (see: Current and Future Developments).

Some gel systems are better designed for aqueous treatments, while others are more appropriate for solvents typically used for removing resinous coatings.

---

<sup>21</sup> Note however that some mechanical action is often still necessary with solvent gels to increase contact between the gel and the surface and to facilitate solvent action. The exception are rigid gels which form a film prior to application to the surface.

<sup>22</sup> Carbopol®-Ethomeen® gels were specifically studied for residues. [https://www.getty.edu/conservation/publications\\_resources/newsletters/15\\_3/news\\_in\\_cons.html](https://www.getty.edu/conservation/publications_resources/newsletters/15_3/news_in_cons.html)

<sup>23</sup> Free publication: <http://dzaohiy03d3idm.cloudfront.net/publications/virtuallibrary/9780892367597.pdf>

ἡ Αγία

Παρθένω



Overview image of a small Greek icon, viewed in ultraviolet-induced visible fluorescence. Several layers of varnish have been removed from the right side of the painting, left the layers of degraded and oxidised varnish are still present.

## Methyl cellulose and Hydroxy propyl cellulose

Cellulose ethers are used as inert thickeners.<sup>24</sup> They play no active role in the cleaning process.

Methyl cellulose and hydroxy propyl cellulose are semi-synthetic cellulose derivatives that can be dissolved in water and other polar solvents (such as ethanol or isopropanol) to form viscous solutions. They do not gel well in acetone and will not swell in hydrocarbon solvents. Their use as a gelling agent is, therefore, limited to a small range of useful solvents. They are frequently used as adhesives in paper conservation, or as a gelling agent for removing water soluble glues, such as protein or polysaccharide gums. However, because they swell well in alcohols, they can be very effectively used to remove aged natural resin varnishes.

A wide variety of manufacturers produce these cellulose derivatives. Different viscosities of each typology are also sold. In Europe, two brand names are commonly used: Methocel™ (methylcellulose) and Klucel™ G (hydroxy propyl cellulose).<sup>25</sup> Both product lines are made for commercial purposes, such as the food industry or pharmaceuticals.

They come in powder form and are generally used in low concentrations (0.5–5% weight to volume). The final viscosity of the gel will depend on the degree of polymerisation (i.e., the grade) of the starting material, the solvent selected and the concentration. Similar concentrations of these materials in different solvents will produce gels of differing viscosity.

Methyl cellulose is a thickener that is more frequently used in consolidation of underbound paint media and application of facings. It gels well in water, but also in ethanol and isopropanol. Other variants exist, such as carboxyl methyl cellulose. Films made with methyl cellulose will re-swell in water and alcohols after they have fully dried. This material is classed as extremely stable. Discolouration was less than other cellulose ethers and thermal degradation was not noted.<sup>26</sup>

Hydroxy propyl cellulose is insoluble in many non-polar organic solvents, but is soluble in mixtures of polar (e.g.

ethanol: acetone, isopropanol: acetone) and non-polar solutions. Hydroxy propyl cellulose is reversible in water and in alcohols after drying. Aging tests on this product have indicated this material is relatively stable and although any residues left on the paint surface may undergo some yellowing, it critically maintains its solubility behaviour and is inert with regards to any chemical effect it may have on the original paint surface.<sup>27</sup> Thermal degradation can result in discolouration and loss of degree of polymerisation (DP).<sup>28</sup>

### Ethanol gelled with hydroxy propyl cellulose (Klucel G):

Take 100 mL of ethanol 99% at room temperature. Mix in 3 g of Klucel™ G powder. Close the jar securely and shake the solution till the powder has completely dissolved and formed a gel with the solvent. It may need to be left overnight to completely dissolve all the powder in the solvent.

A magnetic stirrer and magnetic bean can be used to facilitate the making of this gel.

### Solvent mixtures gelled with Klucel™ G:

Take 75 mL acetone and 25 mL ethanol (99%). Mix together, then add 3 g of Klucel™ G powder to the solvents while stirring (to avoid the formation of lumps). Make sure the jar is closed securely, and shake the solution until the Klucel™ G has dissolved in the solvents and a gel has formed.

Take 50 mL isopropanol and 50 mL acetone. Add 3 g of Klucel™ G powder. Stir in the powder to help it mix through the solvent and avoid lumping. Close the jar securely and shake the solution until the gel has fully formed.

Note that the three gels above can be prepared for testing. Always test the solvent (mixtures) independently to the gel first.

<sup>24</sup> [https://www.getty.edu/conservation/publications\\_resources/pdf\\_publications/cellulose\\_ethers.html](https://www.getty.edu/conservation/publications_resources/pdf_publications/cellulose_ethers.html)

<sup>25</sup> Methocel™ are produced by DuPont Pharma Solutions. Klucel™ products are currently produced by Ashland Inc (formerly Aqualon, formerly Hercules).

<sup>26</sup> Feller, Robert L., and M. Wilt. 1990. *Evaluation of Cellulose Ethers for Conservation*. Research in Conservation 3. Marina del Rey, CA: Getty Conservation Institute. [http://hdl.handle.net/10020/gci\\_pubs/cellulose\\_ethers](http://hdl.handle.net/10020/gci_pubs/cellulose_ethers)

<sup>27</sup> Fife G., Och J.V., Stabik B., Miedema N., Seymour K., *A package deal: the development of tissue gel composite cleaning at SRAL*, In: ICOM-CC 16th triennial conference Lisbon 19–23 September 2011: preprints. 2011. <https://www.icom-cc-publications-online.org/PublicationDetail.aspx?cid=9cbc532d-a034-4215-8a65-36852925ca95>

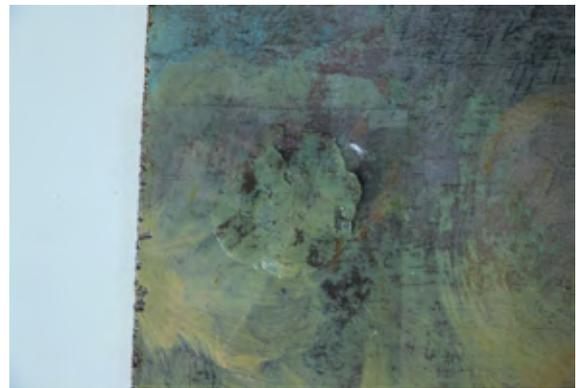
<sup>28</sup> Pataki-Hundt, A., C. Bretzendorfer, and M. Börngen. 2021. *Klucel hydroxypropylcellulose: Its impact on artificial ageing and consequences for conservation usage – A case study*. In: *Transcending Boundaries: Integrated Approaches to Conservation*. ICOM-CC 19th Triennial Conference Preprints, Beijing, 17–21 May 2021, ed. Bridgland, J., Paris: International Council of Museums.



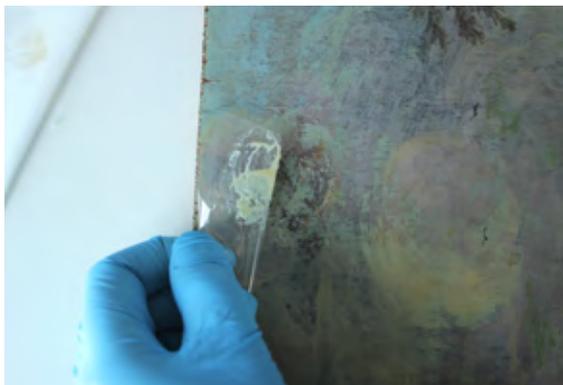
A simple solvent gel containing Klucel G and two solvents. The solvents are measured out first, then the Klucel G powder is weighed out and added to the solvent (mixture).



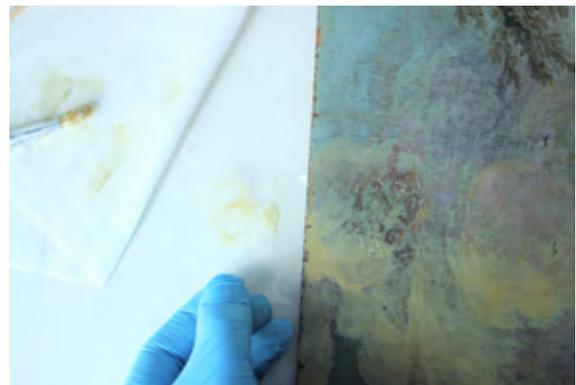
1.



