

23. CONSOLIDATION/FIXING /FACING

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OUTLINE

Consolidation is defined as the application or (in some cases) the regeneration of binding material to improve cohesion of loose or friable media or substrate and reattach it (if necessary) to its support. This treatment can be adopted as an interim measure during treatment (fixing, facing), or as a permanent measure to ensure the long-term integrity of an artifact. For the purposes of this outline the term **media** refers to that material which makes up the design in a work of art or historical object. The term **binder** is used to describe the adhesive which binds together the design media and attaches it to its support.

23.1 Purpose:

- 23.1.1 To secure design media in danger of detaching from support.
- 23.1.2 To substitute for dessicated, insufficient, or otherwise non-functioning binder in original media.
- 23.1.3 To secure media in order to facilitate conservation treatment as a whole (Example: to allow an aqueous conservation treatment to be carried out on an object with water-sensitive media.)

23.2 Factors to consider:

23.2.1 Condition and characteristics of object in question:

- A. The condition requiring consolidation can be a local or general problem.
- B. Description of the problem:
 - 1. Stress cracking of paint layers.
 - 2. Delamination or separation of paint layers.
 - 3. Separation of paint from paper, i.e. flaking.
 - 4. Friable media such as pastel, charcoal or chalk.
 - 5. Dessicated binder.
 - 6. Tenting, or cupping of paint.
- C. Cause of the problem:
 - 1. Preparation or application of design layer.
 - 2. Deterioration of the binder caused by inadequate storage environment of object.
 - 3. Dimensional instability of support.
 - 4. Inherent character of media or binder.
- D. Identification of the problem:

Proper diagnosis often requires thorough examination of the object in question with binocular microscope, i.e. many watercolors possess areas of local, thickly applied paint which may be surprisingly insecure, yet this may be imperceptible to the naked eye.

23.2.2 Possible use of alternative treatments that might avoid the application of a fixative or consolidant, such as the use of an electrostatic plate, washing on the suction table, float-washing, cleaning with damp blotters, etc.

23.2.3 Visual alteration (i.e. saturation) of media and/or paper by the introduction of a consolidant

- 23.2.4 Physical and chemical compatibility of introduced consolidant and selected solvent with original media, binder, and support.
- 23.2.5 Characteristics of adhesive chosen including: long and short term reversibility, flexibility, hygroscopicity, shrinkage, and adhesion initially and over time, chemical reactivity and visual stability.
- 23.2.6 Effect of consolidant on subsequent treatments.
- 23.2.7 Presence of surface soil on area to be consolidated and desirability and possibility of its removal.
- 23.2.8 Handling expectations for the object. Is it to be loaned? Will it be travelling under controlled conditions? How will it be exhibited or stored? Will it be handled frequently?
- 23.2.9 Choice of solvent to enhance desired properties of consolidant.
- 23.2.10 Application technique (see also 17. Sizing)

The fragility of the paint film determines the method of application of consolidant. Fairly stable films may tolerate direct contact such as brush application. Very friable or otherwise delicate films may require the use of a an eyedropper, a gentle spray, or the sparing use of a small brush. Size of the area to be treated also influences the selection of application tool.

23.3 Materials and equipment:

- 23.3.1 Adhesives:
This outline includes a discussion of solubility characteristics, working properties, substrates upon which an adhesive is effective, and advantages and disadvantages of particular adhesive choice. Other names by which adhesive is known, more precise chemical and physical characteristics as well as aging properties etc. are to be found in the outline: 46. Adhesives.

A. Aqueous adhesives, natural

1. Starches
 - a. Traditional rice or wheat starch paste

The practise of using cooked wheat or rice starch paste as an adhesive in paper conservation derives from traditional Japanese scroll mounters' techniques. Reference to the use of starch paste as a mounting adhesive in East Asia goes back at least to the 9th century (see bibliography: IIC Preprints, 1984)). Different starches are obtained from different plant sources, but all are polysaccharides with two basic components: amylose and amylopectin. Initially, the wheat or rice grains from which starch is derived contained also a protein component, gluten, which is removed to obtain pure starch. Wheat starch generally has a higher percentage of amylose (17-27%) than rice starch (16-17%). Amylose has a chemical structure very similar to cellulose, however, amylopectin has been shown to be the better adhesive in combination with cellulose (see bibliography: IPC thesis by Raymond L. Janes). Rice starch paste generally has greater tack than wheat starch paste.

Traditional Japanese scroll mounters use both new (Ginjofunori) and aged (Furunori) cooked starch paste. In the United States, Aytex-P, a highly purified food grade wheat starch (25% amylose) made by the Henkel Corporation, is most commonly used by conservators. Aytex-P starch is sold as a powder, and is mixed with water and cooked. During the cooking process the granules of amylose and amylopectin swell and burst, forming a sticky paste. Many formulas for making paste are available in the conservation literature (see bibliography: Clapp, Library of Congress, and Koyano).

After cooking, the paste must be strained and diluted with water for use. A very thin (skim-milk) solution of starch paste can have considerable tack. Although it is not generally applied topically as a consolidant for paint films, it often behaves like a general consolidant for the design layer when it is applied as a lining adhesive, because it seeps through the back of the paper to the front.

Some conservators use very dilute wheat starch paste added to a gelation solution for use as a local consolidant with a little extra tack. One formula describes adding a drop of water-thin Aytex-P starch paste to 1-1.5 ml of a .4-.5% gelatin solution (the gelatin here is Fisher silver label in sheets). This solution is then used to set down flaking paint by applying it under the flake with a brush. The paint layers consolidated with this solution remain visually and physically stable after 5 years of natural aging.

