MATERIALS INFORMATION and TECHNICAL RESOURCE for ARTISTS – Paint Mediums and Additives

DRYING OILS

Oil paints remain one of the most widely used mediums due to their versatility, range of effects, and long open time which allows for extended reworking as well as sophisticated blending. At their most basic, oil paints are composed of pigments ground into a drying oil. These oils dry by oxidation to become a coherent film as opposed to resins and gums that dry by the evaporation of the diluent. Paints made from pigments and drying oil alone will vary greatly in viscosity, handling properties, and brushability depending on the pigment's chemical and physical characteristics. These qualities also affect how much pigment can be ground into a workable paint. This is often referred to as the "Pigment Volume Concentration" or PVC. Paints that are naturally stiff and buttery are termed "short" while those that tend to flow and are readily brushed out in a long stroke are termed "long." Adulterants, modifiers, stabilizers, and driers can all affect the brushability and long-term stability of a particular oil paint. While specific oil paints have characteristic surface qualities derived from pigment choice, these can be significantly modified with the incorporation of extra thinner/diluent, binding medium, pigments, and other additives. Generally speaking, oils tend to produce paints that are saturated in color, capable of both opaque and transparent effects, and can be worked and re-worked over an extend period of time due to the long dry time of the oil medium.

Oil paints brands were traditionally divided into different categories according to their quality. The term "Artist's Grade" has been used to designate an oil paint containing the optimal amount of pigment to binder ratio and to not contain adulterants or unnecessary stabilizers. The term also suggests that the specific paint contained the actual pigment associated with the paint color (e.g. cobalt blue oil paint actually contained the pigment cobalt aluminate and not a mixture of cheaper pigments that approximated the hue of cobalt blue). The term "Student Grade" tended to indicate a lower quality paint intended for those who were just learning their craft and who could not yet afford the more expensive higher quality paints. Today these terms may or may not apply as some artist's grade paints now contain far more stabilizers and fillers they did in previous years while other manufacturers stringently follow the older model. In general, an artist's line from a particular manufacturer is going to have a much higher pigment load than the student grade that is available from the same company. Most (but not all) oil paint manufacturers now add modifiers and siccatives to normalize the handling and drying of their artist's grade paint line and student grade oil paints generally have a superabundance of fillers, stabilizers, and modifiers.

PROPERTIES OF DRYING OILS

Drying vs. Semi-Drying Oils

Drying and semi-drying oils both polymerize and oxidize through similar chemical processes, mechanisms that allow for the formation of dry, intact paint films. All oils take a fairly long time to dry as compared to other paint mediums. There are several factors that can determine the rate of drying including the relative thickness of the paint, the presence of certain pigments, and the surrounding environment. Depending on these factors even thin films of oil paint can take up to a week to dry while thicker films can take weeks or months.

Oils initially exist as triglycerides, esters that consist of glycerol connected to three fatty acid chains. Classification of an oil as a "drying oil" vs. a "semi-drying oil" all comes down to the degree of un-saturaturation in the fatty acid chains (how many double bonds are present, if any). Generally speaking, the more double bonds present (i.e. the higher the degree of unsaturation) the faster the oil will dry as double bonds provide reactive sites for mechanisms responsible for drying (such as cross-linking). The most common unsaturated fatty acids that are responsible for drying in artist's oil paints include oleic (one double bond), linoleic (two double bonds), and linolenic (three double bonds). This accounts for the quick drying properties associated with linseed oil, as this drying oil has the highest amount of linolenic acids of the three traditional oils used in easel painting (walnut and poppyseed being the other two). However, double bonds can also exacerbate yellowing (in addition to other factors) which also explains why linseed tends to yellow over time as it dries. Conversely, safflower oil exists on the other end of the spectrum. This "semi-drying" oil has recently become popular among paint manufacturers and while it yellows less than linseed it contains no linolenic acid and therefore tends to form a slightly weaker film that takes much longer to dry. In industry, semi-drying oils tend to be differentiated from drying oils using iodine numbers, a numbering system that is used to determine the degree of saturation present in the fatty acids (e.g. the number of double bonds). Non-drying oils have iodine numbers that are less than 115, semi-drying have a rating of 115-130, and drying oils have numbers above 130.

Common Types of Drying/Semi-Drying Oils

Linseed oil (Generally possesses the fastest drying time, but can yellow over time/ Iodine value range is approximately 170-190):

> Obtained from dried flax seeds, this drying oil has been used as a binding medium for centuries. Depending on how it is collected and processed, linseed oil exists in a wide range of colors and viscosities. Various categories of drying oils often include cold-pressed, alkali/acid refined, blown oil (thickened with air), sun-bleached/thickened, and stand oil (pre-polymerized). Sun-thickened oil can be made at home by allowing cold-

pressed linseed oil to remain in the hot summer sun over a period of approximately two months.

Walnut Oil (Generally yellows slightly less than linseed oil, but also has a slower drying
time/Iodine value range is approximately 140-150):

Like linseed oil, walnut oil has also been used as a binding medium since ancient times and can be prepared using many of the processes listed above. In contrast to linseed, this drying oil had less of a tendency to yellow, at least initially, but would often take longer to effectively dry. Sun-thickened walnut oil can be prepared in a similar manner as the sun-thickened linseed oil.

Safflower Oil (Generally produces a pale oil film similar to poppyseed, but possesses a slow drying time/Iodine value range is approximately 135-50)

This semi-drying oil obtained from safflower seeds has only just recently become a popular paint binder (20th century) when compared to the traditional drying oils (linseed, walnut, and poppyseed). As with poppyseed oil, safflower yellows to a lesser degree than both walnut and linseed; however, semi-drying oils tend to produce somewhat softer films. For this reason, safflower oil is often admixed with other types of oil binders and/or contains driers to speed up the slow dry time.

Poppyseed Oil (Generally yellows the least, at least initially, of the three traditional drying oils, but possesses the slowest drying time/Iodine value range is approximately 130-140):

The semi-drying oil obtained from poppy seeds has also been in use as a binding medium for hundreds of years (likely dating to around the 17th century). Although this particular oil has a lengthy dry time in comparison to linseed (and to a certain extent walnut) it also yellows the least. As with walnut oil, artists might choose poppy oil as the primary binder for whites and blues. Semi-drying oils do however tend to produce somewhat softer films.

Soy Oil (Generally produces a pale oil film, but possesses a slow drying time/Iodine value range is approximately 128-143)

This semi-drying oil obtained from soybeans has only just recently become a popular paint binder (20th century) when compared to the traditional drying oils (linseed, walnut, and poppyseed). As with poppyseed and safflower oil, soybean oil yellows to a lesser degree than both walnut and linseed; however, semi-drying oils tend to produce somewhat softer films. For this reason, soy oil is often admixed with other types of oil binders and/or contains driers to speed up the slow dry time.

Sunflower Oil (Generally produces a pale oil film, but possesses a slow drying time/ Iodine value range is approximately 125-140)

This semi-drying oil obtained from sunflower seeds has only recently been adapted for limited artistic use (20th century) when compared to the traditional drying oils (linseed, walnut, and poppyseed). As with poppyseed, safflower, and soybean oil, sunflower yellows to a lesser degree than both walnut and linseed; however, semi-drying oils tend to produce somewhat softer films. For this reason, sunflower oil is often admixed with other types of oil binders and/or contains driers to speed up the slow dry time.

Ageing Properties

All drying oils become less flexible with age. Initially, oil paints retain a good degree of flexibility, but due to oxidation processes, oil paint films become increasingly more brittle and therefore more susceptible to cracking. It is for this reason that artists are advised to use rigid supports if possible (or mount canvas to a rigid support) when using oil paints. This will help to mitigate the development of mechanical cracks in the brittle aged oil paint film. These are primarily caused by the cyclic swelling and shrinking of the support in response to changes in humidity and the environment.