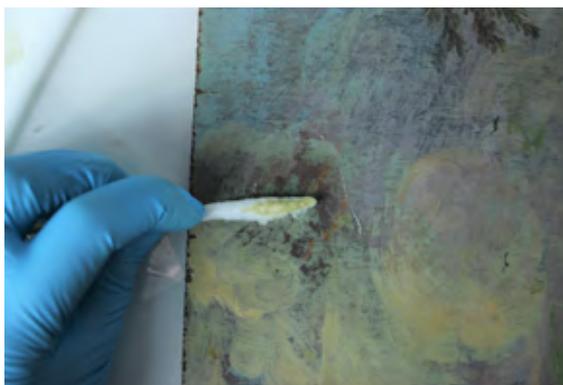
2.



3.



4.



5.

1. The solvent gel is placed onto the varnish or overpaint and moved around with the brush so that there is good contact between the gel and the surface.
2. A sheet of Melinex or plastic foil is placed on the solvent gel to aid absorption into the varnish or overpaint and prevent evaporation of the solvent.
3. After a set amount of time the plastic foil is removed.
4. The varnish or overpaint has become swollen and dissolved into the solvent gel, resulting in its discolouration.
5. A dry swab is used to clear the gel and the swollen varnish or overpaint, followed by a swab lightly dipped in a suitable solvent to remove residues.

---

## Carbopol® (straight chain high molecular weight poly acrylic acid)

---

Highly oxidised varnishes and old oil paint retouches can be notoriously difficult to remove. Solvent-detergent systems have been designed to aid the removal of resins and oil bound layers. These are based on the solution of a polyionic acrylic acid material chemically bonded to a surfactant in solvents. The polarity of the solvent in the gel relates to the polarity of the material that is undesired. Thus, the removal of a non-polar material from the surface will require the use of a non-polar gelled system, and vice versa.

Carbopol® is the trademark for polymers based on acrylic acid manufactured by Lubrizol (formerly the B. F. Goodrich Company). Carbopol® is a white, highly hygroscopic powder and should therefore be stored in sealed containers.

It has been in use in the cosmetics and pharmaceutical industries for over 30 years. Carbopol® comes in different grades, e.g.: Carbopol® EZ-2, Carbopol® 980, 954, 934, 943, 984 etc.. The numbers provide an indication of molecular weight and refer to specific components of the polymer (the higher the Hydrophilic Lipophile Balance (HLB) the longer the polymer chain and the thicker the gel formed). Type 980, which has the highest molecular weight (due to the interlinkage of many molecular chains), shows the highest gel-forming properties and absolute transparent gels are formed. Carbopol® EZ-2 is the most readily available from conservation suppliers, and is slightly less pure than other forms, but also cheaper<sup>29</sup>. Carbopol® works partly as a chelating agent in the presence of water.

Aqueous Carbopol® gels can be made by dissolving the resin powder directly into water or into a buffered aqueous solution. These gels can be used effectively for surface dirt removal or swelling water sensitive adhesives such as proteins or polysaccharide gums. They form a slightly stiffer gel at a lower concentration than the cellulose ethers mentioned in the previous section and release water molecules more slowly.

Carbopol® can also be used, when bound to a base, such as a catationic surfactant, to form a skeletal structure that will allow a solvent to be suspended around it. These

Carbopol® gels are made by mixing the poly acrylic acid resin with a cationic surfactant, Ethomeen®. There are two forms of Ethomeen® that function slightly differently within the system - C12 (used for apolar systems) and C25 (used for polar systems). In order to connect the resin with the surfactant molecule, some rather complex chemistry reactions are required. Following instructions in making these gels is imperative to ensure that the correct gel formation results.

Functional groups on the poly acrylic acid resin (powder) molecules need to be ionised in order to form an ionic bond with a molecule of the surfactant Ethomeen® carrying an opposing charge. Note that one molecule of Carbopol® has multiple functional groups to which the Ethomeen® molecules will be bonded. The ionisation charges are induced on both molecules in the presence of water at a determined pH value. The amount of water used in the formation of this skeletal structure is limited to the formation of the ionic bonds and has no cleaning effect within the resultant gelled system. Note that water must NOT be used for clearance of these gels as this would unzip the intermolecular bond between the poly acrylic acid resin and surfactant.

Ethomeen® C25 is a polar amine, and therefore used with polar solvents such as isopropanol, ethanol, acetone and benzyl alcohol. Ethomeen® C12 has a much lower polarity and is used with solvents such as xylene, Low Aromatic White Spirits (Shellsol D40®). Other surfactants have been used instead of Ethomeen®, but often need additional pH modifiers to perfect the gelation process.

Once made, Carbopol®-Ethomeen® solvent gels have a long shelf life. Stocks of gels can be made with different solvents and used for testing when needed. Gels containing different solvents can be readily mixed. This means that polar-apolar solvents can be readily used together on surfaces that require both solvent types.

**Please note:** Carbopol® gels should never be used on porous paints. The residues will remain in the surface of the paint and prove impossible to be removed completely. Over time, these residues may affect the solubility of the paint film, aid leaching in future treatments and affect the swelling parameters of the paint.

Clearance of Carbopol® gels may be problematic. Typically, a solvent solution (of the same polarity as the gel) is used, but not necessarily the same solvent that is in the gel. Solvents of lower polarity can be used. Therefore, gels made with Ethomeen® C12 can be rinsed

<sup>29</sup> <https://www.mdpi.com/2311-5521/4/1/3/pdf#:~:text=Carbopol%20NF%20980%20polymer%20presents,many%20polymer%20chains%20%5B46%5D>

with low aromatic hydrocarbon solvents such as Low Aromatic White Spirits or isooctane. Gels made with Ethomeen® C25 will require a rinsing solution with some polarity, but if safe for the paint layer, a mixture of alcohol/hydrocarbon solvent can be used. To test whether a rinsing solution is suitable for clearing a Carbopol® gel from the painted surface, put a little of the solvent gel on a spatula and put it in the potential rinsing solution. If the solution goes a bit cloudy, it precipitates which means the solution is not suitable as a rinsing solution. Note: Water should NEVER be used to clear these gels!

#### Carbopol®-Ethomeen® gel recipes:

In general, Carbopol®-Ethomeen® gels can be made according to a stock recipe. For recipes containing Ethomeen® C25 (so more polar recipes) the following proportions can be used:

- 100 mL solvent or solvent mixture
- 2 g Carbopol® EZ-2 powder
- 20 mL of Ethomeen® C25
- 10-15 mL demineralised water

The solvents should first be measured and mixed. In a separate container, the Carbopol® powder is then added to the Ethomeen® C25 and stirred in, until a smooth paste is formed. The solvent (mixture) is then added to the Carbopol®-Ethomeen® mixture and stirred in to make a fluid non-viscous solution. Finally, the water is added 1-2 mL at a time, the jar securely closed, and shaken well until a gel is formed. Note that not all of the water content may be required to form the desired gel!

For recipes containing Ethomeen® C12 (using apolar solvents) the following proportions can be used:

- 100 mL solvent or solvent mixture
- 2 g Carbopol® EZ-2 powder
- 20 mL Ethomeen® C12
- 1.5 mL demineralised water

The solvents should first be measured and mixed. In a separate container, the Carbopol® powder is added to the Ethomeen® C25 and stirred in, until a thick paste is formed. The solvent (mixture) is then added to the Carbopol®-Ethomeen® mixture and stirred in to make a fluid non-viscous solution. The water is added a few drops at a time, the jar securely closed, and shaken well until a gel is formed.

**Note:** Gels made with the same Ethomeen® (so C12 + C12 or C25 + C25) can be intermixed in all proportions (weight : weight). Mixtures of stock gels (weight : weight) made with Ethomeen® C25 and C12 can also be made, as required. The Modular Cleaning Program (MCP), designed by Chris Stavroudis also provides stock recipes for mixtures of Carbopol®-Ethomeen® gels.<sup>30</sup>

**Note:** Gels made with Ethomeen® C12 can be cleared with non-aromatic hydrocarbons (such as Low Aromatic White Spirits or isooctane); those made with Ethomeen® C25 can be cleared with polar solvents such as isopropanol, ethanol etc.

<sup>30</sup> <https://cool.culturalheritage.org/byauth/stavroudis/mcp/>



Carbopol ethomeen gel

---

## Agar, Agarose and Gellan gum

---

Polysaccharide based gelling agents are the most widely available gelling materials. These have been used in various conservation disciplines for some time and are now becoming both popular and useful in the conservation of easel paintings.

