16. Washing

Washing is the use of water, occasionally in combination with other solvents, enzymes, surfactants, etc., to treat a paper artifact. The washing procedure may be used independently or prior to other treatments, such as alkalization and bleaching. Washing is also used as a follow-up treatment step to flush residual chemical agents used to remove stains, adhesives, etc. from paper.

16.1 Purpose

The purpose of washing paper is to remove or reduce soluble deterioration products such as acidic or discolored components, to make the paper more flexible, to reactivate fiber-to-fiber bonding, to remove attachments and/or adhesive residues, to flush treatment chemicals or other impurities from the paper, and in some instances, to reactivate the binder in media. Most papers show an increase in tear strength and folding endurance after washing (Wilson et al. 1981).

16.2 Factors to Consider

Washing is an irreversible treatment step and must be carefully considered. During washing and subsequent drying every component of the piece (specifically paper fibers, sizes, fillers, dyes, all media, and binders) will be affected and altered by interaction with water and/or organic solvents and auxiliary washing agents. In making the decision whether or not to wash, one should take into account the potential benefit to the artifact versus the risk of unwanted alteration or damage to the paper or media. The probability of actual removal of soluble acidic and/or discolored components must also be considered along with the possible need to add new components to restore the appropriate texture, appearance, and stability of the paper and/or media. For example, resizing after washing may be considered necessary for some materials. (See AIC/BPG/PCC 7. **Sizing/Resizing** 1988.)

In choosing to wash, the following philosophy can serve as a useful guide. Although written to address the treatment of works of art on paper, the approach is applicable to all types of paper artifacts.

"Every moisture-sensitive [paper artifact] has a threshold of tolerance for moisture. This may be assessed to a large extent before treatment, but the work's actual reaction to moisture is always unknown until treatment begins. Thus, moisture must be introduced to sensitive works controllably and in a limited quantity during treatment. The success of the treatment depends on using this limited moisture efficiently to achieve the greatest effect" (Keyes in press).

16.2.1 Philosophical Issues

A. Washing treatments may have significant effects on the connoisseurship of paper artifacts, influencing aesthetic and historic evaluation or interpretation. For example, washing may

alter subtle but important characteristics of paper and media, such as paper embossing or burnishing and the tonal balance between paper and media, that are valued and appreciated by connoisseurs of graphic arts. Washing may also change or remove important historic or forensic evidence from papers. Sometimes treatment may be undesirable. Treatment decisions should be arrived at jointly by the conservator and custodian of the object.

B. The extent and location of disfigurement or damage must be considered in deciding when and how to wash. For example, if the margins of a print are stained but the plate area is pristine and the print has not been previously treated, then a decision may be made to leave the print untreated or to consider only local stain reduction.

16.2.2 **Results of Spot Testing**
(See AIC/BPG/PCC **10. Spot Tests** 1990.)

A. Before washing, the conservator should perform spot tests to determine the potential efficacy of treatment and the sensitivities of paper and media. Results are considered with the understanding that spot testing gives only an approximate indication of an artifact's behavior in treatment.

B. One should test all components of an artifact, on both its front and back. Of primary concern in washing are absorbency of the paper and potential solubility/sensitivity of media, fillers, sizing, etc. In testing, the degree and duration of wetting should, as much as possible, reflect the planned washing treatment.

C. Spot testing should be performed with all solutions considered for use in a washing treatment. These include water (at ambient and warmer temperatures), alkaline water, water/solvent mixtures, etc.

16.2.3 **Choice of Washing Method and Washing Solutions**
(See **16.4 Treatment Variations** for specific indications/contraindications of various methods.)

A. Washing methods currently used vary in relative effectiveness, degree of control, and "aggressiveness." For each proposed washing treatment a method must be chosen which is appropriate to the nature of the artifact (its physical make-up and vulnerabilities) and its condition problems. Along with the choice of washing method, modifications of washing solutions should be considered, such as raising pH or temperature of solutions to

enhance removal of degradation products, and using surface-active agents to enhance overall even wetting of the paper.

B. The presence of stable design media on sturdy paper will generally permit complete immersion in a bath, in which large volumes of water can solubilize and dilute discoloration and degradation products. Somewhat sensitive media may tolerate water baths with significant proportions of ethanol or other solvents which reduce media solubility.

C. The presence of more vulnerable media may lead to the choice of washing methods in which the media are not in contact with, or covered by, water. Examples of such methods include local treatments, float washing, felt or blotter washing, Gore-Tex washing, and suction table washing.

D. Where the paper support is particularly fragile, torn, or broken, a washing method that gives continuous overall support and prevents shifting of pieces or multiple breaks is preferred, such as screen washing, blotter or felt washing, washing on a solid support, suction table washing, or brush wetting.