Oil paints go through chemical changes over time making them more transparent. This increase in transparency can be effected by several factors including the various methods used to prepare the oil, the presence of certain pigments, and the thickness of the paint layer, and the technique used by the painter. The primary mechanism that causes oil films to become more transparent as they age is the formation of metal soaps within the paint film. Lead white, for example, can form lead "soaps" when suspended in an oil matrix that is rich in fatty acids. Any free fatty acids (e.g. palmitic, stearic, etc.) can migrate towards the lead ion, creating a "soap" that has a lower refractive index than the lead white pigment. Other additives, such as metal driers (e.g. lead, cobalt, copper, etc.) may also account for this gradual increase in transparency, however research is still needed to confirm this theory. This accounts for the appearance of *pentimenti*, that can now be seen in so many paintings that are over a century old. The term pentimenti refers to passages of paint that have become more transparent over time, revealing sections of underdrawings or underpaintings that may deviate from the final, visible image. Finally, oil paints can experience fatty acid efflorescence, a phenomenon that relates to the migration of free fatty acids within the paint to the surface of the composition, often appearing as a hazy film. This condition can be exacerbated by changes in the environment but can be mitigated by using a soft brush to gently remove the fatty acids from the surface or even wiping the surface down using odorless mineral spirits (although in some cases efflorescence has been found to be a re-occurring problem on certain paintings even after removal). A professionally trained conservator with a graduate degree in Art Conservation should be contacted if you are unable to effectively remove efflorescence on your painting.

Additives and Preparation Processes

Certain additives and preparation processes can affect the overall dry time of oils, handling properties, and even the degree of yellowing and transparency. Driers (e.g. containing lead, cobalt, manganese, zirconium, etc.) can be added to speed up the drying time of oil mediums, although these materials should only be added in sparing amounts as excessive quantities may cause cracking of the paint film. Artists should note that most commercially available oil paints already contain a certain amount of siccatives; any products containing driers should also be handled using the proper health and safety precautions. Other additives can also include fillers (e.g. calcite, silica) and other materials (e.g. castor wax, surfactants, aluminum soaps) that are typically added to alter handling properties of the paint or prevent unwanted separation of the oil from the pigment(s). Finally, oil mediums can be prepared, modified, and processed using a number of different methods, many of which are outlined below.

Common Types of Siccatives Present in Oil Paints

- **Pigments:** Umbers and pigments containing lead, copper, and cobalt can speed up the dry time of oil mediums (NOTE: Lead white alone does not drastically speed up the drying of oil paint; other compounds including litharge/lead monoxide and "Sugar of Lead"/lead acetate contribute far more to the accelerated drying time of oil) Conversely, poor drying pigments include carbon blacks, organic lakes, and bituminous colors.
- **Leaded Oil:** Briefly and gently heat oil over lead salts (e.g. litharge/lead monoxide) to help accelerate the pre-polymerization (drying) process.
- **Japan Drier:** Historically, Japan drier was a dark-brown liquid that usually containing organic acid salts of lead or manganese dissolved in a solution of linseed oil mixed with resin and thinned with turpentine or mineral spirits. Today Japan driers can contain a wide range of additives.
- **Cobalt Driers:** The earliest cobalt driers contained primarily cobalt oleates. However today most cobalt driers contain cobalt naphthenates in addition to compound driers.
- **Calcium Driers:** Common calcium driers include calcium naphthenate and octoate.
- **Courtrai Driers:** Historically, brown Courtrai driers contained lead and manganese, possibly mixed into oil, resin, or solvent while white Courtrai driers contained only lead. Today Courtrai can contain a wide range of driers and additives including lead, calcium, zirconium and/or manganese.
- **Leaded/Cobalt/Manganese Glass Powders:** Crushed glass crystal containing any of these additives were historically used by painters working in the 15th and the 16th centuries. There is some debate in the conservation science community as to the extent that these additives

altered drying rates. They certainly also affected the transparency and handling properties. Today, a few small manufacturers offer paints or mediums with these additives.

Common Fillers/Additives Present in Oil Paints

- **Silica:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects.
- **Barytes/Barium Sulfate:** Can be added as a common pigment extender.
- **Mica (hydrous aluminum potassium silicate):** Added to impart particular aesthetic effects.
- **Calcite:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects. Also added as a common pigment extender.
- **Koalin/Bentonite/Organoclay:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects. Can also serve as stabilizers to help prevent the separation of the oil medium from the pigment(s).
- **Glass Powders:** Can be added to impart/change texture and/or create certain rheological effects.
- **Castor Wax/Beeswax:** Typically added as a stabilizer and/or to create certain rheological effects.
- **Surfactants:** Aluminum stearate, magnesium stearate, etc. are common additions to commercially available paints as they typically serve as stabilizers to help prevent the separation of the oil medium from the pigment(s).
- **Thickeners:** Added to impart body and/or viscosity to the paint medium.
- **Modified Urea/Salt of polycarboxylic acid:** Typically added as a stabilizer, dispersing agent, and/or to create certain rheological effects.

Types of Processed/Prepared Oil Mediums

- **Cold-Pressed Oil:** Any vegetable oil extracted from seeds by crushing in hydraulic or screw-type press at ambient temperature. Cold-pressing extracts a smaller portion of oil, but it produces a higher quality oil that is clearer and has fewer impurities than hot-pressing, at least before additional refining. Cold pressed linseed oil was traditionally considered the best for making oil paint as earlier refining techniques produced a lower quality oil. Cold pressed oils tend to be thin and flow well. In general, cold pressed oils have a higher acid number than alkali refined oils, however, modern alkali refined oils can be produced with a variety of acid numbers. More pigment can be ground into a given volume of oil that

is more acidic than can be ground into an oil with a lower acid number. The more acidic oil, however, does tend to yellow more. Artists should take this into account when choosing the type of oil for a given task.

- **Alkali-Refined Oil:** Far more oil can be pressed from flax seeds if the operation is preformed while the seeds are hot-pressed using steam. The expressed oil contains substantial amounts of impurities and requires further refining, generally using acids. Modern quality linseed oil is then treated with alkalis to remove all acidic and aqueous components to produce a very high quality oil. Alkali refined oil generally have a lower acid number than cold-pressed oil, however, modern alkali refined oils can be produced in a wide range of acid numbers. High quality alkali refined oils seem to yellow less than cold pressed oils of a similar acid number.
- **Water-Washed Oil:** Any drying oil that is washed in water to remove mucilage and water soluble impurities (these impurities were called "the foot" in older literature). This was done by placing the oil, water, and any additives in a large jar. The whole was shaken and mixed and allowed to set until the oil, and water separated, some recommended placing the container in the sun. This was repeated many times until the foot separates and can be found directly above the water and below the oil. The clean oil was then siphoned off. Oils purified by this method are made more acidic than they were before the process.
- **Sun-Bleached Oil:** Drying oils can be exposed to the sun and bleached to make a lighter product. It is possible to continue this process until the oil is water-white. If this is done in the presence of the air, the oil will also become more acidic. All drying oils will yellow after drying and aging. It is probably preferable to not overly bleach a drying oil which will likely revert to a more yellow, darker hue at a later time.
- **Stand Oil:** Originally, stand oil indicated an oil that was allowed to stand for a very long time to allow the foot to fall out of suspension, creating a clear pure product. Modern use of the term almost always indicates a pale, thick, form of linseed oil. Today, stand oil is prepared by heating linseed oil in an oxygen-free environment to around 550 degrees F. This allows the oil to partially polymerize without any oxidation and causes the foot to drop out of the oil without the need of long aging. Anaerobic conditions are obtained using a vacuum or carbon dioxide atmosphere. Stand oil was likely developed by the Dutch in the 19th century. Stand oils tend to be far less acidic than other forms of thickened drying oils. Stand oil dries more slowly and yellows less than untreated linseed oil. Stand oil forms a tough, flexible film that is resistant to weathering and paints containing it tend to level out and not retain brush strokes. Stand oils have been used in varnishes, glazes, and as a high viscosity additive to other paint media.
- **Sun-Thickened Oil:** A thick, partially polymerized and oxidized form of linseed oil that dries faster than regular linseed oil and much more rapid

than stand oil. Sun-thickened linseed oil is prepared by allowing the oil to stand exposed to sunlight and air. It absorbs oxygen and becomes viscous. Sun thickened oils are more acidic than the parent oil. Paints containing sun-thickened oils will level but they do retain brushstrokes better than those containing the same amount of stand oil.

- **Boiled Oil:** Originally, boiled oil indicate a drying oil heated to a very high temperature in the presence of oxygen. This creates a product that varies in viscosity, oxidation, and polymerization depending upon how hot and long the oil was heated. Today, most type of boiled oil is produced by heating the oil to about 130C-150C with small amounts of soluble driers (organic salts of manganese, lead or cobalt, and others) Boiled linseed oil is not considered suitable for artists use as it darkens strongly over time. Boiled oils have been used for industrial paints, varnishes, enamels, waterproofing, and patent leathers.
- **Heat Bodied Oil:** Blown linseed oil is oil that is made more viscous and oxidized by blowing air bubble through it while it is being heated. Blown linseed oil has a high acid number. This is an archaic practice and artists should probably avoid using blown oils.
- **Heat Bodied Oil:** This term does not indicate a specific method of process. The temperature, presence or lack of driers, amount of air incorporated, etc., and all be manipulated to create an oil with specific viscosity, acidity, drying, rates, and degree of yellowing.