Currently, two of the most commonly used physical gels in art conservation are Agar Agar/agarose and Gellan gum (both form rigid gels). Both are naturally occurring polysaccharides. Agar Agar is a heterogeneous mixture of two classes of polysaccharide (Agarose -- around 70% -- and agarpectin -- around 30%) whereas agarose is a purer form of Agar Agar and is predominantly the polysaccharide. While agarose is electronically neutral, Gellan gum is anionic with negatively charged carboxyl groups, which are available to complex with cations.

Agarose/Agar Agar and Gellan gum are available in powder form and are prepared by dispersing dry polymer in pure water—or modified aqueous solution—and heating until clear and boiling. As the polymer dispersions cool, both agarose/Agar Agar and Gellan gum form helical structures.<sup>31</sup> Small amounts of alcohol (ethanol, iso-propanol or benzyl alcohol) can be added.

These gels, often called RIGID gels, are excellent for removing surface dirt from delicate surfaces (see the brochure on *Dirt and Dirt Removal (Dry and Aqueous Cleaning)*).

Agar Agar gels can be classified as reversible sol-gels or reversible hydrocolloid gels. A sol-gel starts from a colloidal solution (the sol) that acts as the precursor for an integrated network of polymers (the gel). Once cooled, it is easily reheated to its sol state, a process that can be repeated multiple times without change to the working properties of the gel (though a loss of water through evaporation should be compensated for with each reheating). Agar Agar gels can also be poured onto the surface when in the sol-phase to conform to the topography, or brushed onto the surface as a sol just before it cools to the gel phase. Agar Agar gels exhibit high gel strength even at concentrations less than 6%. They are stable up to 65 °C and are not enzymatically

degraded by most bacterial species. They are stable in both highly alkaline and acidic conditions, and, prior to the addition of other cleaning agents, they are completely non-toxic and natural. In conservation, Agar Agar is used at a maximum concentration of 8%.

Gellan gum is available in two forms: low-acyl and high-acyl. When prepared, low-acyl Gellan gum is typically more rigid and brittle, whereas high-acyl Gellan gum is softer and has greater conformability. Gellan gum is traditionally used in paper and textile conservation. Low-acyl Gellan gum gels are not thermo-reversible, high-acyl Gellan gum gels often are.

Agar Agar food grade can be obtained from health food stores. The more purified agarose is acquired from chemical suppliers and is more costly than the food grade Agar Agar.

Prepared Agar Agar (and agarose) gels can be kept in the fridge for several days, though if contaminated mould will grow readily.

After heating, it is also possible to add a small amount of solvent (up to 10%), chelating agent, oxidiser or another cleaning agent to the Agar Agar sol. Amounts are calculated according to percentage (volume) of the original volume of the gel. This must be added during cooling of the solution just before it reaches the gel phase, due to the low boiling points of many solvents.

### Recipe for 2% Agar Agar dissolved in demineralised water:

Bring 100 mL water to around 90 °C. Stir in 2 g of Agar Agar powder until completely dissolved. Remove from the heat, pour into a flat container to gel as a film of around 5 mm-1 cm and let cool. The solution will start to gel at around 40 °C. Agar Agar can easily be prepared in the microwave. However, do not let the water boil!

Once it has gelled, the film can be cut into various sizes and shapes, according to requirements. Alternatively, the cooling solution can be poured or brushed directly onto the desired surface while in the sol-phase. It sets without penetrating into the substrate, conforming to the surface topography. This is useful for more three-dimensional surfaces, for example, impasto paint. Once set the Agar Agar can be peeled off, leaving little to no residues.

---

<sup>31</sup> Fife G., Och J.V., Stabik B., Miedema N., Seymour K., *A package deal: the development of tissue gel composite cleaning at SRAL*, In: ICOM-CC 16th triennial conference Lisbon 19–23 September 2011: preprints. 2011. <https://www.icom-cc-publications-online.org/PublicationDetail.aspx?cid=9cbc532d-4034-4215-8a65-36852925ca95>

**Recipe for 3% Agar gel in demineralised water with 20% ethanol:**

Bring 80 mL water to around 90 °C. Add 3 g of Agar Agar powder and stir until completely dissolved. Remove from the heat, and when the temperature of the solution is under 78 °C (this is the Boiling Point of ethanol), add 20 mL Ethanol and mix well. Let cool further in a flat container until a gel is formed. Note: Do not put gels prepared with solvents in the microwave!

The Agar Agar can be allowed to cool and applied as a gel cut to the desired shape and size, or applied with a brush or spatula while warm as a sol.

water-miscible solvents. Xanthan gum is a polysaccharide polymer that is made up of tangled helix chains, which will aggregate at higher concentrations to make little cages that hold water molecules. Oxidising agents, such as bleach, and most cationic materials, such as ammonia, cannot be used as they cause the gel to collapse. Xanthan gum gels can hold non-polar solvents in intermolecular pockets (oil in water emulsion), a property which has the potential to greatly reduce the conservator’s exposure to solvent. In gel form it is able to hold up to 20% solvent. As it is a water-based gel, it is not recommended for acrylics or other water sensitive surfaces.

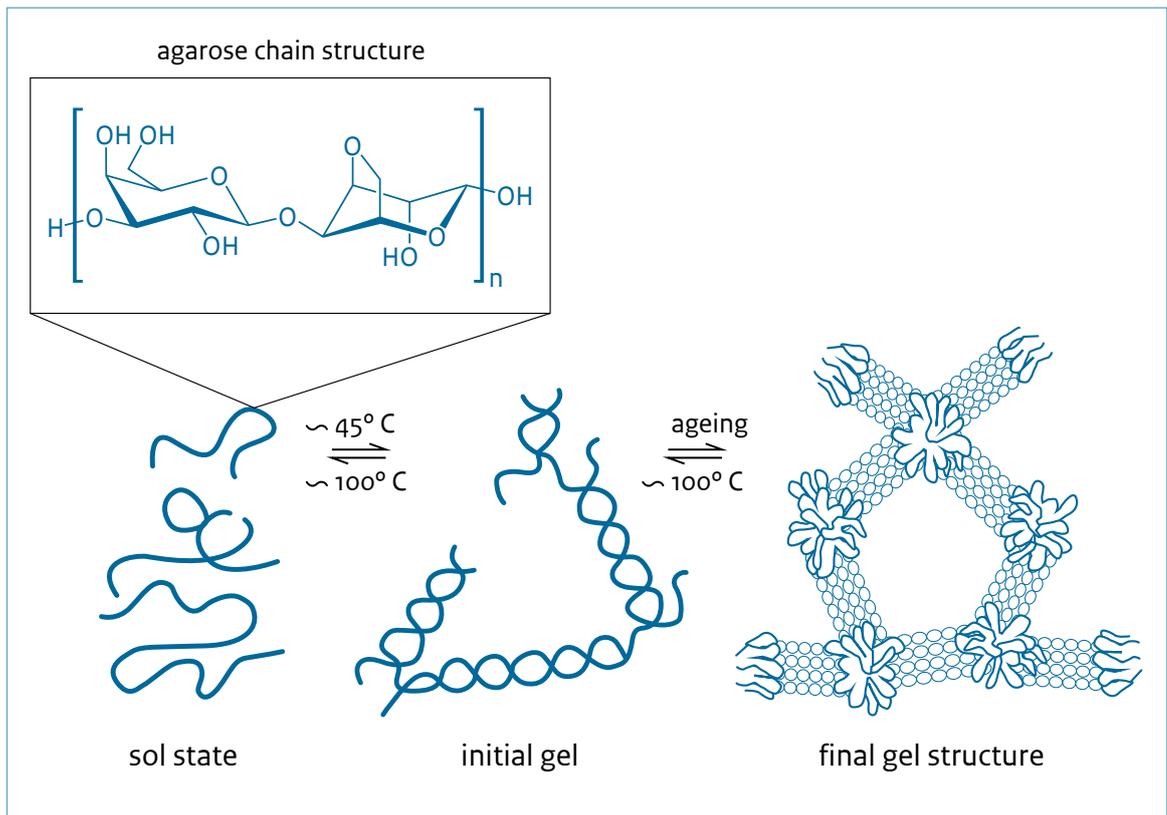
**Xanthan gel gum recipe (20% solvent):**

- 2 g Xanthan gum powder
- 80 mL demineralised water
- 20 mL solvent (in this case acetone)

Add the Xanthan gum powder to the water and stir in well (be aware it takes several hours for Xanthan gum to dissolve in water). Once the gel has formed add the acetone and mix in.