E. Note that some apparently less rigorous washing methods actually call into play powerful forces such as the surface tension of water (e.g., in screen washing) or capillary action (e.g., suction table, blotter or felt washing). Capillary action can also move soluble media.

16.2.4 Physical or Chemical Sensitivity of Paper

A. Alteration of Visual, Tactile, and Dimensional Characteristics of Paper

Washing will alter in varying degrees a paper's appearance (color, tone, sheen, opacity, surface, etc.), tactile qualities (making paper softer, thicker, more or less flexible, etc.), and dimensions.

1. Shifts in paper tone will result as discoloration is removed in bathing. Usually desirable, brightening of the paper can dramatically increase or decrease image contrast. Such color and contrast shifts must be considered prior to washing because of its vital relationship to the overall appearance of the object, especially fine artwork.(HK)

2. Shifts in paper tone can be caused by the pH of the washing solution. In alkaline solutions, ground wood papers may darken and become "cooler" in tone. Washing in

alkaline solutions may, however, have the beneficial result of lightening most other papers. Paper dyes may be affected by changing pH or by the presence of metal ions in the wash solution.

3. Colored papers should be carefully examined and, if possible, tested to determine the presence of dyes or artist-applied tones or ground layers which are soluble in the washing solution. White papers may also contain colored or fluorescent dyes (optical brighteners) which can be solubilized and extracted during washing or leave tidelines through interaction with sizing materials, etc.

4. Fillers such as clay, titanium dioxide, calcium sulfate (gypsum), and calcium carbonate can be affected or lost during water washing which may render the paper more transparent.

5. Transparentized papers may loose translucency if bathed in solvent and/or water baths.

6. Washing can affect physical characteristics acquired during the printing process such as platemarks, sheen from intaglio plates or lithographic stones and plates, letter press, printers' creases from roller and platen pressure, as well as embossed designs. Washing can sometimes diminish embossing or platemarks, but conversely, may revive or increase them. Judicious drying and flattening methods can serve to retain printing marks enhanced by washing. Gampi papers and the fine, shiny tissue used in nineteenth century wood engravings seem especially susceptible to losing surface burnishing or sheen.(JW) Drawings, made with a sharp instrument, even a reed pen, can have an impression in the paper that could be lost in washing.(PDP) Papermakers' creases may be opened in washing which can be disfiguring to a print.(JW) Use caution to preserve such characteristics. Appropriate techniques of drying and flattening will help control the final appearance of the washed paper.

6. Other possible effects of water washing include blistering and delaminating a paper sheet, especially mold-damaged paper. Washing can result in separation of composite works such as collages and chine collé prints.

7. Paper can expand in all directions during washing. Expansion is usually different in each axis and subsequent

shrinkage may not return the sheet to its original size. Choice of drying method to minimize degree of contraction should be considered prior to treatment (see 16.2.7). For some papers expansion can be controlled, to an extent, using the suction table.(LS)

8. Very thick, contemporary papers prepared from paper pulp that is cast and pressed in print or papermaking workshops can expand enormously (like a sponge) when dampened.(RP)

9. If dried under pressure, rough-textured papers may become more smooth-surfaced after washing. Smooth-surfaced papers may become rougher if air-dried.

B. Alteration in Sized or Surface-Coated Papers

Common types of original sizing and coating materials are gelatin, alum-hardened gelatin, starch, gums, casein, wax, clay, alum-rosin, cellulose ethers, soya protein, and cellulose reactive sizes such as alkylketene dimer (Aquapel, Hercon 40). (See AIC/BPG/PCC 17. Sizing/Resizing 1988.)

1. Resistance of the paper to wetting should be considered in selecting appropriate washing materials and techniques. Ability of the paper to wet evenly is necessary to prevent the development of tidelines and to achieve thorough washing. For example, soft, absorbent, blotter-like paper used for steel engravings is very susceptible to forming tidelines on immersion, if not premoistened.(RP) It is possible that the regeneration of original sizing after repeated float washing and drying can result in the development of tidelines and other undesirable effects (Cohn 1982). Internal sizes such as alum-rosin and modern dimer sizes may be water-resistant.

2. Sizes such as gelatin, starch, polyvinyl alcohol, or cellulose ethers can theoretically be solubilized by water washing. A discolored gelatin (glue) size is most readily removed by washing in warmer water (approximately 40°C [100°F]). Alkaline wash water can saponify the fat content of a glue size, thereby rendering it more soluble. Washing such sized papers with water can alter the surface appearance of the paper.

3. Alum-rosin size is inherently acidic. Free aluminum ions, present from the breakdown of alum, catalyze the hydrolysis of paper fibers. Water washing can be helpful in flushing

acids, aluminum ions, and other deterioration products from alum-rosin sized paper. It should be noted that alkaline solutions may enhance the removal of rosin sizing. (See AIC/BPG/PCC **17. Sizing/Resizing** 1988.)