Painting Tips and Recommendations

If artists choose to paint using drying oils, they should consider the following:

- Oil paints can become brittle over time and are therefore susceptible to cracking. This can be mitigated if a rigid support is used or if canvas is applied over a rigid support.
- Store and exhibit oil paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight.
- Oil paints are not compatible when mixed with most water-based mediums such as watercolors, gouache, or acrylic dispersion paints. They can theoretically be applied over these paints but this can greatly change the normal rheology of the resultant paint stratigraphy and the resulting painting could suffer over time unless great thought is put into the layering process. Thin applications of watercolors, gouache, or acrylic dispersion paints can be applied as underlayers as long as they are compatible with the ground (e.g. artists should avoid using these over oil or alkyd grounds)..
- Oils can be applied over acrylic grounds; however, artists should exercise caution when using low quality acrylic ground formulations and/or pre-primed supports as the presence of additives (e.g. surfactants, emulsifiers,

antifoaming agents, etc.) can lead to problems including cracking, delamination, and other issues. Some have worried about the advisability of applying oil paint, which will eventually become brittle over time on a ground known to remain flexible; however, four layers of a high quality acrylic dispersion ground is very close in stiffness to a lead white oil paint layer and even stiffer than oil paints comprised of Naples Yellow, Yellow Ochre, or Raw Umber. These recent studies indicate that proper application combined with a high quality acrylic ground creates a relatively sound paint system. Note that this may not apply to lower quality, commercially pre-primed canvases.

- Emulsions can be made of drying oils and other materials, especially egg yolk due to the presence of natural emulsifiers, but some of these paints have the problems associated with each ingredient rather than the virtues of both. Egg oil emulsions tend to be relatively stable but those of casein and oil yellow strongly, and those of oil and glue or gum can be excessively brittle and unstable.
- It is recommended that oil paintings be varnished with a protective, non-yellowing, reversible varnish layer to prevent dust and other airborne particulates from becoming embedded into the upper paint layers.
- Allow oil paintings to dry for at least 6 months to a year before applying a final varnish layer (preferably storing in a dust free environment with appropriate levels of temperature and humidity). If this is not possible, record the duration of time between the final application of paint and the varnish application on the reverse of the painting. Prior to varnishing, artists should clean the surface carefully with a dampened cloth to remove superficial dust and grime.
- If you are painting in successive stages and want to determine if the underlayers are sufficiently dry for overpainting, one can use the "fingernail test": If you can press your fingernail onto the oil paint without making a dent in it, you can continue to paint atop the surface without significantly biting into the layers beneath if you avoid using too much solvent.
- Consider painting without using solvents. If you are using solvents, use smaller and smaller additions of solvent as you continue to paint subsequent layers.
- Certain pigments have been known to react adversely and/or degrade over time when bound in an oil film. Such pigments include most historical copper greens and blues (discoloration of azurite, malachite, verdigris; formation of copper soaps), bituminous pigments (poor drying quality of bitumen/asphaltum and true Van Dyke Brown), smalt (discoloration of smalt), and zinc white (zinc soaps). While lead soaps have also been encountered in oil paintings, note that not all lead soaps are undesirable as a certain degree of soap formation is needed to impart strength to the paint film. In some instance lead soaps have been observed to migrate to the surface, appearing as disfiguring tiny pustules; however, further research is needed to confirm whether the formation and subsequent migration of lead

soaps is simply due to the presence of lead-based pigments. Lead soap formation/migration is likely exacerbated when paintings are exposed to significant levels of heat and/or humidity (as occurs during lining) and/or by an overabundance of lead driers although further research is needed to confirm these observations.

- As with most tubed paints, the possibly presence of additives (e.g. surfactants, driers, dispersing agents, etc.) will have an impact on the handling and long-term ageing properties of the oil paint. Water-miscible oil paints are such an example, as these paints require the addition of certain surfactants that may prove problematic as the paint continues to age (primarily due to the migration and/or leaching of the surfactants from the paint film).
- If you choose to thin your oil with solvents during oiling out, take care if you are applying over fairly young oil paint as the solvents may begin to bite into the lower paint layers.
- To address problems with "sinking-in," try adding a touch of medium to your paints and/or use less solvent. For additional guidelines on how to address "sinking-in", see the "Varnishes" document for more information.
- For oiling out during the painting process or for cutting the absorbency of a ground layer artists are recommended to 1) apply a thin layer of oil locally as needed or globally (consider using stand oil/thickened oil if your paint/ground layers are extremely absorbent) to matte/sunken-in areas 2) remove any excessive oil using a lint-free cloth and 3) wait until the surface is dry to the touch.
- It is particularly important to avoid applying moderate to thick layers of retouching varnishes or layers of oil during the painting process as this could lead to potential delamination and/or cracking of the paint. As most varnishes remain sensitive to solvents, varnishes should not be used as the primary paint medium or applied in between paint layers. Paint applied over a varnish layer or mixed with certain amounts of varnish can remain sensitive/soluble should the artwork require future conservation treatments.
- If your composition is complete and some areas still appear matte, locally apply varnish instead of oil to even out the overall sheen, wait until dry, then apply a final protective varnish over the entire surface.
- It is inadvisable to paint a fresh oil painting over an abandoned work in oil as the surface may a) contain a buildup or surface dirt/grime b) contain a layer of protective varnish on the surface and/or c) not provide sufficient "tooth" or absorbency, leading to potential delamination or flaking. In addition, oil films gradually become more transparent as they age which will result in the underlying composition showing through in certain areas. If it is not possible to obtain a new support and start afresh, artists should consider removing any varnish coatings and scraping/sanding down layers of paint (exercising appropriate health and safety precautions) before applying fresh applications of oil paint.

- It is possible to gently sand the surface of oil/alkyd paint layers. Remember that inhalation of any type of fine, particulate material (particularly if hazardous pigments are present) is not recommended and that a dust mask should be worn during sanding. It is best to avoid and sanding or scraping of grounds containing lead or other toxic pigments. Once you are finished sanding the ground, wipe down the ground using a cloth dampened with odorless mineral spirits to absorb any remaining loose pigments/particles (be sure to properly and properly dispose of the cloth).

MODIFIED OIL PAINTS (e.g. Alkyds)

Alkyd Paints (Oil-Modified Alkyds)

Alkyd paints are created by reacting a polybasic acid (e.g. phthalic anhydride) with a polyhydric alcohol (e.g. glycerin, ethylene glycol) and an oil/fatty acid (e.g. soybean, linseed, safflower oil). Alkyds created for artists' paints are often referred to as "oil-modified alkyds" or "long-oil alkyds," as they are composed of more than 60% oil (without a higher percentage of oil, the alkyd resin alone would be too brittle to be used as a traditional artist paint). Alkyd paints do offer some benefits over oil paints, although they are still fairly new to the history of art. Alkyds tend to dry faster than oil paint, maintain a certain degree of flexibility, and are generally less expensive (likely due to their lower PVC). Alkyd paints also tend to be "longer" and level more than most oil paints, producing a fairly glossy, durable, and hard film. Over time alkyds (due to their oil component) may yellow slightly although to a lesser degree than most oil mediums. Finally, artists should note that most commercially prepared alkyd resins/paints contain a certain amount of driers.

Water-Miscible Oil Paints

In water-miscible oil paints, the linseed oil molecule is altered so that it becomes hydrophilic. This then allows water to be used as the primary diluent (as well as during clean up), eliminating the need for solvents. Mediums created for water-miscible oils should not be used with other mediums. The presence of additives in these paints (e.g. surfactants, driers, dispersing agents, etc.) can have an impact on the handling and long-term ageing properties of the oil paint. Water-miscible oil paints require the addition of certain surfactants and other additives that may prove problematic as the paint continues to age (primarily due to the migration and/or leaching of these additives from the paint film). More testing is needed to assess the long-term stability of these paints, especially as they have only been available to artists in recent years.