**Xanthan gum**

Xanthan gum is a water-based polymer polysaccharide that is non-toxic, biodegradable and stable at any pH. It can be used to make oil-in-water emulsions for non-



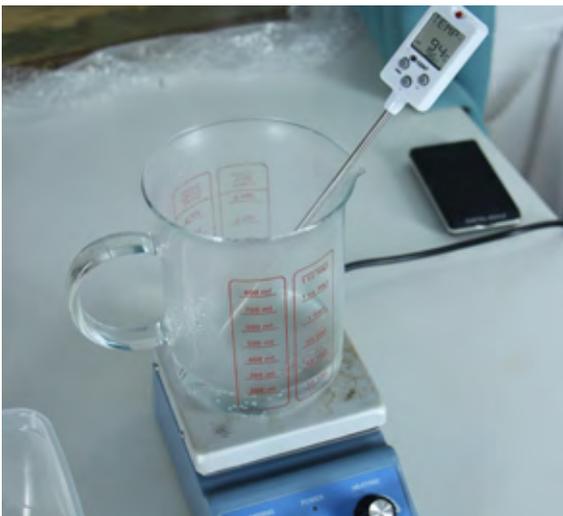
Agar formation helix structure



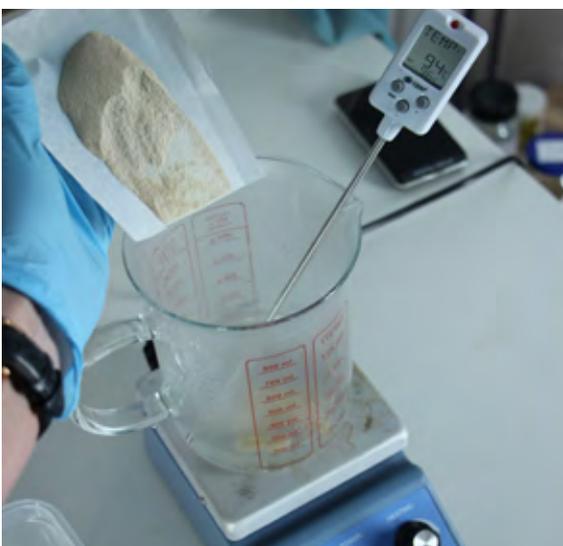
1.



2.



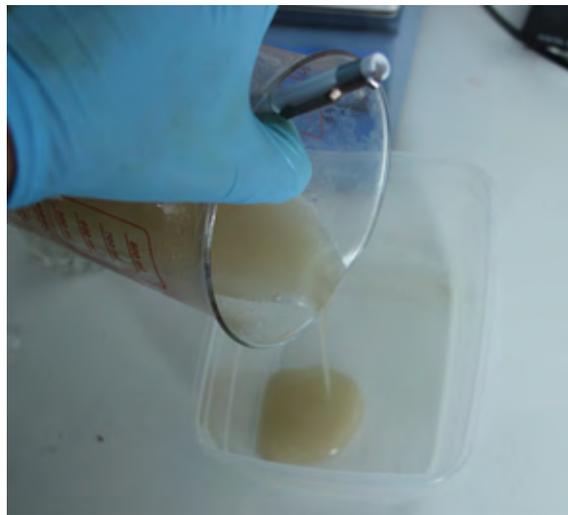
3.



4.



5.



6.



7.

1. Materials needed for preparing Agar Agar gel, including a hot plate, stirrer and weighing scale
2. Measure the amount of water required and weigh out the Agar Agar powder
3. Heat the water to around 90 degrees Celsius
4. Add the Agarose powder
5. Stir in the powder well, while the water is still almost at boiling point
6. Pour the mixture into a clean mould
7. Allow the mixture to cool and set, preferably in the fridge. When it has set it can be cut to the size/shape desired.



Emulsions consist of mixtures of two substances that are normally immiscible i.e. they normally cannot be mixed (for example oil-in-water). There are always two phases, the dispersed phase, which is the small volume, that is suspended in a continuous phase (the dispersant). A surfactant allows the two phases to remain stable and dispersed, rather than one phase segregating from the mixture.

Emulsion systems can be used to suspend a polar solvent in an apolar environment or vice versa. The emulsifying agent is selected depending on the nature of the materials within the system. If a polar material needs to be suspended in an apolar material, a hydrophilic emulsifying agent is chosen (so the emulsifying agent is compatible with the continuous phase). If the continuous phase is apolar, the emulsifying agent should not be too hydrophilic ( $HLB < 10$ ). More complex emulsions usually contain additional emulsifying agents or surfactants to help stabilise the dispersion.

Surfactants can be added to aqueous solutions to create emulsions. Surfactants have a bipolar molecular structure i.e. they have a polar head and nonpolar tail. This means that they are simultaneously hydrophobic/lipophilic and hydrophilic/lipophobic simultaneously. This dual nature allows surfactants to interact with both polar and apolar material. There are three different types of surfactant: cationic, anionic and non-ionic. In conservation practice, and especially in painting conservation, non-ionic surfactants are preferred. These have a more balanced molecular structure and while both the head and tail of the molecule have an opposite polarity, they will not form ionic bonds with substrate material, meaning that rinsing is facilitated.

**Note:** a rinsing is always required when cleaning with surfactants. Residues can expediate dirt pick up on surfaces and facilitate the formation of unwanted metal-ion soaps and crusts.

Emulsions can be classified in two groups: oil-in-water and water-in-oil. This classification depends on the dominance of the continuous phase and the ability of the surfactant to 'hold' material of opposing charge or opposing polarity.

The hydrophilic-lipophilic balance (HLB) of a surfactant is a measure of the degree to which it can bond with water (hydrophilic) or it's affinity to apolar substances (lipophilic). Confusingly, there are two scales which runs from 0 to 40 for ionic surfactants and 0 to 20 for non-ionic surfactants. In both scales, the lower the HLB

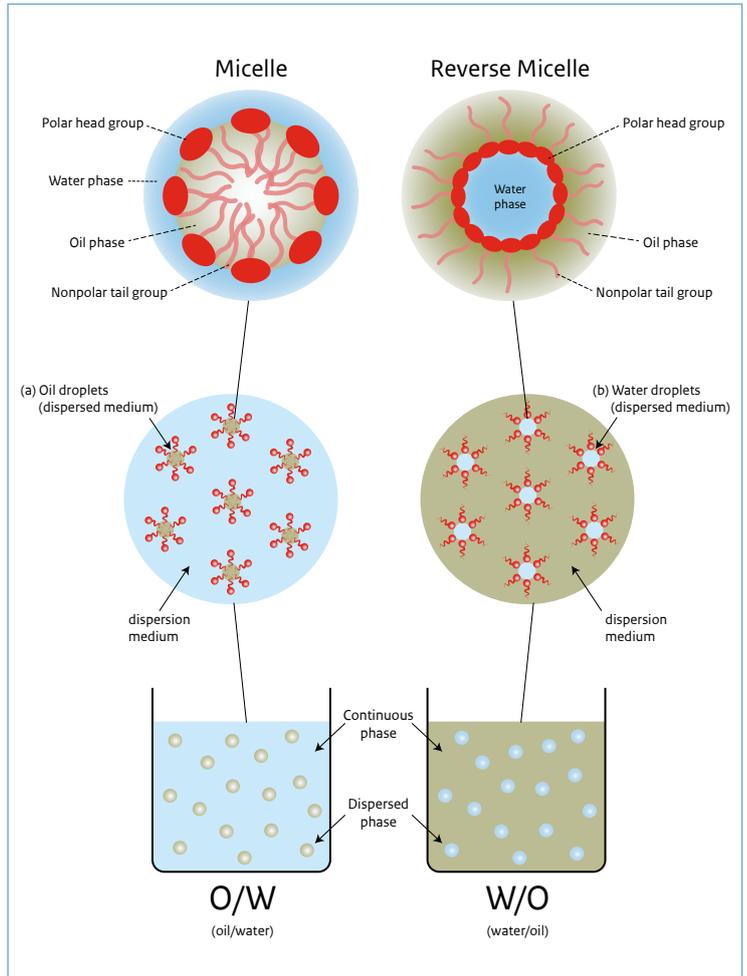


Diagram illustrating the working of an emulsion system: an oil in water emulsion and a water in oil emulsion.