4. Clay-coated or filled papers may lose clay and/or surface sheen during water washing. Glazed papers may also lose sheen. Various grounds on paper are susceptible to water damage including the starch or sugar washes used in Indian and Persian miniature paintings to achieve a "polished" surface.(JW) Not only is alteration of the paper surface possible, but the design layer could be threatened. Clay coating on paper becomes tacky when wet. If these coated papers are allowed to dry in contact with each other or other absorbent surfaces the coatings may fuse. Clay-coated paper is susceptible to staining when wet.

16.2.5 **Physical or Chemical Sensitivity of Media**
(Including pigment, dye, and binder.) (See AIC/BPG/PCC **3. Media Problems** 1985.) The following are classes of media with a selection of specific examples to illustrate potential treatment hazards.

A. Solubility or Softening of Media/Breakdown of Binder

1. Inherent Solubility or Treatment Hazard

a. Water-soluble gums such as gum arabic or tragacanth are used as binder in certain media (watercolors, fraktur, Japanese woodcuts, fabricated chalks, pastels, etc.) or as coatings. Gums may be present applied either locally or overall. Gums may also be present under a varnish coating, applied to prevent penetration of the varnish into the paper.

b. Iron gall inks are water-soluble to different degrees: copybook iron gall inks made with very little binder are especially soluble because they were formulated to create an offset copy when pressed damp against a letter book page. Secondary colorants, used in many inks, may be soluble.(KN) Because the acidity of iron gall ink degrades paper, the majority of inks of this type will appear to test soluble in water. What is observed as bleeding ink, however, may instead be movement of paper degradation products. If thorough testing indicates that only paper degradation products dissolve, then this discoloration will disperse in a water bath and not feather into the paper.(LS) An

important indication of the potential solubility of iron gall ink is the extent of any embrittlement or loss of paper within the strokes. Thick, crusty applications are often quite easily soluble.(RP)

Bistre and sepia can also be water-soluble. Some recipes for sepia involve the use of a gum binder (Watrous 1957).

c. The colored inks of Japanese woodblock prints are water-soluble. Eighteenth-century Oriental dye colorants are extremely water-soluble. The most vulnerable are the blue aigami (indigo) and the pink beni (safflower) which are often used together to make purple. Due to their extreme light sensitivity, these colors are typically found on Japanese prints in their faded color, light brown, which is still exceedingly water-sensitive. The bright reds of the Meiji period prints (1868 on) are also exceedingly water-sensitive.

d. Media with glue binders such as tempera and metal-point grounds are water-soluble. Japanese calligraphy ink (sumi) is water-soluble. Indian and Chinese inks, composed of lamp black in fish glue, are very water-soluble. Modern India ink is lamp black in a shellac binder and, while stable in water, is very sensitive to alcohol.

e. Printing inks with oil binder, both typographic and plate, colored and black, are primarily sensitive to alkaline solutions. As the pH of a solution is increased, so too is the risk of solubilizing printing inks, although properly made inks are generally affected only by high pH levels and/or prolonged immersion.(RP) Some carbon ink printers' recipes include water-soluble elements such as soaps and molasses (usually recipes of the nineteenth century or earlier). Molasses was generally added as a bulking agent to increase viscosity, not to aid cleanup.(RP) Other ink additives such as Prussian blue pigment may be altered in alkaline solutions.(PDH) Blue dyes may also be present in modern printer's ink and may be sensitive to alcohol or acetone.(KN)

f. Colored inks and washes, both traditional and modern, or components thereof, can be water-soluble.

Soluble Western dye colorants include gamboge which is soluble in water and alcohols. It was commonly mixed with blue to create the green used in hand-coloring of nineteenth-century lithographs. Wet treatment can leave areas, originally green, blue instead. Nearly all colored drawing inks are clear solutions of dyes. Waterproofing of water-soluble colored inks is usually accomplished with a solution of borax and shellac. Waterproof colored inks are, therefore, alcohol-soluble (Waters 1940). Acrylic emulsion inks can absorb water which may cause a shift in tone.

g. Dye such as aniline dyes in inks, indelible copy pencils, colored pencils, typewriter machine ribbons, etc. are frequently soluble in water and solvents. Dye additives commonly have a different and more sensitive solubility profile than the other components of the medium. Copy pencils made in the U.S. and Europe since the end of the nineteenth century incorporated aniline dyes in the graphite. The dye bleeds and turns purple on wetting. Sometimes a faint halo of color can be seen on the initial downstrokes as the pencil points were licked by the user to get a darker color (Fairbrass 1984; Mitchell 1937).

h. Dye mixtures used for inks in ballpoint, fountain, and felt tip pens are often, to some degree, soluble in water as well as organic solvents. Each dye element may have a different degree of solubility. Oil or glycol-based ballpoint pen inks can contain up to 25% dye(s), in addition to 25% resins and 50% volatile components. Very recent ballpoint pen ink is quite soluble and becomes less so as it ages (Cantu 1990).

i. Natural white chalk (calcite, calcium carbonate) can be very water sensitive in acidic water which results when an acidic paper is wetted.