Caveats: Starch applied too thickly or dryly can stiffen the paper too much, cause cockling or curling and can give a grey appearance to light colored papers. Starch films shrink upon drying and over time can continue to lose moisture and shrink further under conditions of low relative humidity. Starch is sometimes difficult to reverse as a film and may require the use of enzymes.

b. Funori

Funori is a weak adhesive produced from seaweed mucilage; product of marine algae. It is a polysaccharide like starch. After harvesting, the seaweed is cleaned, soaked, pressed and dried to give thin sheets. The mucilage is extracted with hot water and the residual material filtered off. It is used in aqueous solutions in the Japanese scroll mounters' tradition as a consolidant of friable and water-soluble media. (see bibliography: Evans, Higuchi). It is also used as a weak adhesive in mending and facing. Its advantage as a consolidant is that it has a very low viscosity and can be applied repeatedly without giving bulk to the treated pigment and it appears matte and is more flexible than wheat starch paste. Funori is applied as a warm solution in water for consolidation purposes.

2. Gums

Gums are the natural exudants of certain 'wounded' trees, formed by the tree as a means of protection from outside organisms. They are non-crystalline materials composed of carbon, hydrogen and oxygen. Gums usually come in small beads or tears which vary in their water-solubility. Many of the properties of gums, i.e. purity, solubility and hardness, depend on variables which cannot be controlled by the conservator: i.e. time of exudation from the tree, geographical location of the tree, age of the tree etc...

a. Gum Arabic

Gum arabic is one of the most water-soluble gums and is able to form solutions in water greater than 50% concentration. It was and is still used as the original binder for many

watercolor paints. The principal problem of gum arabic as a binder is its tendency to become dry and brittle over time. Watercolor manuals refer to the brittleness of gum arabic films. Honey and/or glycerin were added to gum arabic solutions to prolong drying time of the binder film and to increase flexibility. These additives have sometimes caused additional drying problems in watercolor drawings, such as cracking or the formation of crystals in the paint films. Some recent studies with gum arabic have shown the following solution properties: A 5% solution of gum arabic containing 6% glycerin produces a dried, flexible film. By comparison, 30% glycerin added to the 5% gum solution produces a film which does not dry completely and remains moist.

The amount of heat used in the solution preparation can alter the gum's solubility. Gum arabic tears prepared in water using moderate heat results in the formation of films that are decidedly more water soluble than those prepared in boiling water. PH of the water is also a factor in the solubility of the gum: low pH (caused by boiling the solution) favors insolubility. (JS)

Caveat: The result of application of gum arabic to flaking paint as a consolidant is most often continued flaking. Because of its tendency to become brittle upon aging, gum arabic is problematic as a consolidant for conservation purposes.

b. Gum Tragacanth

Tragacanth is less water-soluble than gum arabic and is partially miscible with some organic solvents. It has a pronounced gloss and has been identified as a glaze on watercolors where it was also associated with severe flaking. (JS)

c. Tamarind seed gum

Mentioned by O. P. Agrawal as a sprayed consolidant for Indian miniatures and flaking paint. See bibliography.

3. Proteins

a. Gelatin

Many different grades of gelatin are produced. Those recommended for use in conservation are "photographic quality" gelatins which are highly purified, and available from Eastman Kodak and Fisher Chemicals. Low grades of gelatin are not suitable for use in conservation as consolidants as they contain metallic salts and other impurities. Dissolved in warm water, gelatin can be effective as a consolidant in percentages as low as 0.5 or 1%. A warm solution of gelatin can be cooled to room temperature and diluted successfully with isopropyl alcohol up to percentages of 75:25 alcohol:water. Aqueous solutions do not last very long (with refrigeration, only a couple of days) and should be made up fresh before use. Small batches can be made up in a microwave oven (TKM). The temperature of solution, percentage of alcohol, and solution concentration can be varied according to the requirements of the material to be consolidated. Formaldehyde is sometimes used with gelatin as a hardening agent, however, it causes cross-linking of the collagen molecules making the film insoluble (see bibliography: Hatchfield). Gelatin is a strong adhesive and when applied as a warm solution it can be especially effective in setting down flakes of paint which require considerable tack to reattach or softening of the flake prior to reattachment. Gelatin solutions are somewhat viscous which sometimes proves a disadvantage in attempting to penetrate paint layers. Application of this consolidant is usually done locally with a brush. Warmed gelatin solution can also be sprayed with an air-brush for overall consolidation. It is capable, however, of changing the color of a paint film, especially if the paint film is a light color, and should be tested with mock-ups and locally on an object before using overall. Gelatin applied repeatedly can

dry leaving a shiny surface and is capable of discoloring a paper support especially upon subsequent exposure to light and heat or high relative humidity. It may be desirable to use repeated layers of thinner solutions of gelatin to avoid gloss problems.

Caveats: Special care must be taken with this and other protein materials not to dissolve the top layer of a composite paint film or cause reticulation by introducing heat. Gelatin is hygroscopic and can support mold growth in conditions of high relative humidity. It is also attractive to insects. It will become brittle under excessively dry conditions. It is degraded by exposure to ultra-violet light and yellows with age. Before using this consolidant consider the future storage and display of the object to be treated.

b. Parchment size

Like gelatin, parchment size is a protein compound, primarily composed of collagen. An early reference to the making of parchment size for consolidation use is found in Cennino Cennini's Craftsmen's Handbook from the 15th century (chapter CXIII, p. 67 in Daniel Thompson's translation). Parchment size is made from animal skins rather than horns and hooves and its purity depends on the quality and processing of the skins. Traditionally, limewater is used to soak the skins resulting in an alkaline size. Parchment size (Library of Congress formula) is made by cooking (not boiling) scraps of parchment (previously soaked in water overnight and then rinsed) in water for eight hours, then straining the resultant solution through cheesecloth and allowing it to cool to room temperature. Refrigeration or freezing of the concentrated material prolongs its shelf-life for many weeks. It is lighter in color than gelatin solutions, though it is similarly tacky and can be diluted in the same manner using water and isopropyl alcohol.