Xanthan gum package

number, the weaker the surfactant's ability to emulsify oil in water. The higher numbers are designated to the surfactants with the strongest ability to form stable oil in water emulsions (strong hydrophilic and lipophilic properties). There is also a correlation between the HLB value of a surfactant and its Critical Micelle Concentration (CMC). Mid-range CMC surfactants (2-20 mM) surfactants tend to have the highest HLB's.

The CMC refers to the concentration of a surfactant in a solution at which micelles are formed. Micelles are spherical bundles of surfactant molecules with a specific orientation. In an apolar continuous phase, the polar heads of the surfactant will direct inwards, and vice versa. This is an energy efficient system. If in contact with material of similar molecular polarity, the micelle is able to temporarily open. The individual surfactant molecules are able to form inter-molecular bonds with the material. Subsequently, the surfactant molecules will reform, as again an energy efficient system is desirable. The bound material will be 'wrapped up' in the centre of the micelle. In short, the centre of a micelle will have a polarity that strongly opposes the polarity of the surrounding continuous phase of the emulsion. This allows material of opposing electronegative charge to be picked up and effectively put into solution.

In relation to removing soil layers, the HLB number should be between 13-15 for an ionic surfactant, above this range there is the potential to saponify the underlying oil paint, but below this range it is difficult to effectively 'pick up' the soiling material.

Emulsions can be very effective at removing hydrophilic dirt from water sensitive surfaces. These materials tend to be used for cleaning surfaces which have more recent surface dirt deposits, as opposed to surface dirt that has remained in-situ for longer time. Emulsions are also useful for bringing both polar and apolar chemistry to the surface simultaneously, allowing conservators to target the removal of mixtures of materials. Care should always be taken when cleaning young oil paint films and acrylic paintings as surfactants may act directly on the paint binding medium in these cases.

Pemulen<sup>TM</sup> TR-2 is an emulsifier that is being used more frequently in conservation, and depending on the additives to the emulsions, can be used to remove surface dirt and resinous material simultaneously.

---

## Pemulen<sup>TM</sup> TR-2

---

Pemulen<sup>TM</sup> TR-2 is a high molecular weight block co-polymer poly acrylic acid polymer. It is purchased as a white powder which is hygroscopic and so must be stored correctly. It differs from Carbopol<sup>TM</sup> (mentioned earlier) because it contains additional branched functional groups. The molecular skeleton has a lipophilic portion in addition to a larger hydrophilic portion, allowing the molecule to be used in a similar manner to a surfactant (as described earlier). Pemulen<sup>TM</sup> TR-2 polymers are versatile polymeric emulsifiers and have the ability to emulsify up to 20-30% lipophilic material by weight within a pH range of 4 to 11, without an additional surfactant. Pemulen<sup>TM</sup> gels bring water chemistry to the surface for cleaning. Additionally, polar organic solvents can be added up to about 20% (volume : volume).<sup>32</sup>

Gels made with Pemulen<sup>TM</sup> TR-2 are most viscous in the pH range of 5-9. The addition of a base is required to formulate aqueous gels using Pemulen<sup>TM</sup> TR-2; these can include sodium hydroxide, ammonium hydroxide, triethanolamine (TEA), and Ethylene Diamine Tetraacetic Acid (EDTA).<sup>33</sup> The amount of base added will determine the pH of the gel (for example, a gel made from 1.0% (weight: volume) Pemulen<sup>TM</sup> TR-2 in water with 5% TEA gives gel with pH 8.5; the same gel made with 1% TEA has a pH of 6.5). Making the Pemulen<sup>TM</sup> TR-2 gel can be quite tricky. It is best to first buffer the pH of the water by adding the base. Do note that the Pemulen<sup>TM</sup> TR-2 has an acidity value equal to pH 4 and so the pH of the buffered water may drop slightly when you add the powder. The co-solvent is added to the stock gel.

Pemulen<sup>TM</sup> TR-2 emulsions generally are stable over the course of time, for periods up to a month. However, in practice, some of the solvent seems to sink down towards the bottom of the jar overnight. To compensate, the jars of emulsion should be shaken prior to use to redistribute solvent evenly throughout the emulsion.

These cleaning systems are very versatile and can be used to remove complex aged material from the surface of paintings. Both aqueous and solvent chemistry are used to target complex mixtures of aged organic materials. Working at a (tested) specific pH value can ionise protein or oil containing material and even promote hydrolysis

---

<sup>32</sup> [https://www.researchgate.net/publication/284968546\\_Pemulen\\_as\\_a\\_versatile\\_emulsifier](https://www.researchgate.net/publication/284968546_Pemulen_as_a_versatile_emulsifier)

<sup>33</sup> EDTA is an acid, but will work as a base in the right pH conditions.

causing larger macromolecules to breakdown. The surfactant like structure of the Pemulen™ Tr-2 molecule is able to pick up these unwanted molecular structures and put them into solution. The co-solvent used aids this process. Care should always be taken to ensure that Pemulen™ TR-2 cleaning systems do not affect the paint layers. The viscous material should be left on the surface for sufficient time to interact with the surface coating but not to affect the original paint. Application tends to be most effective using a brush as the mechanical action expedites the cleaning action. Stock solutions have a long shelf life and can be intermixed.

Stock recipes are provided in the Modular Cleaning Program (MCP) produced by Chris Stavroudis (these are made to 2% Pemulen™ TR-2 and should be diluted to 1% with an aqueous preparation before use):

[https://www.getty.edu/conservation/our\\_projects/education/caps/just\\_true\\_using\\_Pemulen\\_TR2.pdf](https://www.getty.edu/conservation/our_projects/education/caps/just_true_using_Pemulen_TR2.pdf)

#### Pemulen™ TR-2 gel with a pH of 5

- 1 g of Pemulen™ TR-2
- Approximately 100 mL of deionised water
- 1 g (0.9 mL) Triethanolamine (TEA)

Add 1 g of Pemulen™ TR-2 in 50 mL deionised water. Mix well with a stirrer until the suspension is uniform and the Pemulen™ TR-2 powder well dispersed.

Mix approximately 1 g (0.9 mL) TEA into 45 mL deionised water. Mix the Pemulen™ suspension with the TEA solution while stirring vigorously. Adjust the pH to 5 by adding extra TEA dropwise, if necessary.

Bring the final volume to 100 mL with deionised water.

#### Pemulen™ TR-2 gel with a pH of 6:

- 1 g of Pemulen™ TR-2
- Approximately 100 mL deionised water
- 2.25 g (2.0 mL) Triethanolamine (TEA)

Add 1 g of Pemulen™ TR<sub>2</sub> in 50mL deionised water. Mix well with a stirrer until the suspension is uniform and the Pemulen™ TR-2 powder well dispersed.

Mix approximately 2.25 g (2.0 mL) TEA into 45 mL

deionised water. Mix the Pemulen™ suspension with the TEA solution while stirring vigorously. Adjust the pH to 6.0 by adding extra TEA dropwise. Bring final volume to 100ml with deionised water.

#### Pemulen™ TR-2 gel with a pH of 7

- 1 g Pemulen™ TR-2
- Approximately 100 mL deionised water
- 3.8 g (3.4 mL) Triethanolamine (TEA)

Add 1 g Pemulen™ TR-2 in 50 mL deionised water. Mix well with a stirrer until the suspension is uniform and the Pemulen™ TR-2 powder well dispersed.

Mix approximately 2.15 g (1.9 mL) TEA in 45 mL deionised water. Mix the Pemulen™ suspension with the TEA solution while stirring vigorously. Adjust to pH 7.0 with the TEA and bring final volume to 100 mL.

#### Pemulen™ TR-2 gel with a pH of 8

- 1 g. Pemulen™ TR-2
- 100 mL. deionised water
- 5.6 g (5 mL) Triethanolamine (TEA)

Add the Pemulen™ TR-2 powder to 50 mL of deionised water. Mix well with a stirrer until the suspension is uniform and the Pemulen™ TR-2 powder well dispersed.

Mix approximately 5.6 g (5 mL) TEA in 45 mL deionised water. Mix the Pemulen™ suspension with the TEA solution while stirring vigorously. Adjust the pH to 8.0 with extra TEA if necessary. Bring the final volume to 100 mL.

Further recipes can be found here:

<http://pemulentr2.pbworks.com/w/page/15636418/How%20to%20make%20the%20gel> <https://cool.culturalheritage.org/waac/wn/wn34/wn34-2/wn34-206.pdf>

Note that these are stock gels, to which the co-solvent is added!