Whites and "body color" in drawings are almost always diminished by water washing. Three factors may be involved: acid consumption of alkaline pigments when water solubilizes acids in the sheet; compacting of friable medium and pigment; or drawing of discoloration from the sheet by poultice action into the white pigment. Simple tests on clean and artificially-stained papers showed modern tube and

pan watercolors and chalk whites more diminished by washing on the vacuum suction table than by float washing, but they became more yellow with float washing. Ethanol-water sprays on a blotter with very light suction may show less damage, but still the whites seem thinner.(JW)

j. Collectors marks or collector stamps are usually not soluble. Artists' seals can be very soluble, e.g., Degas' atelier sales stamps, Mary Cassat's blue *M*, Felix Buhot's owl stamp are all notoriously water-sensitive.(JW) Early twentieth century red printing inks, such as those employed in lithography have been observed to bleed after exposure to water for fifteen minutes or more.(LS)

B. Other Physical, Chemical, and Mechanical Alterations

1. Certain media are friable and susceptible to mechanical damage (manifested by design loss or color shifts from compacting of media and movement of pigments across and into paper) during washing or afterwards, while the sheet is still wet. Media are more likely to be susceptible to mechanical damage if the paper support is very smooth and has little tooth. This is because the media may not be well bound to or settled into the paper fibers.(LS) Such media include pastel, chalk, and charcoal.

   a. Some pastels may shift, be compacted, or suffer permanent color shifts when wetted. Unfixed pastels should only be subjected to minimal use of moisture (e.g., mist from an ultrasonic humidifier or spray wetting).

   b. Unfixed charcoal should only be subjected to minimum use of moisture (e.g., spray-wetting or mist from an ultrasonic humidifier).

   c. Natural red chalks are particularly susceptible to color shifts due to compacting of media.

   d. Pencils: Graphite pencil generally shows little or no alteration after immersion. A colored pencil image could have water, solvent, or pH sensitive components, depending on its composition.

e. Printing inks.

1) During aqueous immersion printing inks, especially intaglio, can become soft or friable. Ink may offset from the wet print onto blotters, therefore initial air drying face up is advised.(KN) Minimal rewetting by spray of ultrasonic mist to relax paper support and allowing the object to dry between polyester web, blotters, felts, under glass and light weight is often possible.

2) Saponification of printing inks can occur through interaction of the oils in the binders with alkaline solutions. Inks which are initially stable may become less stable after interaction with such agents. It has been observed that after alkalization treatment and drying, particularly with magnesium bicarbonate solutions, the pH of the dried paper tests considerably higher than that of the solution used; the media may become vulnerable during subsequent rewetting. Printer's ink may become friable or powder off. Tideline stains may occur around areas that are locally rewetted.(PDH)

f. Dyes, Pigments, Glazes, and Binders

1) pH induced color shifts of dyes and pigments can occur under acid or alkaline wash conditions. Prussian blue and Turnbull's blue of cyanotypes and blueprints decolorize under alkaline conditions. Gamboge yellow turns orange at a high pH.(KN) Some Japanese pinks turn yellow in acid conditions. In blotter washing with hot water, buffered blotters may release enough calcium carbonate to damage Prussian blue.(JW) It is possible to destroy ultramarine watercolor merely by dampening the paper or float washing if this pigment occurs in areas that have become particularly acidic with the passage of time (e.g., within the area of the vertical brown stains caused by or related to the openings between wooden slatted backings in frames).(RP)

2) Water baths can cause blanching of resins, gums, or oil-based media, e.g., resin highlighting or

modelling on watercolors, hand-colored prints, and chromolithographs, and/or resin or oil varnish-coated paper.

3) Glossy gum modelling or highlighting can become matte with very little moisture (e.g., modelling on Currier and Ives or Audubon prints). Sometimes this can be prevented by spray washing on the vacuum suction table.(JW)

4) Heavily-applied resinous or oil-based media are often susceptible to cracking or splitting when paper is wet, because of the different capacity of the paper support and the media to expand when wet.

5) Color shifts may occur when wetting media with soluble binders such as pastel or colored pencil.