Parchment size can be useful in fixing areas of hand-coloring on prints and maps. Even if applied rather thickly, the parchment size sinks into the paper upon washing the treated object and is less visible upon drying than many synthetic fixatives. Some conservators feel that it is more compatible with the original binders of coloring materials and inks, than synthetic adhesives. Parchment size can be quite effective in consolidating flaking or powdery pigments in medieval manuscripts, oriental materials, parchment pieces and pieces which contain inks with very little remaining binder. Application locally by brush is the most common method. Humidification of the object aids the penetration of the size invisibly into the paint layer. Pre-spraying the area to be consolidated with alcohol can also aid in penetration. Repeated applications may be necessary for best protection when attempting to subsequently wash an object. Spray application using a thin solution can be successful on larger areas. Parchment size is not always effective with modern materials and dyes in a washing treatment. It can cause bleeding of some materials upon application or sinking of colors to the back of a paper support. Synthetic dyes and colors may need a stronger fixative.

Additional Formulas:

At the Austrian National Library, parchment clippings in water are cooked for 24 hours, adding water to the solution as the cooking water evaporates. After straining the solution, equal parts of wine-vinegar and alcohol are added to the warm solution so that each liquid (size, vinegar, alcohol) represents one-third of the whole volume. The vinegar must be added to the solution before the alcohol for adequate mixing. This solution is used for consolidation of pigments on parchment or vellum supports. The solution does not need to be refrigerated nor does it form a gel. Spraying the parchment support with alcohol before applying the size is recommended for better penetration of the size into the skin. The vinegar is said to soften the skin and encourage penetration of the consolidant. It also acts as a preservative.

Some conservators like to cook the parchment scraps in alkaline water (such as calcium hydroxide or magnesium bicarbonate). The alkaline solution breaks down the collagen

more effectively than neutral water does. The solution is cooked for 16 hours and then a few drops of acetic acid are added to reduce the viscosity and prevent the formation of a gel. Other conservators feel this solution is too alkaline, and that since the skins are processed in a lime solution to begin with additional alkali is unnecessary.

Caveats: Similar to those associated with gelatin. It is more difficult to document actual concentration of the parchment size in solution.

c. Sturgeon glue (Isinglass)

Sturgeon glue is a protein material obtained from the dried swim bladders of the sturgeon fish. Small clippings of the material are dissolved in hot water and the resulting solution can be diluted with isopropyl alcohol when cooled to room temperature. It is a strong adhesive consisting of a very pure form of collagen and can be diluted to a thin viscosity (thinner than gelatin) because of its extreme water-solubility, and can be used in a low concentration as a consolidant. It is used in the Soviet Union as a paint medium and consolidant for icons and manuscripts. It is somewhat difficult to obtain in the West. Like gelatin it can be used to soften brittle, cupped and cracked paint films. It is also very responsive to moisture and can become dry and embrittled in conditions of storage with low relative humidity. Sturgeon glue has been mixed with plasticizers such as polyvinyl alcohol or glycerin to make a more flexible film. Application is usually by brush, using a warm solution. **Caveats:** Sturgeon glue is subject to the above noted deterioration factors associated with gelatin and parchment size.

d. Casein

A traditional binder used for pigments and grounds as well as paper coatings, casein is made from the precipitate which occurs upon acidifying skim milk. Artists such as Edgar Degas and John Sloan (and many others) are known to have used casein in combination with their pastel techniques. Casein has been suggested for use as a paper coating (see bibliography: Technical Studies Vol I, No. 4, 1937). The use of casein as a matte fixative for pastel is recommended by contemporary artists's handbooks (see Bibliography: Kurt Wehlte, p.466. A formula for casein fixative is given which contains powdered casein, ammonium carbonate, water and alcohol. Wehlte states two advantages of casein as a fixative: it binds effectively in low concentrations and it causes little change in saturation of the pastel media). **Caveats:** The disadvantages of using casein for conservation treatments include its dry, brittle character as a film and its gradual insolubility upon drying and aging.

Note: Artist John Sloan used to draw with pastel and then make washes by using a brush in skin milk to smear part of the pastel...or he would coat the paper first with skim milk. Some of his drawings look like they are part pastel and part 'watercolor' but they are the skim milk pastels. (Submitted by Antoinette Dwan from a conversation with Mrs. John Sloan.)

B. Cellulose Ethers (Synthetic water soluble adhesives)

1. Methyl cellulose

Methyl cellulose is a non-ionic ether produced by many manufacturers in various grades, viscosity and degrees of polymerization (DP). The best methyl celluloses for use as consolidants are the highly purified varieties produced for adhesive applications (adhesive grades). Methyl cellulose is a more flexible adhesive than starch or gelatin. Low DP methyl celluloses like Dow Methocel A 15C or A 4C can be made into solutions of 1-2% with water and used for consolidating large areas of weak paint layers (e.g. deteriorating binder of printed ink on a large map). Higher DP adhesive grade polymers like Methocel A 4M or Process Materials Methyl cellulose Paste Powder have more tack. These larger DP methyl

celluloses sometimes do not fully penetrate the paint film and may dry leaving a sparkling or shiny residue on the surface, which can be difficult to remove. Success of the consolidant depends on the skill of the conservator in preparing the correct concentration for the particular paint film and in applying it in a sensitive fashion.

Considerable percentages of alcohol can be added to specific grades of methyl celluloses (e.g. Dow Methocel A and Process Materials) as a diluent. See manufacturers' product literature for individual instructions in making up solutions. Application is usually by brush but some conservators also apply methyl cellulose as a spray.