Similarly, to the Carbopol® gels described above, Pemulen™ TR-2 gels are not recommended for porous materials because of issues with rinsing the emulsion gel from some painted surfaces. To rinse the surface after using the emulsion gel, use pH adjusted water at the same pH or a lower pH as the emulsion gel (for aged oil

surfaces). For example, if a gel has a pH of 7.5, the pH adjusted water must have a pH of 7.5 or slightly lower). If the surface is sensitive to the rinsing solution, wait for the cleaning solution to evaporate out of the surface and lower the pH of the clearance buffered solution. Clearance solutions can be made with dilute acetic acid or carbonic acid; both of which are volatile water-soluble gases. One of the recipes for a rinsing solution at pH 6.5 has been given below. Further recipes are included in the Modular Cleaning Program (MCP).<sup>34</sup>

#### **pH adjusted rinsing solution with Glacial acetic acid at pH 6.5:**

- 1 mL Glacial Acetic Acid
- 2000 mL distilled or deionised water
- Ammonium hydroxide (10%) in solution

Add 1 mL Glacial acetic acid to 1000 mL of distilled water. Set the pH to 6.5 by adding ammonium hydroxide (10%) slowly, adding it dropwise. Stir regularly. Once a pH of 6.5 has been obtained, bring the final volume to 2000 mL.

In general, Pemulen™ Tr-2 emulsions are effective at removing oily grime (when used in the range of pH 7.5-8) and can be very effective at removing stubborn varnishes, especially those containing an oil or oil of turpentine, with the addition of a co-solvent. Young oil paints and acrylic paints may be sensitive to the combination of aqueous and solvent cleaning systems.

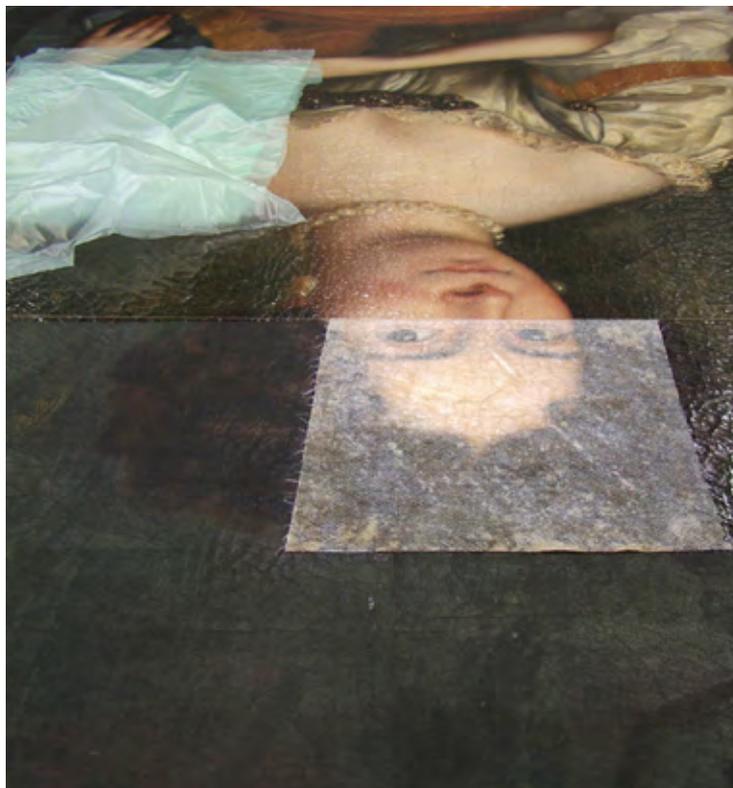
<sup>34</sup> <https://cool.culturalheritage.org/byauth/stavroudis/mcp/>  
[https://www.getty.edu/conservation/publications\\_resources/teaching/caps\\_downloading\\_mcp.pdf](https://www.getty.edu/conservation/publications_resources/teaching/caps_downloading_mcp.pdf)

Conservators are now leaning toward an increasingly controlled application of solvents during varnish and overpaint removal. Gelling solvents to enhance viscosity is one way to do this. Solvents in free form, and gelled, can be applied through a variety of materials to retard their diffusion into substrates or retain them on the surface. These working practices vary from country to country. One method that has been developed at the Stichting Restauratie Atelier Limburg (SRAL) in The Netherlands is the 'Compress Tissue Method'.<sup>35</sup> There are a number of benefits to using the tissue cleaning method for the removal of varnish and overpaint from a painted surface.

The Compress Tissue Method holds a gelled polar solvent on the surface of the painting, inhibiting penetration of the solvent into more sensitive substrates. The gelled solvent is selected for optimum swelling and dissolution of the varnish material. Once mobile, the dissolved varnish is sucked up into absorbent tissues placed over the surface. This lessens any mechanical action required by swabbing to pick up the dissolved varnish and stops the penetration of this material through cracks in the paint layer to the (canvas) support. The gelled solvent can be applied to large areas by using an impregnated tissue. This facilitates the removal of varnish from larger surface areas and reduces both the amount of solvent required for cleaning and the exposure of the conservator to that solvent.

The Tissue Cleaning with Free Solvents technique is the second tissue cleaning method described below. With this technique, the amount of solvent required is controlled. By calculating the weight of any tissue and the weight of any given solvent, it is possible to attain an optimal loading/percentage of solvent to tissue. In this way, the most effective solvent at the lowest concentration (weight/weight) for the least amount of time can be determined.

As the step-wise application process is systematic and timed with both techniques, an even result over a large surface can be achieved. This makes them suited to very large paintings when multiple people are required to achieve the same result. This system removes an even amount of varnish from the surface, and is thus not suitable for use on all paintings. It is most suitable for removing thickly and evenly applied varnishes. Any



The removal of varnish and overpaint using the Tissue Cleaning Method.  
Image: Stichting Restauratie Atelier Limburg

residues of older varnishes left on the surface may not be picked up in the initial varnish removal using the Compress Tissue Methods. Further cleaning targeting these residues or overpaint may then be necessary.

The Compress Tissue Method has been used effectively for sensitive surfaces, such as those with slightly cupped paint films, cracking or other physical damage, which would potentially be further degraded by the use of mechanical action, i.e. rubbing a swab with solvents over the surface of the paint film. Edges of paint could be chipped off or abraded, and areas of loose paint may be taken up by the swab, resulting in losses. Note that severely cupped paint may need to be pre-treated (flattened or consolidated) before using this cleaning approach.

---

## Compress Tissue Cleaning with Solvent Gel:

---

The Compress Tissue Method with gelled solvents, as designed by the SRAL, can be undertaken by following these steps:

<sup>35</sup> Fife G., Och J.V., Stabik B., Miedema N., Seymour K., *A package deal: the development of tissue gel composite cleaning at SRAL*, In: ICOM-CC 16th triennial conference Lisbon 19–23 September 2011: preprints. 2011. <https://www.icom-cc-publications-online.org/PublicationDetail.aspx?cid=9cbc532d-a034-4215-8a65-36852925ca95>



1. Applying the absorbing tissue to the surface. Care is taken to avoid over or underlaps with adjacently cleaned areas.



2. The gel tissue is covered with a HDPE plastic foil that conforms closely to the surface.

The solvent or solvent mixture for the removal of the varnish is selected by testing with free solvents, as described above. Tests of varnish solubility are paramount in establishing the solvent sensitivity of the varnish and solvent resistance of all colour areas of the painting. Areas that have been tested can be masked out when full cleaning is in progress.

- The chosen solvent (typically ethanol or isopropanol which diffuse rapidly into aged natural resin varnishes) can then be gelled by adding 2-4% (weight to volume) with Klucel™ G (or other appropriate cellulose ether). When the solvent is gelled, further tests are necessary to finetune the exposure time. This is done by using small pieces of tissue (ca. 2.5 cm x 2.5 cm) impregnated with the gel (a small amount of gel is brushed onto the piece of tissue until the tissue has absorbed the gel) and trialled on the surface for set intervals.
- Once the desired solvent, gel and time has been selected, larger sheets can be prepared. The size of the sheets prepared will be dependent on the size of the painting and the length of time required for each sheet to be on the surface of the painting. Note that when possible, the full size of the sheet is used (40 cm x 40 cm). This eliminates the potential for overlap between tissue sheets. The gelled solvent is evenly applied to the tissue, either by brush, roller or even immersing



3. The HDPE plastic foil is removed and replaced with an absorbent high-wet strength absorbent paper. The varnish is drawn up into the paper by gentle rubbing over the surface. The HDPE plastic sheet or Melinet sheet can be placed over the absorbent paper at this stage to stop the rubbing action scrunch up the paper.