6) Alkaline solutions swell paper, making it more absorbent and softer. Because of this swelling otherwise non-water-soluble media, such as inks, can be drawn into paper's structure and/or become visible on the reverse of the sheet.(LS)

16.2.6 Potential Problems in Handling Wet Paper

A. Physical Considerations

1. Fragility/brittleness of paper.

2. Ability of weak or short-fibered paper to support its own weight when wet.

3. Ability of weak paper, when wet, to support the weight of heavy deposits of iron gall ink (e.g., a heavy writing stroke or filled-in area). The iron gall ink may have embrittled the paper in these areas enough to cause severe cracking and/or loss of paper support upon wetting.

4. Oversized paper.

5. Presence of tears, breaks, loose fragments, skinned areas, creases, mold-affected areas, and other damages which weaken the paper or may require special handling.

6. Areas of previous repairs and/or treatment(s) can expand differently from areas not treated or repaired, causing tension and possible damage at their juncture.

7. Number of items being treated at one time (mass treatments). One may observe some media movement from capillary action which may not ordinarily occur during single item treatments.

B. Damage During Washing

Damages which can occur during washing include abrasions, skinning, pilling, alteration in surface texture; fractures or loss from stress caused by uneven expansion when wetting composite structures (i.e., collages, previously repaired paper, etc.); tearing; wrinkling; planar distortions; dimensional distortions; and staining from uneven wetting or allowing some areas to dry in the course of washing.

16.2.7 Choice of Drying and Flattening Method

Consider which drying and flattening technique to use as part of the washing procedure since the ultimate success of the treatment depends on the choices made. Sometimes the special problems of flattening tracing paper, gampi, oil on paper, very thick acrylic media, etc. may dissuade the conservator from washing the item at all. Similarly, prints on which most of the paper surface is covered with ink may not be candidates for washing because of the potential for distortions in the paper due to uneven expansion during humidification or washing. Because these distortions may be exceedingly difficult or impossible to remove on drying and flattening, wet treatments may not be appropriate for such items.(PDP)

The drying and flattening method chosen can affect the appearance of both paper and media. Too rapid or nonuniform drying can result in cockling, "springing" or separation of tear edges, or splitting and tearing of fragile or very expansive papers. Slow drying can reduce stress on paper. Soluble components not completely removed during washing may redeposit and dry in unwanted ways, i.e., at the edges of the sheet, around losses, or in tidelines that reflect patterns of wetting out or insolubility caused by adhesive residues, previous treatment, undissolved sizing, etc. Note that solubilized discoloration moves in the direction of most rapid evaporation. Media softened by water treatment may offset onto interleaving material or other objects. In suction table drying, the object's exposed surface dries first, so curling can occur if the object is dried completely on the suction table.

Interleaving sheets are used with most drying techniques to enhance drying and flattening, and/or to protect the media. Examples of

interleaving materials are polyester web, lens tissue, Japanese tissue and Gore-Tex.

Drying Methods

A. Air Drying, completely or partially, followed by methods below, alone or in combination.

B. Between blotters and under glass and weight.

C. Between blotters shaped to protect any embossing or relief element and weighted between, on, or under felts.

D. Against mat board or other smooth-surfaced material to protect or regenerate a burnished or polished surface.

E. Between felts, with or without blotters, glass, and weight.

F. Initially on the suction table until "surface" dried and then transferring to another drying/flattening process. Use of the suction table in a "clean room" or within a chamber with air-filtering capability prevents dirt and other airborne pollutants from being embedded in the paper during lengthy drying. A Gore-Tex barrier placed over the object while drying also has air-filtering capabilities.(TBW)

G. Stretch drying with edges weighted, with edges adhered to a Japanese drying panel, or attached by various means to another surface or strainer frame (Dutch method).

H. In a press between interleaving felts or blotters.

I. Friction drying between interleaving layers of Japanese paper (Fletcher and Walsh 1979; Keyes 1984).

J. Between felted Gore-Tex.(RP)

16.3 Materials and Equipment

16.3.1 Water

A. Quality/Purity

1. Some conservators choose to use **tap water** in treatment. Chlorine, which is routinely added to tap water to inhibit microorganisms, can be assumed to have a mild bleaching action and a detrimental effect on paper. Also detrimental are metallic contaminants such as iron and copper from

water pipes. Tap water may vary considerably from season to season and its acceptability for use in treatment will vary. Tap water is not acceptable if it has a noticeable odor of chlorine or other substances, it is turbid or discolored, or it leaves copper or rust stains or particles in sinks.

Prior to choosing tap water for treatment purposes, the water should be analyzed. It may be possible to have well water analyzed by a home extension agent. Analyze city tap water regularly or attempt to obtain regular reports from city water treatment facility.