Painting Tips and Recommendations

If artists choose to paint using drying oils, they should consider the following:

- Although alkyd paints retain a certain degree of flexibility, they can still become brittle over time (or when subjected to temperatures close to freezing temperatures) and are therefore susceptible to cracking. This can be potentially avoided if a rigid support is used or if canvas is applied over a rigid support.
- Alkyd paints are not compatible with most water-based mediums such as watercolors, gouache, or acrylic dispersion paints. Alkyds can be used with oils (e.g. adding small amounts of alkyd medium to oil paint, painting in oils atop alkyd grounds, etc.)
- Store and exhibit alkyd paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight.
- Consider painting without using solvents. If you are using solvents, use smaller and smaller additions of solvent as you continue to paint as this falls in line with the "fat over lean" rule of thumb.
- Alkyds can be applied over acrylic grounds; however, artists should exercise caution when using low quality acrylic ground formulation and/or pre-primed supports as the presence of additives (e.g. surfactants, emulsifiers, antifoaming agents, etc.) can lead to problems including cracking, delamination, and other issues.
- It is recommended that oil paintings be varnished with a protective, non-yellowing, reversible varnish layer to prevent dust and other airborne particulates from becoming embedded into the upper paint layers.
- Certain pigments have been known to react adversely and/or degrade over time when bound in an oil film (although some to a lesser extent than others). This may hold true for alkyd resins as well. Such pigments include most historical copper greens and blues (discoloration of azurite, malachite, verdigris; formation of copper soaps), bituminous pigments (poor drying quality of bitumen/asphaltum and true Van Dyke Brown), smalt (discoloration of smalt), and zinc white (zinc soaps). While lead soaps can also form in alkyd paints , note that not all lead soaps are undesirable as a certain degree of soap formation is needed to impart strength to the paint film. In some instance lead soaps have been observed to migrate to the surface, appearing as disfiguring tiny pustules; however, further research is needed to confirm whether the formation and subsequent migration of lead soaps is simply due to the presence of lead-based pigments. Lead soap formation/migration is likely exacerbated when paintings are exposed to significant levels of heat and/or humidity (as occurs during lining) and/or by an overabundance of lead driers although further research is needed to confirm these observations.

- Most commercially prepared alkyd paints/mediums contain driers (check with the manufacturer to determine what kind of driers are present). Artists should therefore exercise caution when adding additional driers to their alkyd (alkyd mixed with oil) paints. Additives that increase drying time promote cross-linking which in turn can produce a more brittle film (please refer to the section on siccatives in the "Drying Oils" section to learn more about the types of driers that are often present).
- Allow alkyd paintings to dry for at least 3-6 months before applying a final varnish layer (preferably storing in a dust free environment with appropriate levels of temperature and humidity). If this is not possible record the duration of time between the final application of paint and the varnish application on the reverse of the painting. Prior to varnishing, artists should clean the surface carefully with a dampened cloth to remove superficial dust and grime.
- If you are painting in successive stages and want to determine if the underlayers are sufficiently dry for overpainting, one can use the "fingernail test": If you can press your fingernail onto the oil paint without making a dent in it, you can continue to paint atop the surface without significantly biting into the layers beneath if you avoid using too much solvent.
- To address problems with "sinking-in," try adding a touch of medium to your paints and/or use less solvent. For additional guidelines on how to address "sinking-in", see the "Varnishes" document for more information.
- For "oiling out" with alkyd medium during the painting process or for cutting the absorbency of a ground layer artists are recommended to 1) apply a thin layer of alkyd locally as needed or globally to matte/sunken-in areas 2) remove any excessive oil using a lint-free cloth and 3) wait until the surface is dry to the touch.
- It is particularly important to avoid applying moderate to thick layers of retouching varnishes or layers of unpigmented alkyd medium during the painting process as this could lead to potential delamination and/or cracking of the paint.
- If your composition is complete and some areas still appear matte, locally apply varnish instead of oil to even out the overall sheen, wait until dry, then apply a final protective varnish over the entire surface.
- It is inadvisable to paint a fresh alkyd painting over an abandoned, completed work as the surface may a) contain a buildup of surface dirt/grime b) contain a layer of protective varnish on the surface and/or c) not provide sufficient "tooth" or absorbency, leading to potential delamination or flaking. In addition, alkyd films may become more transparent as they age which will result in the underlying composition showing through in certain areas. If it is not possible to obtain a new support and start afresh, artists should consider removing any varnish coatings and scraping/sanding down layers of paint (exercising appropriate health and safety precautions) before applying fresh applications of oil paint.

- It is possible to gently sand the surface of oil/alkyd paint layers. Remember that inhalation of any type of fine, particulate material (particularly if hazardous pigments are present) is not recommended and that a dust mask should be worn during sanding. It is best to avoid and sanding or scraping of grounds containing lead or other toxic pigments. Once you are finished sanding the ground, wipe down the ground using a cloth dampened with odorless mineral spirits to absorb any remaining loose pigments/particles (be sure to properly and properly dispose of the cloth).

ENCAUSTIC (WAX-BASED PAINTS)

Encaustic paint is made from a mixture of dry pigments mixed and wax which can be made liquid with heat and then be applied to the support. These paints are often made with refined beeswax due to its clarity and light color, excellent plasticity, and melting temperature, although carnauba wax can also be added to increase the hardness and durability of the paint film. Some recipes include additions of natural resins (most commonly dammar, up to 20% by volume) that also help to increase the film's hardness and raise the refractive index of the binder while very small additions of oils can be added to aid in workability of the wax medium. Encaustic paint is generally applied while warm and fluid, with a spatula, brush, or specialized heated tool. The paint can be manipulated to produce a wide range of aesthetic effects; the surface of the wax can be buffed or polished, carved, scraped, layered, collaged with different objects, sculpted, textured, and combined with oils and alkyds while molten. The final surface can then be fused if desired by gentle heating with a tool, radiant lamp, or heat gun.

Dissolved Encaustic or **"Cold Wax"** paints do not require the use of heat during preparation and application. These techniques involve the use of pigments added to wax dissolved into a solvent. These are generally in the form of a creamy paste.

Saponified Wax paints or **Wax Soaps** are paints made by mixing pigments with wax made water miscible by heating it in water in the presence of an alkali. Wax soap paints made using ammonia become insoluble in water after short aging while those containing other alkalis will be more sensitive to water. These paints can be made from a number of processes and the resultant pH of the paint can vary. Pigments used with this medium should be carefully selected as only certain colorants can withstand high pH levels. Generally, pigments that are used with lime/fresco painting are considered suitable for alkaline paint systems.

Ageing Properties

Wax mediums have been used since antiquity and in most cases have demonstrated excellent ageing properties. While the wax medium itself is not especially prone to yellowing, additions of dammar, mastic, oil, and other additives (depending on the amount added and the amount of pigment present) will cause the medium to yellow/discolor over time. As with oils, alkyds, and tempera, wax-based

paints can experience fatty acid efflorescence, a phenomenon that relates to the migration of free fatty acids within the paint to the surface of the composition, often appearing as a hazy film. This condition can be exacerbated by changes in the environment but can be mitigated by using a soft brush to gently remove the fatty acids from the surface or even wiping the surface down using odorless mineral spirits (although in some cases efflorescence has been found to be a re-occurring problem on certain paintings even after removal). A professionally trained conservator with a graduate degree in Art Conservation should be contacted if you are unable to effectively remove efflorescence on your painting.

Painting Tips and Recommendations

If artists choose to paint using wax-based mediums, they should consider the following:

- It is generally considered best practice to apply wax paints on rigid supports as the paints can potential crack on flexible supports, especially at lower temperatures.
- Store and exhibit alkyd paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight.
- When wax mediums are exposed to extremely low temperatures they become increasingly more brittle and therefore more susceptible to cracking. Conversely, high temperatures can lead to softening of the medium and in some cases can cause the medium to permanently deform. Environments with higher levels of temperature and humidity can also lead to the accumulation of dust and grime on the surface; if the wax becomes soft, dirt and grime can become permanently imbibed in the surface. High humidity alone has also been found to cause wax coatings/layers to bloom, as water molecules can become trapped in voids or interfaces between layers creating an overall hazy appearance.
- It is not advised to apply paints containing large amounts of wax over other mediums; however, some artists prefer the aesthetic effects created by applying wax mediums over oils, alkyds, acrylics, etc. Such layering is still considered to be an experimental technique.
- It is best to not apply a varnish over paints that are rich in wax. Varnishes that are dissolved in common solvents (e.g. mineral spirits) will likely dissolve the wax medium in the underlying paint layers, causing smearing and/or becoming permanently incorporated into the wax paint.
- As an alternative to varnishing, it is far preferable to buff the surface to create an appropriate level of sheen using a piece of silk fabric.
- Certain pigments have been known to react adversely and/or degrade over time when present in high pH environments (saponified wax). Artists should select pigments that are known to withstand high pH mediums (e.g.

lime/fresco) when working with saponified wax mediums.