Image 1 to 3: Stichting Restauratie Atelier Limburg



4. Lifting tissue off (showing varnish/overpaint on tissue). Image: Stichting Restauratie Atelier Limburg

the tissue in the gelled solvent. Excess gelled solvent is removed. Multiple tissues can be impregnated prior to use and kept in a plastic sheet envelop devoid of air. It is imperative that the gelled solvent be evenly distributed throughout the tissue. The tissue used at SRAL is a perforated polyester gauze distributed by Hanotex. Other solvent resistant textiles may be appropriate, but should be tested prior to substitution.<sup>36</sup>

- The tissues impregnated with solvent gel are typically placed (adjacent to each other in sequence) on the surface covered with a sheet of solvent resistant plastic foil, which conforms to the surface topography and which stops the solvent evaporating from the gel and holds the gelled solvent on the surface. This is done for a timed period of between 30 and 300 seconds. The tissue can be smoothed with a roller, brush or finger to aid optimal contact with the painted surface. During this time, the tissue must not dry out (it must remain wet) as the method will otherwise not work.
- The plastic foil is removed and replaced with an absorbent paper on top of the solvent tissue. The absorbent paper used at SRAL is a semi-synthetic paper produced by Kimtech.<sup>37</sup> This has high absorbency and wet-strength. The swollen varnish is encouraged to pass into the paper by gently but firmly rubbing over

the surface, through a sheet of solvent resistant plastic foil. Once the paper visibly changes colour, the whole package (tissue, paper and plastic foil) is removed, while still damp.

- Depending on the individual painting, additional cleaning of the surface or removal of any gel residues can then be carried out with free solvents and a swab, while the varnish is still swollen. Again, the solubility of any varnishes left on the surface should be tested. The gel residues can be rinsed with a lower polarity solvent or even water (if deemed safe).

The process is timed to precision and replicated over the whole surface of the painting.

As mentioned, similar systems with distinct adaptations exist. Conservators in The Netherlands also often use Evolon® CR tissue, a highly absorbent polyester/polyamide microfilament fabric as the tissue. Different companies sell different weight tissue, the heavier tissues will absorb more solvent (up to 4 x it's weight).<sup>38</sup> Evolon® CR Tissue with a weight of around 98 g/m<sup>2</sup> generally works the best as it is not too flimsy and will absorb the gel and varnish well, but also not too thick and stiff to hinder handling.

<sup>36</sup> Evolon CR tissues have been trialled unsuccessfully for this system, although these microfibre cloths are used for other cleaning systems.

<sup>37</sup> <https://www.fishersci.nl/shop/products/kimtech-absorbent-towels/10144914?searchHijack=true&searchTerm=10144914&searchType=RAPID&matchedCatNo=10144914>

<sup>38</sup> <https://www.preservationequipment.com/Catalogue/Conservation-Materials/Materials-and-Fabrics/Evolon-Microfilament-Material>  
<https://deffner-johann.de/en/evolon%C2%AE%20cr%20on%20roll,%20102%20cm%20x%2010%20m.html>  
<https://www.talasonline.com/Evolon-CR-Non-Woven-Textile>



Removing the tissue with varnish and overpaint absorbed into the tissue. A mirror image is made on the tissues, and once the solvents have evaporated, the tissues can be pieced together to create a physical document of what was removed from the paint surface.  
image: Stichting Restauratie Atelier Limburg

### Tissue Cleaning with Free Solvents<sup>39</sup>:

The process for the Tissue Cleaning method with free solvents is described below<sup>40</sup>:

Before varnish removal, timed trials are done with small pieces of tissue to choose the best free solvent (or solvent mixture), exposure time and amount of solvent. Small pieces of tissue (ca. 1 x 1 cm) are placed in glass pots or stoppered glass tubes and the solvent is added onto the tissue with a pipette. Typically, Evalon® CR tissue is used, but adaptations using thick Japanese paper are also practiced. The jar is closed to allow for the solvent to be fully absorbed by the tissue. Once each trial piece is prepared, they are placed one by one on the painted surface and covered with a piece of transparent polyester film to prevent evaporation of the solvent. The tissue can be pressed down gently with a roller or soft brush to ensure good contact with the painted surface. After the set time, the tissue is removed and the surface analysed

- Once the optimal solvent mixture, time and amount of solvent has been found, the sheets of tissue are cut to size, rolled up and placed in a test tube or jar. This is

then loaded with the solvent using a pipette or syringe. The tubes are tightly sealed with a plug to prevent evaporation and the sheets left for a few hours to allow the solvent to diffuse evenly through the fabric.

- Once the sheets are ready, they can be placed one by one on the surface and covered with a transparent polyester film to prevent evaporation of the solvent. The surface can then be smoothed with a roller or soft brush to ensure good contact with the paint surface. Again, here the problem of abutting adjacent sheets is problematic.
- After the set time, the polyester film and the tissue are removed from the surface. The next tissue can then be placed carefully on the surface, taking care to not overlap with the cleaned area.

One of the drawbacks of the two Tissue Cleaning Methods described above is the placement of the impregnated tissues. Adjacent tissues need to be placed very accurately to avoid an overlap and thus excess cleaning at the interface. Under cleaning by leaving gaps between tissue placement is also undesirable. However, under cleaned areas are preferred to overcleaned sections. Varnish residues can be immediately removed after the tissue methods, as the varnish is still soft from the solvents. Generally, they can be removed by rolling a swab dipped in solvent over a thin strip of tissue, which is placed on the varnish remnant. Any additional swollen varnish remains can be removed at this stage.

In general, a very large painting will require larger sheets of tissue, to reduce the number of 'lines' of remaining varnish from between two sheets. These lines can be greatly reduced by abutting the sheets of tissue together on the surface as accurately as possible.

A second drawback of these methods is the opacity of tissue. It is not possible to see through it and observe what is happening on the surface of the painting. During the process of varnish solvation and absorption, the colour of the tissue will change to the colour of the varnish and/or overpaint. This can vary per area of the painting.

These systems have the additional advantage in that the varnish is absorbed into a paper substrate during varnish removal. These papers can be kept and used as a document, recording what was removed and from where. Once the solvents have evaporated, the tissues can be further analysed or used to create a physical document of what was removed from where.

<sup>39</sup> Tauber G., et al. *Evolon CR. Its use from a scientific and practical conservation perspective*, in: AIC Paintings Specialty Group Postprints. (2018) vol. 31, pp 45–50 <https://www.culturalheritage.org/publications/books-periodicals/library/specialty-group-publications/paintings-specialty-group-postprints/docs/default-source/publications/periodicals/painting-specialty-group/psg-postprints-vol-31-2018>

<sup>40</sup> This method is further described in: Baij, L., et al. Understanding and optimizing Evalon CR for varnish removal from oil paintings, *Heritage Science*, (2021) vol. 9 pp 155-172

---

## Chemical Rigid Gels

---

Chemical gels are structurally different from physical gels, and may be more suitable for some conservation purposes. One of their benefits is reducing the danger of leaving residues from the gel itself on the substrate being cleaned due to the presence of covalent crosslinks. Chemical gels can be shaped into a desired form and can swell in a liquid without gel solubilisation. Acrylamide-based gels have been suggested as a residue free alternative to physical gels.

Current research is now focussing on chemical gels tailored for the removal of aged varnishes. These new types of gelling agents are showing promise for the future. These gels require less invasive solvent action and do not leave residues. There are two types of chemical gels currently being investigated and developed.

Chemical *hydrogels* are chemical gels compatible with aqueous cleaning solutions, some polar solvents, and microemulsions that are mostly water (i.e., oil-in-water). Hydrophilic functional groups attached to the polymeric backbone allow hydrogels to absorb water and swell, while intermolecular bonding between network chains make them chemically and thermally resistant.