2. There are a wide variety of **filter types**. Filters are designed for particular purposes which may not always suit conservator's needs. The two chief filters of use to paper conservators are particulate filters and activated charcoal filters. Particulate filters, made with different pore sizes, specified in microns, remove dirt and other solid particles. A coarse particulate filter is generally the first step in a purification system. Finer particulate filters may be incorporated as a final step. According to product literature, a 0.2 micron filter will retain all bacteria. Activated charcoal filters remove chlorine and hydrocarbons. Some combination filters have a particulate filter exterior and an activated charcoal center.

   Once water has passed through activated charcoal, the chlorine is removed and bacteria, fungi, and algae are free to grow. Thus, the location of the charcoal filter bed should be carefully considered. Various measures to prevent microbial contamination of the water include regularly changing all filters (at least every six months), installing a recirculation pump to keep water moving constantly, or installing ultraviolet sterilizing units to kill microorganisms in the water.

3. **Deionized** water is water from which dissolved ions have been removed by passing the water through cationic and anionic ion exchange resins. Deionization columns can produce moderate volumes of purified water. If the maximum flow rate for a particular column is exceeded, the purity of the resultant water will decline. Regular maintenance of the resin beds is necessary. Disposable resin columns often change color to indicate depletion. Refillable columns should be serviced periodically. The conservator should regularly monitor the resistivity of the water, either with a resistivity meter or with indicator lights which show

when resistivity has dropped below a predetermined level, suggesting depletion of the resins.

Deionized water is sometimes called "ion hungry" because it may leach out beneficial ions, such as calcium, from the paper. It can also dissolve ions from piping material, so it should be delivered through inert plastic piping. Deionized water may be modified to reduce the "ion hungry" characteristic by adding desirable ions such as calcium or magnesium carbonates, which also act to raise its pH to neutral or mildly alkaline. The water can be run through a column containing calcium carbonate, such as calcite or marble chips. (Some conservators are concerned that marble chips are often contaminated with iron.) Or calcium or magnesium bicarbonate can be added directly to the bath. (See Tang and Jones 1979.)

4. **Distilled** water is prepared by heating tap water to create steam and collecting the condensation product. Distillation removes all metals, anions, cations, and microorganisms. Fresh distilled water has a neutral pH, but soon dissolves carbon dioxide and becomes slightly acidic. If exposed to airborne contaminants, distilled water can quickly become contaminated with microorganisms. It is considered beneficial to add calcium or magnesium carbonates to modify distilled water in the same way as deionized water. Distillation produces small amounts of water very slowly and uses large amounts of energy.

5. **Reverse osmosis** produces large volumes of roughly purified water by applying pressure to force purer water across a membrane, leaving behind 85-95% of ions and 100% of bacteria and particulates. Gasses and small organic molecules are not removed. The resultant water can then be distilled or deionized for final purification. Reverse osmosis can assure large volumes of purified water for a large laboratory and increase the lifetime of the deionized columns.

6. **Boiling** water will kill microorganisms, however it does not remove dissolved ions or particulates.

7. **Bottled** water may be distilled or deionized water for use in appliances where dissolved ions are undesirable, or alternately, spring or mineral water which is considered more desirable and palatable because of its mineral content. Beneficial ions should be added to distilled or

deionized bottled water if used in treatment. Conservators should check the mineral content of mineral waters, prior to use in treatment. (See Kohler 1984 for analyses of some spring waters.)

B. Water Purification Systems

There are a wide variety of systems available offering different types of purification and different capacities. Disposable deionizing columns and small wall-mounted distillation and deionization units can be ordered directly from scientific supply houses. Labs requiring larger volumes of purified water should consult with several local water purification companies to obtain proposals for larger systems. The cost for maintenance (periodic service calls) should be included in the operating costs of the system.

C. Resistivity Meters, pH Meters, Electrodes, pH Measuring Materials

Conductivity is the inverse of resistivity. Ions dissolved in water make it conduct electricity (i.e., conductive). Water with few ions has low conductivity, or conversely, high resistivity. Water's purity of ions is measured by its resistivity, given in megohms-cm. One megohm-cm resistivity is an easily attained purity. Eighteen megohm-cm resistivity is the highest attainable standard used in many chemistry and analytic labs. (See also AIC/BPG/PCC **10. Spot Tests** 1990, 68-71.)

16.3.2 Wetting Agents/Surfactants

A surface active agent (surfactant) used in small quantities reduces surface tension in a fluid or the interfacial tension between two immiscible fluids, such as oil and water. A wetting agent is usually also a surface active agent which reduces the surface tension of a liquid and therefore increases its adhesion to a solid surface. Improved wettability can be observed visually as a droplet of liquid on a solid surface forms a lower contact angle (Roberts and Etherington 1982; Skeist 1977).

A. Alcohols

Ethanol is less toxic than methanol, iso-propyl alcohol, etc.