- Unlike oils, tempera, acrylics, and other mediums, encaustic paintings can be re-worked years after they have been completed, although this may trap any accumulated surface grime between/within layers of encaustic paint.

ACRYLIC PAINTS

There are two types of acrylic paints: solvent-based and water-based. Solvent based paints or **Acrylic Solution or MSA Paints** are comprised of a solution of acrylic resin polymers dissolved in mineral spirits. These early paints gained popularity beginning in the 50's, 60's, and 70's (e.g. Magna paints) and generally consisted of a combination of ethyl acrylate and methylmethacrylate polymers. The mineral spirits used to thin these paints should not be odorless as these binders require a certain amount of aromatic hydrocarbon solvent to re-dissolve and/or thin the resin (see "Solvents and Thinners" document for additional information on solvents). Although these paints are fairly new to the history of art, they do not appear to yellow significantly over time and remain somewhat more flexible than oil films. They do not become insoluble in their diluent over time and remain sensitive to solvents. This practically precludes the use of varnish since any future conservation treatment to remove the varnish would also remove the paint. This can theoretically be surmounted if the resin used in the surface coating is dissolved in alcohol or another solvent that does dot dissolve acrylic resins (alcohol soluble PVA resins have been used by some).

Acrylic Dispersion paints, more commonly referred to as "acrylic paints" or "acrylics," consist of an acrylic resin combined with various additives (e.g. surfactants, de-foaming agents, thickeners, pH buffers, fungicides, anti-freezing agents, etc.) that is then dispersed in water. The resin in these paints are typically based on homopolymers or co-polymers of vinyl acetate and an acrylic ester (e.g. propenoate ester). The fact that these paints do not require the use of solvent presents an attractive option to artists who are concerned with some of the health and safety risks that solvents can pose (although it is possible to paint using oils without solvents). There is also a wide range of acrylic mediums available that can be used to alter the working properties and overall appearance of acrylic paint. Mediums can be added to alter transparency, increase sheen, reduce/increase viscosity, improve adhesion, and add texture.

Most acrylic binders appear milky when before drying; depending on the additives present, however, they can to dry to form a fairly clear film that is water-resistant. Acrylics dry through the evaporation of the water, which then allows the resin particles to coalesce into a film. Acrylic paint films should be allowed to fully dry before additional layers are added. While acrylic paints may feel dry to the touch after only a few hours or days, it can take around thirty days for the paint film to completely lose all of its residual water and up to a year for the resin particles to fully coalesce. This can depend on how much medium is used, how thick the paint layer is, what type of additives are present (e.g. whether a retarder has been used), as well as the relative humidity/temperature and airflow conditions.

Commonly Used Additives

Just as with many commercially available paints, the presence of additives in acrylics (e.g. surfactants, dispersing agents, anti-foaming agents, anti-freezing agents, etc.) can have an impact on the handling and long-term ageing properties of the paint film. Some low quality acrylic paints can contain certain surfactants and other additives that may prove problematic as the paint continues to age (primarily due to the migration and/or leaching of these additives from the paint film).

Common Types of Fillers/Additives Present in Acrylic Paints

- **Silica:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects.
- **Barytes/Barium Sulfate:** Can be added as a common pigment extender.
- **Mica (hydrous aluminum potassium silicate):** Added to impart particular aesthetic effects.
- **Calcite:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects. Also added as a common pigment extender.
- **Koalin/Bentonite/Organoclay:** Can be added to impart/change texture, alter absorbency, and/or create certain rheological effects.
- **Glass Powders:** Can be added to impart/change texture and/or create certain rheological effects.
- **Surfactants/Emulsifiers/Wetting Agents:** There are a number of non-ionic surfactants (such as those based on polyethylene oxides) and other additives that are used in acrylic paints; these additives typically serve as stabilizers to help prevent the separation of the acrylic medium from the pigment(s).
- **Thickeners (acrylic acids, cellulose thickeners, urethanes):** Added to impart body and/or viscosity to the paint medium.
- **Defoamers:** Helps to prevent the formation of air bubbles in the paint film.
- **Thickeners (acrylic acids, cellulose thickeners, urethanes):** Added to impart body and/or viscosity to the paint medium.
- **Fungicides:** Helps to prevent fungal growth.
- **Plasticizers:** Added to help maintain the paint film maintain flexibility.
- **Flow Releases:** Added to cut the viscosity of the medium.

Ageing Properties

Not all acrylics are created equal. Generally speaking, acrylics have tended to exhibit decent long-term ageing properties, maintaining a satisfactory level of transparency and resistance to UV degradation. However, when acrylic films are exposed to significant levels of UV light (UVB) the ethyl acrylate polymer can undergo chain scission which in turn can lead to an overall weakening of the paint film. While yellowing is not a great concern with most acrylic paints, thickly applied, acrylic films have exhibited a certain degree of yellowing and/or discoloration over time. This is generally attributed to "support induced discoloration" (SID) which is due to the presence of surfactants that can leach water-soluble components from the support up through the ground and/or paint layers. SID can be prevented/mitigated if the proper steps are taken to adequately size/prime the support (refer to the document "Adhesives and Sizes" to learn more about how to prevent/mitigate SID).

While acrylic films tend to maintain a certain degree of flexibility over several years (longer than oil and alkyd paints), this advantage can also have a downside. Acrylic films are also more prone to be being scratched, marred, and accumulating dirt and grime. However, the flexible nature of acrylic films also relates to the fact that these paintings are more resistant to cracking (other than in near freezing conditions). Artists should note that acrylic paint films can become more brittle when exposed to low levels of temperature and humidity and therefore more susceptible to cracking and permanent deformation.

Perhaps of greatest concern to artists is the presence of additives in acrylic paints (although oils and alkyds can also share some of these same additives). The wide range of these materials can cause a number of changes to the paint film: yellowing/discoloration, a decrease in transparency, leaching, and the formation of superficial films. Many of these additives, which are required to make a stable and workable paint, are volatile and evaporate, and ultimately leave the dried acrylic film. The additives that remain behind, however, can directly influence changes in the film as it ages. The most commonly encountered problem associated with these additives relates to the surface accumulation of certain surfactants, a material that is required as part of making the actual acrylic polymer dispersion. Upon drying they no longer serve a purpose but can migrate to the surface over time, producing hazy films and/or white blemishes that can reduce the gloss and evenness of the painting. Artists may be able to remove surfactants by carefully wiping the surface with water; however, in some cases surfactants have been found to return to the surface even after removal. It is the responsibility of the manufacturer to keep these required additives to a minimum and to evaluate each additive for its potential contribution to any changes in the dried acrylic.

Painting Tips and Recommendations

If artists choose to use acrylic paints, they should consider the following:

- Store and exhibit acrylic paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-55%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight. Note that if acrylic paint films are subjected to temperatures below 40 F they can become more susceptible to cracking while high levels of humidity and/or temperature can cause acrylic films to become tacky. Avoid near freezing conditions as acrylic paints can become more prone to cracking.
- The temperature, humidity, and even airflow can affect how fast/slowly an acrylic film dries. A temperature range between 70 to 90 F with humidity below 75% and a slight, steady airflow is ideal for drying. Acrylic polymers are not able to successfully coalesce in temperatures below 50 F (leading to possible cracking, powdering, etc.) while temperatures above 90 F can cause other issues such as the formation of bubbles. In addition, relative humidity levels above 75% can slow down the evaporation of the water thereby slowing the drying process. It is not advised to position a fan towards your painting during drying, as a strong, directional airflow can interrupt the film formation process, leading to potential cracking, wrinkling, and other issues.
- Just as with oils and alkyds, the "fat over lean" rule of thumb still applies. It is therefore not advisable to apply over-thinned acrylic washes over thick, glossy, and non-absorbent acrylic films.
- Some acrylic paints/grounds that are allowed to remain in the wet state for an extended period of time may yellow/discolor and/or separate. Often this has little impact on the final color of the film although artists are encouraged to paint out small amounts to ensure that this is the case. On the other hand, this may or may not indicate that the product has exceeded its designated shelf-life (artists are advised to check with the manufacturer and/or distributor if they suspect the product is not suitable for use).
- Acrylic mediums should not be used with other types of paints (e.g. oils, alkyds, egg tempera, etc.).
- Artists should exercise caution when applying acrylic paints over low quality acrylic grounds and/or pre-primed supports as the presence of additives (e.g. surfactants, emulsifiers, antifoaming agents, etc.) can lead to problems including cracking, delamination, and other issues.
- Misting the palette with water while working and/or adding small additions of retarders intended for acrylic mediums (e.g. glycols), can also help to extend your working time during the painting process. NOTE: Adding too much retarder can cause adverse effects, leading to a weakened paint film that can remain tacky.
- Although opinions are divided as to whether it is considered best practice to varnish acrylic paintings, artists should note that acrylic films tend to be

considerably more porous than oil/alkyd films and can therefore suffer from the accumulation of dirt and grime over time. If a varnish is applied, artists should choose a non-yellowing, reversible varnish layer to prevent dust and other airborne particulates from becoming embedded into the upper paint layers. In addition, artists should note that acrylic films can possess additives that may migrate to the surface over time. This can create a hazy and/or cloudy appearance that may or may not require the eventual removable of the varnish layer. If a varnish has not been applied it may be possible to carefully brush away some of these additives; however; in some cases, these materials reappear on the surface as they can continue to remain mobile depending on a variety of factors.