Methyl cellulose vary in strength, according to grade, concentration and DP, however, some can be effective in consolidating crumbly white or other light colored gouaches such as those sometimes found in English watercolors and Indian miniatures. Methyl cellulose in low percentage solutions can be brushed on local areas needing consolidation. It tends to remain on the surface of a paint film for a few seconds before sinking in, and may not be suitable for very water soluble media. Dilution of the methyl cellulose solution with alcohol improves penetration of the consolidant and enhances drying time. If it successfully penetrates into cracks or under flakes it can be applied more than once without altering the optical quality of media. It can cause distortions to some paper supports if applied repeatedly in the effort to achieve an adequate adhesive bond. Some conservators first apply a small amount of alcohol to the area to be consolidated and then follow with an application of the methyl cellulose. There is a chance that this technique may cause tidelines if the timing of application is not just right. Occasionally, some pigments may darken, again depending upon timing of application of alcohol and consolidant. Tidelines and darkening are more common with the use of more concentrated solutions of methyl cellulose. Methyl cellulose is useful for treatment of insecure paint where a stronger consolidant may actually enhance cupping and local distortion of loose flakes (especially upon aging).

Methyl cellulose is not soluble in water at temperatures above 38° C. This feature is noted by some conservators who use methyl cellulose as a fixative during warm washing treatments.

2. Sodium carboxy methyl cellulose (CMC, Cellofas B 3500)

CMC is a cellulose ether like methyl cellulose, but containing an additional sodium compound which has caused some conservators to reject it for use on paper. Unlike other methylcellulose ethers discussed here, it is an anionic compound. Sodium carboxymethyl cellulose behaves like methyl cellulose, however it has been shown to yellow in a percentage of 2.5% under artificial humid aging conditions compared with Dow Methocel A (see 1984 IIC Conference *Preprints*).

3. Ethyl hydroxyethyl cellulose (Ethulose)

Ethulose, available from Conservation Materials, is a water soluble non-ionic cellulose ether, produced by the Chemical Master Corporation. Ethulose solutions (2-4% in water) can be diluted with an equal volume of pure ethyl alcohol (denatured alcohols may cause precipitation of the ethulose). Ethulose is also soluble in benzene, toluene and xylene. It forms hazy mixtures in solutions combining acetone and alcohol. Conservators find it an effective adhesive with a matte appearance and a desirable flexibility. It is especially good for consolidating gouache paints which require a matte surface. It has also been recommended for use on dark colors because it sinks into the film with little alteration of the surface. Alcohol can be brushed on the surface to chase off excess consolidant. Humidifying the object before consolidation with Ethulose is very useful in helping penetration of the consolidant and in reducing any alteration of the paint's surface. **Caveats:** More studies are needed to determine the aging qualities of this adhesive.

4. Hydroxypropyl cellulose called Klucel G

A cellulose ether which can be dissolved in water or alcohol. It is possible to make a solution of Hercules Klucel G in 100% absolute, methyl, ethyl, or isopropyl alcohol. Product literature from Hercules Corp., claims it is soluble in other polar solvents such as methyl cellosolve, and mixes of polar and non-polar organic solvents like toluene:ethanol, acetone:water. Solution is subject to acid hydrolysis and can be made alkaline to pH 6-8 with ammonium hydroxide. Has similar working properties to methylcellulose. Can be used to very lightly consolidate or protect water soluble colors such as gouache during a treatment such as float washing or lining. Does not have very strong adhesive properties, but has been used successfully in water/alcohol solutions to consolidate pigmented ethnographic materials which have a matte surface quality. (See bibliography: Heumann). Klucel has been used in ethanol to consolidate darker colors like the blues and browns of water-based paints which are sensitive (i.e. darken) with aqueous consolidants.

C. Solvent soluble adhesives

1. Cellulose Acetate

Cellulose acetate is made by at least two companies. Celanese is the trade name of cellulose acetate from British Celanese and Kodacel is made by Eastman Kodak. It is a synthetic adhesive which is soluble in acetone, ethyl acetate and methyl ethyl ketone (MEK). It is available in different viscosities. Two varieties used in conservation are Kodak #4655 and Celanese P911. Cellulose acetate has been studied as an adhesive by Wilson and Forshee (see bibliography) and is used commonly as a consolidant. According to Horie(see bibliography) "Cellulose acetate oxidizes at room temperature, the molecular weight is reduced and it becomes weaker and more brittle. Degradation is increased considerably by traces of acid catalysts remaining from manufacture. Process of degradation can be reduced by incorporating an acid acceptor, e.g. a buffer...." Some commercially available cellulose acetates (like Kodacel) contain buffers such as calcium carbonate.

Cellulose acetate does not add gloss to a matte surface or darken light colors and can be used successfully for consolidation of thin powdery white paint films. Some conservators consider it very good for the consolidation of thick crumbly paint films (CN). It is usually effective when applied by brush in a solution of 2% or 3%. It found by some to be more satisfactorily applied using a suction table or disk. When applying cellulose acetate to paint films on thick papers or paperboard where suction is useless, residual surface adhesive is flushed into the lean paint film with local applications of either acetone or MEK. A range of higher concentrations --up to 20% can be useful (TJV). The application of acetone or MEK after the cellulose acetate can help to eliminate the surface shine.

Caveats: MEK, acetone and ethyl acetate are fast evaporating solvents and when using a solution of cellulose acetate the adhesive tends to dry on the applicating brush before the material reaches the paint film to be consolidated. Because it dries so quickly in these solvents, cellulose acetate can leave an iridescent film or white ring on the surface of a dark pigment. Flushing with solvent may eradicate this.

2. Polyvinyl acetate

PVA, a thermoplastic resin, has been in use in conservation since 1930. It is available in different grades (AYAA, AYAC, AYAF, AYAT) from the supplier Union Carbide. Physical descriptions such as viscosity and glass transition temperature are given by the manufacturer with the resins dissolved in acetone, however, they are also soluble in alcohols, toluene and

chlorinated hydrocarbons. PVA AYAC is the principal consolidant used in the paper conservation field. Solutions of AYAT and AYAF are often considered to be too viscous for normal consolidation procedures, though they may be useful in some circumstances where their hot melt properties would be desirable.