B. Surfactants

Commonly used surfactants include Orvus WA (anionic, sodium butylsulfate, Procter and Gamble), Aerosol OT (American Cyanamid), Fotoflo (Kodak), Triton X-100 (nonionic alkylaryl polyether alcohol, Rohm and Haas), Igepal CA 630 (nonionic), Tergitol, Merpol SH, and Lissapol. Soaps and detergents also act as surfactants, allowing aqueous solutions to remove oily dirt.

There is concern that some surfactants may remain in the paper and have deleterious effects, such as attracting dust or reducing paper strength (See Strumfels 1989; MacKay and Smith in press.)

Many conservators take advantage of the surfactant and soil-suspending properties of cellulose ethers in removing adhesive deposits and ingrained grime (Strumfels 1989). Plain solutions of sodium carboxy methyl cellulose or methyl cellulose can be quite effective. Conservators at the Library of Congress use a mixture called Formula D, made of two different viscosity grades of Methocel F-4 and F-50 (hydroxypropyl methyl cellulose 4000 cps and 50 cps) in the proportions 40 to 60 of 1% Methocel F-4 and 1% Methocel F-50 (i.e., 100 ml of 1% Formula D is composed of 40 ml 1% F-4 and 60 ml 1% F-50).(SRA)

16.3.3 Agents for Limiting Access of Water

A. Solvent/water combinations can be used during washing to limit access of water and control the extent of paper swelling. Large proportions of ethanol are often used, as it appears to limit paper swelling and reduce the solubility of some media such as iron gall inks.

B. Fixatives are often used as an interim measure during treatment to allow washing of soluble or sensitive media. For a range of materials most often used and their working characteristics see AIC/BPG/PCC **23. Consolidation/Fixing/Facing** 1988. If fixatives cannot be completely removed after treatment, permanent color change may result.

16.3.4 Enzymes

Enzymes may be used locally or in a water bath to increase the rate of dissolution of adhesives or discolored and/or degraded size. They are especially useful when washing soft papers that are easily abraded.

Commonly used are:

A. α-Amylase for starch adhesives;

B. Protease for protein (animal glue) adhesives;

C. Pancreatin - mixture of enzymes for mixed adhesives.

16.3.5 **Alkaline Solutions**

Alkaline solutions can be used for local treatment prior to an overall bath or added to the wash water to raise the pH (e.g., calcium carbonate, calcium hydroxide, magnesium bicarbonate, or ammonium hydroxide). Some of these agents leave a residual alkaline buffer. (See AIC/BPG/PCC **20. Alkalization and Neutralization** 1985.) There can be a danger of alkaline degradation of paper. A pH of 10 or above is generally considered unsafe. Some conservators recommend cautious, gradual increases in pH of baths from neutral to the desired end point because of the increased swelling of the paper fibers in alkaline solutions and associated effects on media which may result.

16.3.6 **Chelating Agents (KE)**

Chelating or sequestering agents (chele – from the Latin for claw) combine or complex with various metallic ions to inactivate or solubilize them. Use of these agents may be considered when decolorizing metallic stains, when metallic ions are catalyzing the hydrolysis of the cellulose, or when a process such as peroxide or borohydride bleaching is desirable which would be deleteriously effected by the presence of metal ions. Chelating agents are commonly used in the manufacture of paper (Casey 1960, 547). Their use in conservation is relatively rare, however, because of the perceived risk that some of the reagents could remain bound in the paper matrix. It may, therefore, be preferable to apply sequestering agents locally when their use is required.

A. EDTA (salts of ethylene diamine tetraacetic acid). Powder available under various brand names from several manufacturers. May be acidic or alkaline in aqueous solution, depending on cations present.

B. Versene chelating agents (Dow Chemical Company). Versene Fe_3 Specific, a highly alkaline liquid designed to chelate ionic iron, has virtually no complexing activity for the hardness metals.

C. Magnesium and calcium also combine with ionic iron, inhibiting its catalytic activity.

16.3.7 **Sinks/Trays**

A tray or sink is selected to be large enough to allow all materials, including washing supports, to lie flat and accommodate safe handling (2 to 3 inches on all sides is adequate). If the only tray or sink available is considerably larger than the object(s), then corners or glass weights may be used to reduce the size of the working area. Often a white tray is selected for its ability to show any changes in the color of the washing solution and is especially helpful when washing until all discoloration is removed or when monitoring especially water-sensitive

media. By placing a wash tray within a larger tray or sink (filled with circulating hot water) the wash solution can be heated and a constant temperature maintained.

A. Sinks (heated and unheated) made of stainless steel, fiberglass, or polyethylene are available in a range of standard or custom-built sizes through photographic suppliers and plastic fabricators. Drainage is an important factor. Extremely large trays should have plugs. Sinks need a gently sloping bottom for draining.