- Some manufacturers advise applying a thin layer of clear acrylic dispersion medium over the surface to serve as a barrier between the varnish coating and the paint. As high quality acrylic mediums do not yellow/discolor significantly with age (as does oil and/or alkyd mediums), this layer can potentially serve as a protective barrier should the varnish need to be removed.
- To address problems with "sinking-in," try adding a touch of medium to your paints and/or use less water. For additional guidelines on how to address "sinking-in", see the "Varnishes" document for more information. The nature of the acrylic ground can also heavily influence the level of sheen across the surface of a painting.
- It is particularly important to avoid applying moderate to thick layers of retouching varnishes or layers of unpigmented acrylic medium during the painting process as this could lead to potential delamination and/or cracking of the paint.
- If your composition is complete and some areas still appear matte, it is possible to locally apply thin layers of clear acrylic medium to even out the overall sheen (particularly if the artist chooses not to apply varnish to the surface) or to apply an overall coat of medium. Another option is to locally apply varnish to matte areas, wait until dry, then apply a final protective varnish over the entire surface.
- It is inadvisable to paint a fresh acrylic painting over an abandoned, completed work as the surface may a) contain a buildup of surface dirt/grime b) contain a layer of protective varnish on the surface and/or c) not provide sufficient "tooth" or absorbency, leading to potential delamination or flaking.

EGG TEMPERA

Traditional egg tempera is created by diluting the contents of egg yolk with water, although many variations of tempera formulations exist and can include the use of whole egg or egg in combination with other additions (e.g. oil, gums, resins). Egg yolk itself contains a natural emulsifier (lecithin) that helps to form a stable suspension of both oil and proteinaceous components. Although the medium

initially possesses a slight yellow color, these colorants (carotenoids) have little impact on the overall color of the film as they are incredibly light-sensitive. The drying time of egg tempera paint is based on evaporation of water and, like other water-based paints, dries almost immediately and is therefore typically applied in multiple, thin layers. Tempera paint cannot be re-worked after it has dried and forms films that become brittle relatively quickly. It is for this reason that rigid supports are recommended for tempera paints, often in combination with a brilliant white ground to maintain a certain degree of luminosity to the thinly applied layers. While commercially available tempera paints are available today, artists should note that these are typically egg-oil emulsions which may contain certain additives (e.g. preservative, etc.) that may or may not perform well overtime.

Ageing Properties

Egg tempera has been used since antiquity and in most cases has demonstrated excellent ageing properties. While tempera paints do not yellow with age, they can discolor if certain pigments prone to degradation are present (e.g. vermillion, copper-based pigments, etc.). As with other proteinaceous paints like casein and distemper, tempera paints can be susceptible to mold growth particularly if they are kept in a damp, dark environment. Finally, tempera paints can experience fatty acid efflorescence, a phenomenon that relates to the migration of free fatty acids within the paint to the surface of the composition, often appearing as a hazy film. This condition can be exacerbated by changes in the environment but can be mitigated by using a soft brush to gently remove the fatty acids from the surface or even wiping the surface down using odorless mineral spirits (although in some cases efflorescence has been found to be a re-occurring problem on certain paintings even after removal). A professionally trained conservator with a graduate degree in Art Conservation should be contacted if you are unable to effectively remove efflorescence on your painting. A similar phenomenon can occur with surfactants that may be available in commercially available egg tempera paints (which are often egg-oil emulsions) as surfactants can migrate to the surface, forming a hazy film.

Painting Tips and Recommendations

If artists choose to use tempera paints, they should consider the following:

- Tempera paints become quite brittle overtime. They also require the use f a hard brittle ground like glue gesso. Artists are therefore highly encouraged to use rigid supports to prevent cracking and/or delamination of the paint and ground.
- Store and exhibit tempera paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight.

- Tempera paints should not be applied in thick, impastoed layers as this can lead to potential cracking and delamination from the ground/support.
- Several types of emulsions can be made with egg tempera. *Tempera grassa*, or egg-oil emulsions tend to be the most commonly, although other recipes involve additions of other materials (e.g. gums, resins).
- While egg tempera paints can be applied over clayboards and possibly certain acrylic grounds, these types of grounds may not be absorbent enough for those who are accustomed to homemade, glue-based grounds (containing gypsum or chalk) typically used by traditional egg tempera painters. However, these types of grounds for artists who prefer a longer open-time as tempera paints will dry slightly slower when applied over less absorbent grounds.
- Artists should note that the presence of certain additives in commercially available tempera paints (e.g. surfactants.) can lead to problems in the long term.
- It is generally recommended that tempera paintings not be varnished, although early Italian tempera paintings were often varnished and the decision is entirely up to the artist and the desired final aesthetic. As egg tempera is often applied in extremely thin absorbent layers, applying a varnish coating to the surface essentially causes the varnish to become irreversibly integrated within the paint layer(s). This is especially problematic if the varnish yellows and/or degrades over time. Thin spray coats of a non-yellowing, reversible varnish layer may be considered if the artist wishes to apply a protective coating to the surface.
- Certain pigments have been known to react adversely and/or degrade over time when bound in a tempera film (although some to a lesser extent than others). Such pigments include most historical copper greens and blues (discoloration of azurite, malachite, verdigris; formation of copper soaps), smalt (discoloration of smalt), and lead white (lead soaps). While lead soaps can form in egg tempera paints, note that not all lead soaps are undesirable as a certain degree of soap formation is needed to impart strength to the paint film.
- Avoid applying moderate to thick layers of retouching varnishes or layers of tempera medium during the painting process as this could lead to potential delamination and/or cracking of the paint.
- It is inadvisable to paint a fresh tempera painting over an abandoned work in oil as the surface may a) contain a buildup or surface dirt/grime b) contain a layer of protective varnish on the surface and/or c) not provide sufficient "tooth" or absorbency, leading to potential delamination or flaking. As tempera is applied in thin layers, it is incredibly difficult to obscure any underlying composition. If it is not possible to obtain a new support and start afresh, artists should consider removing any varnish coatings and scraping/sanding down layers of paint (exercising appropriate health and safety precautions) before applying fresh applications of oil paint.

- It is possible to gently sand the surface of well dried tempera paint layers. Remember that inhalation of any type of fine, particulate material (particularly if hazardous pigments are present) is not recommended and that a dust mask should be worn during sanding. It is best to avoid and sanding or scraping of grounds containing lead or other toxic pigments. Once you are finished sanding the ground, wipe down the ground using a cloth dampened with odorless mineral spirits to absorb any remaining loose pigments/particles (be sure to properly and properly dispose of the cloth).

WATERCOLOR AND GOUACHE

Both watercolor and gouache paints are typically composed of pigments bound in a gum (e.g. gum Arabic) that can be further diluted and applied using water. **Watercolors** are inherently more transparent than gouache paints; commercially available watercolors are generally bound in gum Arabic (although other vegetable gums and dextrin are also used) and can also contain additives such as plasticizers (e.g. honey), wetting agents (e.g. ox gall, glycerin), thickeners (e.g. cellulose thickeners, acrylic polymers), opacifiers in gouache, and preservatives. Traditionally, higher quality watercolors contained gum Senegal (a premium grade of gum Arabic). Commercial watercolors are available in cake or semi-liquid forms (the latter tends to contain more additives to help keep the paint in suspension while the former may also contain greater amounts of wetting agents to facilitate rewetting with the moistened brush) and are typically executed on paper supports, however other supports such as vellum, parchment, and gessoed panels can be used. Watercolor brushes should be soft and springy so that they can hold color while maintaining a fine point. Conversely, mop brushes can be used for those wishing to apply washes of paint over larger areas.