Organogels are compatible with organic solvents. Depending on the desired characteristics, these gels can be engineered to have different properties based on the polymers used, synthesis procedures, and degree of intermolecular bonding or crosslinking between polymer chains.<sup>41</sup> Examples of polymers include acrylamide/bisacrylamide, with polyethylene glycol (PEG) and silanes (crosslinkers), polyvinyl alcohol, pHEMA, poly vinyl pyrrolidone, and methyl methacrylate (MMA).<sup>42</sup>

Over the past few years, chemical gels have been developed by the Nanoforart (<http://www.nanoforart.eu/>) and Nanorestart (<http://www.nanorestart.eu/>) projects in the EU, and can be bought pre-made: <http://www.csgi.unifi.it/products/cleaning.html>. These gels are relatively new in the

field of conservation, but show promising results for future use.

The novelty of organogels is that the gel can be applied directly onto the painted surface, left in contact with it for the minimum time necessary to achieve the desired cleaning action, and then removed by converting the gel to a low-viscosity fluid in-situ by applying a buffered water solution.<sup>43</sup> By using the rheological properties of the gel and switching it from a gel to a fluid on the painted surface, the removal of the gel can be complete with minimal residues remaining on the surface.<sup>44</sup>

---

## Shin Etsu KSG® (Silicone Based Pickering emulsifier)

---

Shin Etsu KSG® 210 or KSG® 350-z are silicone polymers with ethoxylate/propoxylate chains or polyether chains to bridge between the silicone chains. These systems make water in oil (w/o) emulsions in non-polar silicone solvents without the need for surfactants. This means that there are no issues with potential surfactant residue however the silicone polymer will still need clearing from the surface. As yet, insufficient research has been carried out to establish the long-term interactions between silicone polymers and oil paint in terms of promoting chemical changes, discolouration, physical changes and embrittlement.

The polar groups can emulsify water into the silicone system, while the silicone side chains are compatible with silicone solvents and hydrocarbon side chains are compatible with other conventional solvents. Emulsions made with these polymers can hold acetone, acetone/alcohol mixes (e.g. acetone/isopropanol) or benzyl alcohol. KSG® 210 can be used to create stable emulsions in a silicone solvent continuous phase. They are able to be mixed with both polar solvents (including aqueous solutions) and non-polar solvents, up to about 20% each. KSG® 350-Z can make similar emulsion systems in mineral spirits as well as silicone solvents and can hold up to 40% solution.<sup>45</sup>

---

<sup>41</sup> Baglioni P., Bonelli N., Chelazzi D., Chevalier A., Dei L., Domingues J., Fratini E., Giorgi R., Martin M., *Organogel formulations for the cleaning of easel paintings*, Applied Physics A (2015) vol. 121 (3) pp 857–868 doi:10.1007/s00339-015-9364-0

<sup>42</sup> Carretti E., Dei L., Weiss R., Baglioni P., *A new class of gels for the conservation of painted surfaces*, Journal of Cultural Heritage – Journal of Cultural Heritage (2008) vol. 9. Pp 386–393 DOI: 10.1016/j.culher.2007.10.009 [https://www.researchgate.net/publication/248546007\\_A\\_new\\_class\\_of\\_gels\\_for\\_the\\_conservation\\_of\\_painted\\_surfaces](https://www.researchgate.net/publication/248546007_A_new_class_of_gels_for_the_conservation_of_painted_surfaces)

<sup>43</sup> Carretti E., Dei L., Weiss R.G., Baglioni P., *A new class of gels for the conservation of painted surfaces*, Journal of Cultural Heritage 9, (2008) pp 386–393 DOI: 10.1016/j.culher.2007.10.009

<sup>44</sup> Converting a gel to a fluid on a painted surface using an aqueous solution may also be problematic in certain cases, such as when the surface is porous.

<sup>45</sup> Ormsby B., Lee, J., Bonaduce I., Lluveras-Tenorio A., *Evaluating Cleaning Systems for use on Water Sensitive Modern Oil Paints: A Comparative Study*. In: Van den Berg K.J., et al. Conservation of Modern Oil Paintings: 2020 pp 11–38

As the polymeric emulsion stabilisers are macromolecules, they are less able to penetrate into a surface and are therefore easily rinsed with non-polar solvents (for example cyclomethicone, a solvent with extremely low polarity, which may however be toxic).

These cleaning systems are useful for removing soil and dirt from paintings that are highly sensitive to water, aqueous cleaning systems and polar solvents. They have been successfully used for the removal of dirt and unwanted material from acrylic paintings. A 2014 film 'Restoring Rothko' produced by the Tate is an excellent example of engineering a cleaning solution.<sup>46</sup>

---

<sup>46</sup> <https://www.youtube.com/watch?v=AGqAggmwyMU>

The removal of varnish and overpaint from a painting is a complex and irreversible process. Removal of aged, discoloured varnish and overpaint can enhance the tonality and depth of a painting and reveal details previously hidden. Prior to removal, testing must be undertaken to understand the solubility parameters of both the varnish and overpaint, but also the underlying paint layers that must remain intact. Testing should be done using a variety of free solvents in an unobtrusive area of the painting where the results can be easily analysed for effectiveness under a variety of lighting conditions. Once a suitable solvent or solvent mixture has been selected, various methods of application can be trialled -- as a free solvent applied with a swab -- gelling

the solvent or solvent mixture, or application through a tissue. These application methods have a variety of benefits but also some drawbacks; containing a solvent in a gel or tissue reduces the amount of solvent required and also reduces the exposure of the conservator to the solvent, but conversely may require more contact time between the solvent and paint layer, and reduce the visibility of the paint surface during treatment. Varnish and overpaint removal should ideally be completed in stages when the solubility parameters of these two layers differ. When the solubilities of the varnish and overpaint layers are similar, they can be removed simultaneously to reduce the exposure of the paint to the solvents or solvent mixture.



Removing the layers of oxidised, yellowed varnish with a swab and solvent mixture. Personal protective equipment (PPE) should always be worn to minimise the risk of exposure to solvents.

## Relevant Additional Literature

Alan Phenix, Building models: Comparative swelling powers of organic solvents on oil paint and the cleaning of paintings, Conservation Journal, Spring 2002 Issue 40  
<http://www.vam.ac.uk/content/journals/conservation-journal/issue-40/building-models-comparative-swelling-powers-of-organic-solvents-on-oil-paint-and-the-cleaning-of-paintings/>

Stavroudis C., A Novel approach to Cleaning II: Extending the Modular Cleaning Program to Solvent gels and Free solvents (2007)  
[https://restauratieschilderijen.nl/wp-content/uploads/2016/01/Modular-Cleaning-Program\\_A-Novel-Approach-to-Cleaning-II-Extending-the-Modular-Cleaning.pdf](https://restauratieschilderijen.nl/wp-content/uploads/2016/01/Modular-Cleaning-Program_A-Novel-Approach-to-Cleaning-II-Extending-the-Modular-Cleaning.pdf)

Watch Chris on Youtube Preparing a Pemulen gel from the MCP:

<https://www.youtube.com/watch?v=zO5pYyc45Qo>

Chris Preparing a silicone Microemulsion: <https://www.youtube.com/watch?v=xDpwloLqJS4>

Informal Zoom meetings: Drunk Conservation Science for Conservators:

<https://www.iiconservation.org/content/drunk-conservation-science-conservators-dcsc#:~:text=DCSC%20is%20an%20informal%2C%20educational,scientific%20of%20fundamentals%20applied%20to%20conservation.&text=beverage%2Fmocktail%2Fcoffee%2C%20or,Halloween%20edition%20costumes%20are%20optional.>



Julia van den Burg

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

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



Kate Seymour

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



Klaas Jan van den Berg

**Klaas Jan van den Berg** is senior scientist at the Cultural Heritage Agency of the Netherlands (RCE) and professor of Conservation Science (Painted Art) at the University of Amsterdam, Faculty of Humanities, Group of Conservation and Restoration of Cultural Heritage. He teaches organic chemistry, technical art history and other chemical aspects of painted art. His main focus is the study of formulations, techniques, material changes and surface cleaning in 20th Century oil paintings.

Klaas Jan has written or co-authored over 140 scientific publications has been supervisor of a number of students of both science and conservation background. He organised the Issues in Contemporary Oil Paint symposium in 2013, and the Conference on Modern Oil Paints in 2018, and is editor of their Proceedings (Springer Nature, 2014 and 2019). He was project leader of the HERA-JPI EU project 'Cleaning of Modern Oil Paints'. Klaas Jan is currently leading the 20th Century Cultural Heritage research programme (2021-2023) at RCE.



Lia Gorter

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





This is one of a series of six brochures describing various aspects of conservation practice of works of painted art:

The brochures are intended for practicing conservators as well as other professionals involved in the field of painted cultural heritage.

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