AYAC resin in solvent (2-10% solution) has been used as a temporary consolidant on lean paint films where it will be removed later, using solvent on the suction table. This application has been found to be especially useful for projects requiring consolidation to protect cupped, lean paint during a backing removal with the object face-down. AYAC has also been very useful for adhering insecure cupping oil paint passages on paper or paperboard. Application can be either by brush or (if object can be placed on the suction table) by airbrush, but care must be taken with the latter to use only very low air volumes and pressures on sensitive areas of the paint film. The suction table has been found useful for holding the loose paint in place while consolidation proceeds. The fritted glass suction disk which operates at a high suction is useful for holding severely cupped paint passages in place during consolidation, or for pulling the consolidant deeper into the paint paper composite. The suction table or disk is useful for removing excess consolidant or completely removing temporary consolidant. Solvent can be sprayed or brushed through the object. (TJV)

As a dried film, PVA AYAC resin can have a shiny appearance and is quite a strong binder. The PVA resins have been found to be permeable to water and water vapor.

PVA AYAC in ethanol has been used successfully as a spray consolidant for historic wallpapers such as the French Historic Scenic papers designed by Dufour and Zuber. These wallpapers are block-printed in many layers of color and often exhibit flaking paint problems, especially when they have been previously restored or overpainted. Often, the challenge in consolidating wallpapers is to provide adequate adhesion for the flaking paint film without altering the color. AYAC has been used effectively as a spray consolidant in ethanol (3% PVA in ethanol) with a quantity of acetone added (solution cut by one-third or one fourth with acetone). (EKS)

3. Soluble nylon

Soluble nylon, a chemically modified form of nylon produced by treatment with formaldehyde, has had widespread use as a consolidant in the conservation field. One commercially available variety discussed in conservation literature is Calaton CA or CB sold by Imperial Chemical Industries. Soluble nylon is typically applied by brushing or spraying a 2-5% solution (warm) in alcohol or alcohol cosolvent systems with water, aromatic hydrocarbons and chlorinated hydrocarbons. Desirable properties of the consolidant include a matte appearance upon drying and permeability of the consolidated film to water. Soluble nylon has been used to consolidate large paper objects such as wallpapers which require both consolidation and washing.

In recent years the material has been studied and proven to cross-link and become insoluble upon aging. In addition, tests show that soluble nylon films become brittle with age, and can rupture and even pulverize. Questions have been raised concerning the possible absorption of dust into the nylon film and the clarity of the film when used on humid surfaces. The most recent literature contains studies of the degradation mechanism of soluble nylon which determines that it is an oxidative process related to environment, light and temperature. The addition of stabilizing materials to soluble nylon to prevent these chemical changes is suggested. Until further study, however, it is not advisable to use soluble nylon as a consolidant in paper conservation. (See bibliography: De Witte, E., Studies in Conservation 20, 1975, Sease, C., Studies in Conservation 26, 1981, and Preprints ICOM 8th Triennial Meeting, 1987).

4. Ethyl methacrylate/methyl acrylate copolymer called B-72 (Rohm and Haas)

B-72 is one of the most stable resins known for conservation use and has been studied thoroughly by conservation scientist Robert Feller (see Bibliography). B-72 is soluble in toluene, xylene, toluene:ethanol mixtures, MEK, DMF, acetone, diacetone alcohol, and methylene chloride. The solvent diethylbenzene has been suggested for use with B-72 because of its slow evaporating quality which allows for good penetration of the resin into the paint film. While this is true, the solvent is also very heavy and strong smelling and should only be used when the conservator has adequate ventilation in the working space. Ethanol added to a concentrated solution of B-72 resin in toluene or xylene can slow down drying somewhat, and is less toxic.

B-72 can be used successfully as an overall consolidant for certain types of gouaches or pastels which suffer from a general condition of insufficient or deteriorated binders. The resin has the advantage of appearing quite matte if used sparingly and in low percentages. A solution of 2% B-72 in toluene/ethanol 40/60 sprayed through an airbrush in the fumehood or using the suction table can effectively consolidate very loose media. It is especially useful when that media is water-sensitive. The airbrush nozzle can be directed at specific as well as general areas. It can work well with heavy paint chips which need reattachment, when applied in a solution of 3% or more with a brush. It has the advantage of being flexible and is not subject to excessive brittleness under dry conditions. It is not subject to attack by micro-organisms. Spraying solvent through the fixed area on the suction table after treatment can remove the consolidant if this is desirable.

Caveats: B-72 can appear shiny or yellow in high percentages (even 3%) and puddle on the surface of a picture. Application of B-72 around a signature before washing can result in uneven washing of the object and possible 'haloing' around the signature. If the resin is sprayed onto a pastel or flaking gouache, the correct pressure is critical to avoid media disturbance. B-72 changes the appearance of some colors. Using mock-ups can help to identify possible color changes in a particular piece. The distance of the spray-gun to object is critical for another reason. If one is spraying in the fumehood, the solvent may dry before the resin reaches the surface of the picture resulting in a 'beaded' coating. Testing with colored papers can aid in determining the proper working distance of the spray gun and evaporation rate of solvent.

5. n-Butyl methacrylate called B-67 (Rohm and Haas)

A softer resin than B-72 and soluble in less toxic solvents such as petroleum benzine, VMP and mineral thinner. Has been shown to yellow slightly with age.

6. Paraffin Wax

Paraffin wax (P-21 from Fisher) dissolved in heptane (Reagent Grade) and locally applied can be an effective fixative for very water-sensitive media on an object which requires aqueous treatment. Sensitive areas like water-soluble felt-tip pen or drawing ink and signatures can be fixed successfully with wax. Also, areas of glazing can be protected with wax from water during treatment. Wax is only applied with the intention of fully removing it after treatment from the object in question.