Gouache paints (also called "body color") contain a similar range of binders and additives found in watercolor paints but tend to contain a higher ratio of pigment as well as chalk and/or other white fillers (such as chalk, *blanc fixe,* or barium sulfate) to increase the opacity of the paint. Artists should note that certain brands of gouache paints contain acrylic binders as opposed to the traditional gum base and the paint may not be re-dissolved with water after drying. Commercial gouache paints are available in liquid form and are used on a wider range of supports, including paper, gessoed panels, and have even used to execute underpaintings, preferable on rigid supports. Watercolors as well as most gouache paints can be easily reconstituted with water ("fresh" paints are not necessary to use with each painting session) and combined with additions of mediums (such as Aquapasto, ox gall, etc.) to modify the consistency, gloss, and workability of the paints.

Ageing Properties

In general, watercolor and gouache paints have been found to be relatively stable mediums as most problems associated with long-term preservation tend to

relate to the delicate supports (e.g. paper, vellum) on which they are painted. Other conservation issues (e.g. discoloration, powdering) also tend to be attributed to the specific pigments used and method of application. In both types of mediums, the pigments are not completely coated by the binder (as with oils, acrylics, etc.) and therefore remain more exposed and vulnerable to light and atmospheric pollutants. Artists are therefore advised to use pigments that are stable and lightfast when painting with watercolors and gouache. The thin nature of these paint films also contributes to their delicate nature as they are easily prone to being scratched, abraded, and rubbed. Finally, if certain additives such as surfactants are present (particularly in gouache paints), the surface of the paint may form hazy films due to the migration of these surfactants. This condition can be exacerbated by changes in the environment but may be mitigated by using a soft brush to gently remove these deposits on the surface. A professionally trained conservator with a graduate degree in Art Conservation should be contacted if you are unable to effectively remove efflorescence on your watercolor and/or gouache painting.

Painting Tips and Recommendations

If artists choose to use watercolor or gouache paints, they should consider the following:

- Both watercolor and gouache paints are easily re-constituted with water. Therefore, both mediums are highly prone to damage if they come into direct contact with water or excessive amounts of moisture.
- Watercolor/gouache paints should not be applied in exaggerated thick, impastoed layers, as the paint layers can delaminate and/or crack.
- Store and exhibit watercolor/gouache paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 100-150 lux or exposed to direct sunlight as the pigments tend to be relatively exposed when bound in these mediums and more susceptible to light damage.
- As these mediums are often applied on relatively delicate supports (e.g. paper, vellum), they are usually stored flat. Vertical storage is possible but artworks should be properly hinged and matted, with a sheet of paper, glass, or other archival material used to protect the surface.
- For both types of mediums, the nature of the ground and/or support will have a profound effect on the long-term preservation of the artwork. Watercolor paintings, for example, are typically executed on 100 percent cotton or pH neutral paper, but other supports such as vellum, parchment, gessoed panels are sometimes used. Plain drawing papers may not be sized, and sizing is important as it will prevent uncontrolled spreading and bleeding of the paint. When choosing a paper, heavier-weight watercolor papers or illustration/Bristol boards are preferable as they will not wrinkle as readily when flooded with water as lightweight papers will. If using lightweight paper, stretch the paper on a rigid drawing board or use a

commercially available block or pre-made watercolor stretching frames.

- Artists should note that the presence of certain additives in commercially available paints (e.g. surfactants.) can lead to problems in the long term.
- It is generally recommended that watercolor and gouache paintings not be varnished, although this decision is entirely up to the artist and the desired final aesthetic. As both mediums tend to require the application of very absorbent paint layers, applying a varnish coating to the surface essentially causes the varnish to become irreversibly integrated within the paint layer(s). This is especially problematic if the varnish will yellow and/or degrade over time. Thin spray coats of a non-yellowing, reversible varnish layer may be considered if the artist wishes to apply a protective coating to the surface. Artists should note that many proprietary fixatives/spray varnishes have not yet been tested for their long-term ageing properties.
- Certain pigments have been found to discolor in watercolor/gouache mediums such as vermillion and lead white. However, this phenomenon is less attributed to the mediums themselves and related more to the fact that these pigments are more exposed to humidity, light, and atmospheric pollutants.
- Acrylic-based additives/mediums tend to make gouache paints more water-resistant, more plastic, and also increase the overall transparency of the paint.
- Ox-gall is generally added to assist with the flow of the paint, as it can be used to cut the surface tension, allowing water-based paints to be spread more evenly across the surface.

CASEIN

Casein paints are water-based paints made by hydrolyzing the casein protein (a phosphoprotein derived from the dried curds of skim milk) using an alkaline material (e.g. lime, borax, ammonia). This combination forms a matte, brittle film that over time becomes insoluble in water and impervious to most solvents. These paints lighten in color and value after drying and possess a flat, matte appearance. Like acrylic, casein allows for the application of impasto and relatively thick layers using a water-based medium. Casein paints tend to form incredibly strong films and on occasion have been known to pull away at underlying ground and/or paint layers upon drying. Due to the inherent strength of the medium as well as its brittleness, rigid supports are highly recommended in order to avoid potential cracking and deformation to the ground and/or support. For easel painting, there are two methods that are commonly used to hydrolyze the protein after soaking casein powder or raw milk overnight (skim milk is preferred since these is fat in other grades of milk): 1) with borax or 2) with ammonia. While using ammonia is considered by some to be a superior method (as the ammonia theoretically evaporates away after the protein has been hydrolyzed), actual practice has revealed that the liquid casein can retain the ammonia for some time which can cause the medium to lose its viscosity and degrade more quickly (making it difficult

to store for long periods of time). Note that strong alkalis should not be used as these can have an adverse effect on certain pigments and/or permanently damage the protein if used in high concentrations. While commercially available casein paints are available today, artists should note that these paints may contain certain additives (e.g. surfactants, r other materials emulsified into the binder) that could lead to defects in the long-term.

Ageing Properties

Casein has been used since ancient times, both as an adhesive as well as a binder. It has remarkably good ageing properties as it forms a tough film that is resilient to most solvents and does not discolor to a significant degree. If casein is prepared from milk that contains certain additives (e.g. vegetable oils) it can become more likely to yellow over time. As with other proteinaceous paints like egg tempera and distemper, casein paints can be susceptible to mold growth particularly if they are kept in a damp, dark environment. Finally, commercially available casein paints may contain stabilizer or other additives that could affect long term stability and appearance of these paints. A professionally trained conservator with a graduate degree in Art Conservation should be contacted if you need to have a casein painting treated.

Painting Tips and Recommendations

If artists choose to use casein paints, they should consider the following:

- While casein is initially water-soluble, over time the medium becomes stronger and more resistant to water and most solvents; however, care should be taken not to expose the painting to water or excessive moisture (especially soon after the painting has been completed).
- Paper and illustration boards are common substrates for casein paints. Due to the strength and brittleness of the casein medium, which can also be applied in greater impasto than watercolor, highly flexible supports like thin paper and fabric should be avoided to mitigate cracking and planar deformation.
- If a ground is desired, glue or casein based gesso applied to ridged supports is considered appropriate for casein paints.
- If casein is prepared from milk that contains certain additives (e.g. vegetable oils) it can become more likely to yellow over time. It is best to use raw milk (skim is easiest to work with) or casein powder purchased from an art supply store.
- When preparing casein paints, note that strong alkalis (e.g. soda/sodium carbonate or potash/potassium carbonate) should be avoided. If used in high concentrations, strong alkalis can not only permanently damage the protein binder, cause issues with grounds and substrates, and can have an adverse

effect on certain pigments. Kremer Pigments suggests that artists should also avoid using anhydrous or crystalline borax when making casein paints.

- Casein solutions that retain their alkalinity can limit the artist's choice of pigments. Certain pigments have been found to discolor and/or degrade when exposed to alkaline materials. Artists should consider using pigments that are intended for lime/fresco painting to avoid any potential damage.
- While casein paints can be applied in moderately thick, impastoed layers, care should be taken to not make the paint too thick as cracking may occur.
- Store and exhibit casein paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight as the pigments tend to be relatively exposed when bound in these mediums and more susceptible to light damage.
- When painting with casein paints, use plenty of water to keep the brushes moist; dried casein paint can be extremely difficult to remove from brushes.
- Varnish is not generally suggested for casein paints unless the artist is seeking the change in saturation and deepening of tone. Commercial casein varnishes have sometimes been formulated from shellac. Casein films remain porous so the application of a surface coating will penetrate the upper paint layer(s) to some degree and become a part of the paint
- Artists should note that the presence of certain additives in commercially available paints (e.g. surfactants.) can lead to problems in the long term.
- If necessary, casein paints can be sanded or scraped down (e.g. using a cabinet scraper). Remember that inhalation of any type of fine, particulate material is not recommended and that a dust mask should be worn during any sanding.
- There are many recipes for emulsions involving casein. If you are considering using a specific recipe and have questions or concerns regarding its long-term ageing properties, please post an inquiry on the MITRA forum.