Preparation of the solution requires dissolving wax shavings in solvent and heating the solution in a double boiler system to a temperature close to the melting range (53-57°) of the wax. A typical proportion used is 20 ml by volume of wax and 30 ml solvent. More solvent can be added if the wax is too thick. A stock solution of the dissolved wax may be kept and simply reheated for future use. Application of the wax is done while the solution is warm but not hot, the goal being to completely encase the sensitive area to prevent contact of that area with water or aqueous solution. Wax must be applied to both sides of the object to prevent penetration of liquid. Several applications of wax is usually necessary to provide

adequate protection, especially if the paper support is particularly thick or dense. Application of the wax using a suction table or disc is helpful in getting good penetration. More solvent or locally applied heat from a tacking iron may also aid in embedding the wax. Before aqueous treatment of the object, the fixed area can be tested by placing a drop of water at the perimeter of the dried wax and watching its penetration and the wax's resistance. Wax offers protection during treatment, however the object can not be left soaking in a bath for extended periods of time. Eventually water will penetrate even the wax-fixed area. Continuous monitoring and quick treatment is advised.

The wax can be removed in a number of ways. 1. Immersion in a warm solvent (heptane) bath will remove most of the wax. The solvent bath is kept warm by floating it over a warm (55°) water bath. Several baths may be necessary for complete removal. 2. A tacking iron applied to the fixed area, using a silicone release paper interleaf can remove the bulk of the wax into blotters. 3. Additional wax is removed locally on the suction table by applying warmed solvent over the fixed area. (MW)

Caveats: An area fixed with wax is stiff and cannot be humidified or flattened, therefore the wax must be removed before this treatment step. Any area embedded with wax will not be washed and may contrast with the treated area, especially if the paper is bleached. Application of the wax requires great care. Its removal must be done completely or the paper will react differently to moisture in the future.

8. BEVA 371

Original Formula BEVA 371 is an adhesive mixture developed by Gustav A. Berger with the following components: 60%:toluene/heptane, 40%: mixture of ethylene vinyl acetate copolymer (Elvax 150), cyclohexanone resin (Lapropal K80), ethylene vinyl acetate copolymer (Allied's A-C copolymer), phthalate ester of hydroabietyl alcohol (Hercules' Cellolyn 21), and petrolatum (paraffin). It comes as a white opaque gel with an aromatic odor, and can be further diluted by the following solvents among others: Naphtha, petroleum benzene, acetone, alcohol, toluene. The gel has a melting point of 50-55° C.

BEVA 371 has a long history of use as a consolidant for paintings and textiles, however, it has applications for paper conservation as well. The adhesive is very sticky even in dilute solutions. It is applied warm for best results has good flow properties for setting down flakes or consolidating interlayer cleavage in a delaminating acrylic or oil paint film. Use of binocular microscope during application is advantageous. BEVA 371 can be applied with a brush or can be sprayed on. Spraying the adhesive can produce a 'flocking' effect which may be desirable for a lining coating but not necessarily for consolidation. Upon drying, the adhesive appears matte and has a waxy finish. The film remains heat-sensitive and a tacking iron can be used to activate it further using a silicone release paper interleaf. Solvent can be applied topically to remove residual surface adhesive.

Caveats: Some media and paper supports can appear translucent when treated with BEVA 371.

D. Synthetic Adhesive Dispersions

1. Elvace 40-704 (KM)

This adhesive, formerly called Elvace 1874 and manufactured by the DuPont company, is now manufactured by Reichold Chemicals, Inc. Dover, Delaware (see bibliography: Abbey Newsletter). It is an internally plasticized ethylene vinyl acetate copolymer dispersion, and is distributed as Vinamul 3252 in Great Britain. The material has shown excellent aging properties (see bibliography: Baer et al and Howells et al). When first diluted with water, Elvace can subsequently be further diluted with ethanol. The solution should be stirred

frequently during use. Pre-wetting of the area to be consolidated with ethanol aids the penetration of the adhesive. Elvace is particularly effective as a consolidant for matte, gouache films which are severely cupped and flaking. In dilute solutions the adhesive is still quite strong and tends not to leave a shiny surface deposit when carefully applied (if necessary, one can chase excess adhesive from the paint film surface with acetone). If applied by brush in a controlled manner, an Elvace solution can successfully relax cupped water-based paint without harm to the medium. Alternatively, the dried adhesive is heat-sensitive and a tacking iron can be used to set down cupped paint, using a silicone paper interleaf.

2. Rhoplex AC-234

Rhoplex AC -234 is an acrylic resin copolymer dispersion made by the Rohm and Haas company. AC-234 has replaced Plexitol 500, a similar material, in the formulation of Library of Congress Heat-Set tissue. A solution of Rhoplex AC-234, water and acetone has been used successfully as a consolidant by paper conservators. The consolidant is prepared by mixing two separate solutions: Solution A is made of 20 ml Rhoplex mixed with 20 ml water. Solution B is composed of 10 ml water mixed with 20 ml acetone. Equal amounts of solutions A and B are mixed together to make the consolidating solution. The components must be mixed in this way or the resin will coagulate and the solution will be stringy and unusable.

The Rhoplex mixture is usually applied by brush locally and has the desirable qualities of having good tack and being transparent when dry. AC 234 yields a shiny, flexible film upon drying. The solution has good flow properties and the water component helps to soften and relax some paint films. Some conservators like to use it for setting down flakes of paint, in particular. The consolidant is fed under the flake or into the cracked paint until it is no longer wicked into the surface. The dried adhesive is heat sensitive, and if necessary a tacking iron can be employed to assist in setting down paint. It is described by users as successful on shiny surfaces, like some acrylic paints, especially if the consolidation problem involves an unstable heavy impasto. Other conservators have used the consolidant on surfaces such as glossy watercolors and ivory miniatures, with success.

Caveats: The adhesive remains heat-sensitive and will swell with water. It is also a fairly soft and remains slightly tacky at room temperature and could collect dust if left on the surface of an object. The solution as described above is fairly concentrated and does not go through a paint film if applied full strength to the surface with a brush. Residual adhesive on the surface is difficult to chase with solvent. If sprayed, the solution can clog up an airbrush very easily as the addition of acetone solvent quickly evaporates.

23.3.2 Water or solvent as a regenerative agent

It is sometimes unnecessary to apply an actual glue or resin to unstable media. Reactivation of the existing binder can be accomplished by the addition of water or the correct solvent in the appropriate amount. For example, flaked or cupped media which has a protein binder such as gelatin can be relaxed or even reformed with the application of warm or hot water to the cracks. If the object is not subjected to conditions of low relative humidity, i.e. it will be maintained in a stable environment, this treatment can act as a sufficient consolidant. Application of warm water, simple humidification of the object in a chamber, or application of steam can reactivate gum or glycerin binders as well. The technique will not necessarily suffice as a consolidant if the object needs further aqueous treatment.

Likewise a synthetic pigment which has undergone a change in stability or appearance can sometimes be returned to its original color or state by the application of a slow-evaporating

solvent. Some types of blanched varnishes in watercolor paintings can be returned to transparency by applying a slow evaporating alcohol, or by exposing the object to a solvent vapor chamber. Blanched, slow drying printing ink on 20th century prints (lithographs and serigraphs, especially) can be reformed sometimes with petroleum based solvents. Testing a very small area under magnification is necessary before performing an overall treatment. **Caution:** 'Sinking' of the treated pigment can occur (the color can come through to the back of the paper).

23.3.3 Facing materials

Various materials have been used in combination with Japanese paper or lightweight tissue to support crumbling or fractured media during treatment. The most important factor to consider before applying a facing is whether it can be successfully removed. The simplest facing is a thin mylar support (not attached with adhesive at all but simply by electrostatic cling) in a water bath. For more damaged objects solvent-soluble adhesives can be used to attach Japanese paper over broken areas of paper and media (such as fractured maps) before immersion in water. Adhesives such as cellulose acetate, Lamatec or Rhoplex have been used successfully for facings. (see Bibliography: Rodgers). For example these sorts of facings will prevent the paper pieces from scattering into the water bath after an enzyme digestible or water soluble adhesive is released. If the adhesive to be removed is tested and found to be a protein or starch, then the use of a specific enzyme will enable using a facing with the other adhesive (note: crude enzyme will not apply here).

23.3.4 Matting agents

1. Fumed silica
Very fine, inert powder composed of silicone dioxide which can be added to solutions of some consolidants to lessen their shine.
2. Alcohol or other solvents
Applied to an area after consolidating can disperse adhesive, or create a capillary pull to deposit more adhesive into the paint film and reduce slight surface deposit or shine.

23.3.5 Equipment

1. Spray tools
 - A. Airbrush
 - B. Airbrush cleaner, such as ultrasonic cleaning tank
 - C. Airless spray gun
 - D. Crown Spra-tools, chromatography sprayers
2. Brushes (Japanese/western/synthetic/natural)
3. Surgical tools: Spud-eye Dix (eye surgeon's tool available through Arista supplies NY) for tapping down paint flakes. Bone folder or spatula or dental tools for this also.
4. Hot plates and chemical glassware
5. Binocular microscope, Optivisor magnifier.
6. Suction table or fritted glass bead disk.
7. Fumehood

8. Table easel to use for upright spraying in fumehood.
9. Humidity chamber.
10. Tacking iron. e.g. Ademco tacking iron with variously sized heads for use with heat-activated adhesives to set down badly cupped or flaking paint. Use with small strips of silicone release paper.

23.4 TREATMENT VARIATIONS:

A. Suggestions from practising conservators:

1. Hydroxypropyl cellulose:
 - a. Used occasionally for consolidation of powdering material that isn't to be washed. (TK)
 - b. Klucel G in ethanol used successfully as a fixative for thick gouache in order to stabilize sensitive colors on a French 18th century large historical print, before float washing. The fixative enabled the conservator to float wash individual pieces of the multi-panel print with no harmful effect other than temporary swelling of the gouache. (FH, France)
2. B-72
 - a. Occasionally used as a spray consolidant for wallpaper if it is to be washed, just as a safeguard since washing of wallpaper is generally limited. Is not removed afterwards as it is not detectable on the surface, if applied correctly. (TK)
 - b. Used as a local and overall consolidant for the treatment of Covarrubias drawings as reported in the bibliography: Couch, R. Book and Paper Annual 1985.
3. Methyl cellulose
 - a. Process Materials Methyl Cellulose Paste Powder
Process Materials Methylcellulose Paste Powder was found very useful for local consolidation of water-based paint (i.e. gouache, watercolor, Indian miniature opaque watercolor) and pastels, which are not to be washed. A thin syrup-like aqueous solution of methylcellulose is diluted with ethanol to the required consistency. The ethanol serves as a wetting agent, enhancing penetration and allowing for quick surface evaporation, and helps prevent darkening and shininess. Just underneath the dried surface, the methylcellulose remains damp, acting like a subtle poultice, allowing the paint to swell and the binder to reform. This aspect may allow the paint to relax in its original configuration with only a little manipulation of a fine brush. Slight manipulation with a tool such as a fine blunt needle may aid flattening of a distorted flake while the paint is in its slightly damp softened state. For a complex painting with a number of pigments, an array of different concentrations of the consolidant is necessary. (Note: cleaning the brush in ethanol after each application of consolidant yields best results). Addition of ethanol to the consolidation solution in larger concentrations enables treatment of even generally water-soluble paint. (DT and FZ)
 - b. Had success using repeated, air-brush applied coats of 0.5%-1.0% methyl cellulose to secure heavily applied gouache layers to original newspaper support (work by a modern Australian artist). The consolidation treatment penetrated the paint well and caused little visual change to the media which included whites. (JS).