DISTEMPER (GLUE-BASED PAINTS)

Distemper or glue size paints consist of pigments dispersed in warm animal glue (e.g. rabbit-skin glue). Distemper paints dry extremely quickly upon application as they both gel upon cooling and become hard through the evaporation of water. These paints tend to appear lighter in color upon drying and generally possess a matte appearance. While distemper paints are not commercially available, they are relatively easy to make (and clean-up) and are usually prepared before each painting session. Animal glue will swell in the presence of even cold water and will easily dissolve in hot water even after drying so care should be taken to make sure that paintings executed in distemper do not come in contact with water. While glue-bases paints can form fairly brittle films, they also remain hygroscopic. As with glue sizes, glue paints can experience continual swelling and shrinking due to changes in the environment; therefore, rigid supports are highly recommended in order to avoid cracking and/or potential delamination.

Ageing Properties

Glue mediums have been used since ancient times, both as an adhesive as well as a binder. Depending on a variety of factors, glue paints can discolor slightly with age. They tend to form fairly brittle paint layers that can also swell and shrink in response to changes in the temperature and relatively humidity, a characteristic that often gives rise to mechanical cracks. Distemper paint films are quite porous and can attract dirt/grime. As with other proteinaceous paints like egg tempera and casein, distemper paints can be susceptible to mold growth particularly if they are kept in a damp, dark environment.

Painting Tips and Recommendations

If artists choose to paint using a distemper medium, they should consider the following:

- Rigid supports are highly recommended for distemper mediums as they can form fairly brittle films and remain hygroscopic (i.e. prone to swelling and shrinking with changes in relative humidity).
- Paper and illustration boards are common substrates for distemper paints (although many famous artists have used acidic cardboard,. a practice that should be avoided as the substrate quickly darkens and becomes extremely brittle) Due to the brittleness of the glue medium, which can also be applied in greater impasto than watercolor, highly flexible supports like thin paper and fabric should be avoided to mitigate cracking and planar deformation.
- If a ground is desired, glue based gessos applied to ridged supports are considered appropriate for casein paints.
- Store and exhibit distemper paintings in dust free environments with relatively stable levels of temperature (60-70 F) and humidity (45-60%). Paintings should not be subjected to light levels over 200 lux or exposed to direct sunlight as the pigments tend to be relatively exposed when bound in these mediums and more susceptible to light damage.
- Varnish is not suggested for distemper paints. Distemper films remain porous so the application of a surface coating will penetrate the upper paint layer(s) to some degree and can alter the perceived color saturation of the paint.
- If necessary, distemper paints can be sanded or scraped down. Remember that inhalation of any type of fine, particulate material is not recommended and that a dust mask should be worn during sanding.
- Pigments bound in distemper tend to be more exposed to humidity, light, and atmospheric pollutants, making them more susceptible to degradation and/or discoloration.

ADDITIONAL RESOURCES AND REFERENCES

General

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Painting Materials, A Short Encyclopedia by Rutherford J. Gettens and George L. Stout (New York: Dover Publications, 1966).

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https://newamericanpaintings.wordpress.com/2013/05/16/painting-youre-doing-it-wrong/

University of Delaware – Kress Technical Art History Website
https://www.artcons.udel.edu/about-us/kress/historical-materials-techniques

Natural Pigments – Making your own Water-Based Paint
http://www.naturalpigments.com/art-supply-education/water-based-paint-pigments/

Kama Pigments – How to Make your Own Paints
http://www.kamapigment.com/en/information/how-to-make-your-paints.html

Drying Oils

Natural Pigments – About Drying Oils for Painting
http://www.naturalpigments.com/art-supply-education/drying-oil-painting/

Natural Pigments – Zinc White in Oil Paint
http://www.naturalpigments.com/art-supply-education/zinc-white-oil-paint-color/

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Golden Artist Colors – Weighing in on the Drying of Oils
http://www.justpaint.org/weighing-in-on-the-drying-of-oils/

Golden Artist Colors – Oil over Acrylics
http://www.goldenpaints.com/technicalinfo_oil_over_acrylic

LeFranc & Bourgeois – Mediums and Siccatives for Oil Painting
http://www.lefranc-bourgeois.com/beaux-arts/telechargement/A_TELPDF_2009080313251318.PDF

WebExhibits – Pigments in Oil
http://www.webexhibits.org/pigments/intro/oil.html

GEA Mechanical Separation Division – Basics of Alkali Refining of Vegetable Oils
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Golden Artist Colors – Williamsburg's New Safflower Colors
http://www.justpaint.org/williamsburgs-new-safflower-colors/

Oil and/or Resin-based Mediums

Natural Pigments – Should Oil Painters Use Resin-Based Mediums such as Dammar and Maroger?
http://www.naturalpigments.com/art-supply-education/resin-mediums-damar-maroger/

Natural Pigments – Resins and Balsams
http://www.naturalpigments.com/art-supply-education/resins-balsams/

Acrylic Dispersion

Golden Artist Colors – Oil over Acrylics
http://www.goldenpaints.com/technicalinfo_oil_over_acrylic

Golden Artist Colors – Instructional Videos
http://www.goldenpaints.com/videos

Golden Artist Colors – The Acrylic Drying Process
https://www.goldenpaints.com/technicalinfo_drying

Golden Artist Colors – Technical Forum
http://www.justpaint.org/technical-forum-your-acrylic-materials-questions-meet-technical-expertise/

Golden Artist Colors – Gels and Mediums
http://www.goldenpaints.com/technicalinfo_gelsmeds

Golden Artists Color – Defining the Acrylic Patina
http://www.justpaint.org/defining-the-acrylic-patina/

North Light Shop – Learn Acrylic Paint for Beginners
http://www.northlightshop.com/how-to-use-acrylic-paint

Smithsonian Museum Conservation Institute
http://www.si.edu/mci/english/learn_more/taking_care/acrylic_paintings.html

"The Natural and Accelerated Ageing of an Acrylic Artists' Medium" by Paul M. Whitmore and Dr. Val G. Colaluca, *Studies in Conservation* 40 (1995), pp. 51-64.

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C.A.S. Alkyd Pro – Professional Fast Drying Alkyd-Oil
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Additives/Driers/Fillers

Natural Pigments – Oil Paint Additives
http://www.naturalpigments.com/art-supply-education/oil-paint-additives/

"Paint Driers Discussed in 19th-Century British Oil Painting Manuals" by Leslie Carlyle in *Journal of the American Institute for Conservation* 38 (1999): 69-82.
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Prospector – Inert Pigments: The Unseen Contributor to Improving Paint Performance
http://knowledge.ulprospector.com/3489/pc-inert-pigments-the-unseen-contributor-to-improving-paint-performance/

CAMEO – Inert Pigments
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http://www.handprint.com/HP/WCL/pigmt1.html#fillers

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http://www.handprint.com/HP/WCL/pigmt1.html#additives

Egg Tempera

The Society of Tempera Paintings – Egg Tempera Paint
http://www.eggtempera.com/technical-info/egg-tempera-paint

WebExhibits – Egg Tempera
http://www.webexhibits.org/pigments/intro/tempera.html

Daniel Smith – Making Egg Tempera
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Koo Schadler – Techniques of Egg Tempera and Silverpoint
http://www.kooschadler.com/techniques.htm

A Comprehensive Guide to Painting in Egg Tempera by Koo Schadler (2009).

Watercolors/Gouache

Handprint – How Watercolor Paints are Made
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Handprint – Additives in Watercolors
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Handprint – Plasticizers in Watercolors
http://www.handprint.com/HP/WCL/pigmt1.html#plasticizers

Handprint – Humectants in Watercolors
http://www.handprint.com/HP/WCL/pigmt1.html#humectants

Studio Arts – Winsor and Newton Hints and Tips Designer Gouache
http://www.studioarts.co.uk/links/hintsandtips/gouachehintsandtips.htm

Encaustic/Wax

R&F Handmade Paints – Encaustic Technical Resources
http://www.rfpaints.com/resources/encaustic

Yodelout! Art – Ancient and Modern Encaustic Painting
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Casein

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Distemper

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