4. Elvace

When isolated, heavy, loose flakes of matte paint do not respond to any other consolidant the following formula has been used: Elvace diluted with water to skim milk is further diluted with ethanol. A very small amount of quite dilute solution applied to a loose flake of paint yields a strong bond without shine. A single application gives the best results (Michelle Gewirtz developed this technique as a possibility for thick, badly flaking, poster paint using Jade 405). This has also been used for holding down very strongly cupping paint. The consolidant is applied just after the cupped flake has been relaxed using water and ethanol or methylcellulose in ethanol. The technique has been used when all else fails and immediate paint loss is the alternative. Caution must be exercised in application: excess consolidant may not be diminished. This is not a reversible technique. (DT)

5. Cellulose acetate

- a. Cellulose Acetate 911 from the Celanese company, is used by the National Gallery in ethyl acetate solvent for holding down flakes of paint. Used successfully on a Gorky drawing done in poster paint/gouache and a Hechel portrait also done in poster paint/gouache.
- c. Cellulose Acetate (Kodak #4655 viscosity 46 +/- 6 sec.; 39% acetylation) in MEK is an almost universal consolidant for 'lean' paint films (gouache type) when applied using a fine brush into and around the flaking paint. Cellulose acetate as well as other consolidants is found to be more satisfactorily applied when used in conjunction with a suction disk under the stereo microscope.

When applying Cellulose acetate to paint films on thick papers or paperboard (where suction is useless) residual surface adhesive is flushed into the absorbent paint flakes with local applications of acetone or MEK. Fluids and adhesives will be pulled into porous media by capillary action. This effect is similar to that created by using the suction table, but smaller in magnitude. Application of just the right amount of adhesive followed by delicate flushing with solvent must be done with dexterity, careful judgement and precision timing in order to obtain the desired results with a particular media. If the treatment is skilfully performed within the limits of the composite system of the paper, paint film, solvent and consolidant, then the surface of the consolidated film will be free of visible adhesive, unchanged in appearance yet well attached to the paint and paper interface. (TJV)

6. Ethulose

National Gallery conservators have used Ethulose in water, diluted with alcohol for consolidation of unstable matte paint films. Ethulose has also been used successfully by KK for this problem.

7. Parchment size

- a. Two French and Flemish 15th century vellum Books of Hours from Library of Congress were successfully consolidated using parchment size diluted with water and isopropyl alcohol (solvent was 1:2 water:alcohol, solution was 1:4 parchment size:solvent) applied by brush using microscope as magnifying aid. A good range of colors was represented in the treatment. The parchment size both consolidated these and remained invisible. Flesh tones which were composed of multi-layered paint were not treated with the consolidant. (JM, PS)

- b. Parchment size was used successfully as a spray consolidant on a complex 20th century gouache with both dark and light unstable pigments. Humidification of the object aided in the penetration of the consolidant. (FP)

8. Polyvinyl acetate AYAC

- a. 19th century White House Zuber wallpaper samples were consolidated by spraying locally with PVA-AYAC 2% in alcohol, further diluted by 1/3 with acetone. Teflon spatulas were used to help smooth loose areas after consolidant was applied. (EKS, AS, NP)
- b. PVA AYAC is used as a temporary consolidant (similar to a facing) and as a consolidant for oil paint on paper or paper board. (TJV)

B. Penetration and aging Studies of consolidants:

A preliminary comparative study of several consolidants was made in a student research project (by YS) for the Winterthur Conservation Training Program. The study focused on penetration and aging characteristics of the following consolidants: Conservation Materials PVA-AYAC, Dow Methocel, Process Materials methyl cellulose paste powder, Hercules Klucel G, and Fisher G-5 sheet gelatin (white silver label). The Process Materials methylcellulose as well as gelatin penetrated through three layers of a prepared paint sample into the supporting paper layer. Dow Methocel penetrated through the first two layers of paint. Klucel G showed poor penetration ability. PVA-AYAC in ethanol penetrated well both downward and laterally. Samples were artificially aged and visual evidence showed that the PVA-AYAC sample seemed to yellow. The sample consolidated with gelatin showed severe paint losses after aging. The difference between consolidants was not conclusively proven using scientific methods. More work is necessary to confirm this. (YS)

C. Improving penetration of consolidants:

- 1. Overall humidification of an object before fixing overall should be considered as well as the use of the suction table to aid in the penetration of consolidant. Humidification aids in the receptivity of the medium and paper to the glue which is newly introduced. Humidification also relaxes any distortions in paint or paper which are present. (KK)

The aid of humidification in penetration of the adhesive is reflected in unpublished tests done by the Library of Congress which indicate topically applied adhesives (Ethulose, parchment size, Plexitol 500, and B-72) are consistently less visible when applied to a humidified sample than a dry sample of the same porous paint film. (FP)

- 2. The suction table and small fritted glass suction disc can be very useful in aiding the conservator in the application of consolidant. Severely cupped or fragile paint on an object can be held in place with suction during consolidation. Also, suction will pull the consolidant deeper into the paint paper composite. (TJV)

D. Overall consolidation of normally friable media (e.g. pencil, chalk, pastel)

Pastel fixatives were studied by Francoise Flieder, who came up with two materials which successfully consolidated pastel mock-ups with the least visual effect on the material. The two materials are 1% Klucel G in ethanol:water 50:50, and 0.5% Elvamide 8061 (a copolymer of polyamide 6/6 6/10 from Dupont) in ethanol:water 90:10. Both solutions darkened the pastel mock-ups overall slightly. Other solvents tended to react with organic colorants in pastels, or produced migration of colors to the back of the test object. (See bibliography: Flieder).

23.5 Special Considerations

1. When fixing signature ink or sensitive media such as hand-coloring on maps or prints, inscriptions, or collection stamps to prepare artifact for water washing or other treatment the knowledge and study of inks and pigments used in different periods of history is important, in order for the conservator to be prepared for susceptibility of particular colors (e.g. gamboge or verdigris) to various solvents used in treatments. (TK)
2. Consistency between original binder and introduced consolidant should be carefully considered. The aspect of hygroscopicity should be examined for long-term compatibility between the two. This relationship has not been studied sufficiently. Future stresses may be introduced to an organic object or paint layer which is fixed or consolidated with a synthetic binder. (KK)

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