B. Stainless steel trays.

C. Inert plastic trays should have flat bottoms rather than ridges. Trays may be inverted and tilted as a rigid support for rinsing.

D. Metal trays coated with baked-on enamel (especially good for use with solvents or enzymes).

E. To accommodate oversized items, trays constructed of polyethylene sheeting over a wooden frame are especially useful. Custom-made Mylar trays can be used to line a whole sink and are useful for large objects. Alternatively, large trays can be constructed of wood coated with epoxy resin. These can be built into a work table and covered with a work surface when not in use.(MKW)

F. Clear trays of polyester film (Mylar, 4 to 5 mils), made by folding up four sides and stapling the corners, are convenient for small items, but adequate for objects up to 10" x 14" in size. Even larger trays are possible when the outside walls and corners are supported by long strips of corrugated board. The strips bend cleanly around the corners, thus making a very stable large tray. Especially useful as disposable trays for treatments leaving residues or needing numerous baths. These are also useful in conjunction with a heating pad to maintain warm baths for enzyme treatments.(PDP)

G. Water-filled beakers or heavy L-shaped corners, made of stainless steel or enamel-covered iron can be placed at four corners of the materials to be washed, creating a small work area in any size sink or tray and allowing wash water to circulate without disturbing materials. For large washing projects, more than one group can be set up at a time within a single tray or sink.

H. Glass weights (slabs and discs) can be used to hold down edges of interleaving to safely allow circulating wash water. Plexiglas rods and tubes can also be used.

I. Clear, flexible hoses attached to water faucets and solution containers direct fluids where needed, reduce handling of trays, and allow for frequent inspection of hose's cleanliness.

16.3.8 Felt Washing

A. Select a flat-bottomed stainless steel tray with a valved drain. Drain outlet should be located along short side in a corner adjacent to the long side. A ½" x 6" stainless steel pipe nipple with the threads cut off one end and swaged into the tray and provided with a ½ inch gate valve will allow drainage control. Suitable blocks of varying sizes and shapes are used to support tray during drainage and rinse procedures.

B. Prepare a 100% wool felt (minimum thickness of ¼ inch) 1 inch smaller than the tray in all directions. Felt should be marked to allow it to be placed in tray the same way each time. A single new felt can be dedicated for plain water washing.

C. Use a lightweight, porous washing support at least 1 inch smaller than felt in all directions.

D. Have ready a washing hose long enough to be manipulated over entire tray with a little extra length for ease of handling.

E. Brayers (3 inches and 6 inches long).

F. Polyester strips, 2 inches wide, and creased lengthwise to form a slight angle, to use during rinsing when no water over object is desired.

16.3.9 Suction Table

A. Spray equipment: Water spray gun, Dahlia sprayer, airbrush, or other compressed air system for delivering a fine mist of water. (Some conservators don't use Dahlia sprayers because they have a brass lining which corrodes readily.)

B. Ultrasonic humidifier with or without a nozzle for directing the mist. Possible nozzles include blotter funnel, large glass dropper (for testing and spot treatment), etc.

C. Droppers: Glass and disposable plastic. Disposable plastic droppers provide greater control than glass/rubber droppers when applying solutions. The strength of their suction creates an agitating motion which can be successful for dislodging or removing stains.

D. Soft brushes for depositing solutions, controlling movement, and gentle lifting.

E. Masking material such as dental dam or invalid sheeting (medical supply companies), polyester film (Mylar) or plastic garbage bags - some conservators feel these conform to table surface better, though they are not solvent-resistant.

F. Gore-Tex as a permeable membrane through which moisture vapor can be applied to the object. The object can then be dried on the suction table.

G. Moisture chamber and/or air filtration dome for suction table. A dome such as "The System," a moisture chamber designed by Weidner and Zachary, allows for the continuous controlled wetting of water-sensitive objects without the drying that accompanies spray washing on the suction table or preliminary humidification. It allows paper to remain damp during local stain removal, preventing the formation of tidelines, and also filters incoming air (Weidner and Zachary to be published).

16.3.10 Supports for Washing Paper

A. Non-woven Materials

1. Spunbonded polyester webs with different surface textures and porosity include Hollytex 3200 series (Ahlstrom Filtration, formerly Eaton-Dikeman, P.O. Box A, 122 West Butler St., Mt. Holly Springs, PA 17065, Tel: 1-800-233-7171), 100% polyester web in various weights with very smooth surface texture; Reemay (Ahlstrom Filtration), assorted weights of polyester web with a more fibrous surface texture; Pellon (Pellon Corp., 20 Industrial Ave., Chelmsford, MA, Tel.: [508] 250-8328), nonporous sheets with burnished surface texture. Pellon 910 contains an acrylic foam binder which can yellow.

2. Spunbonded nylon web such as Cerex (James River Paper Co., Non-woven Division, Gonzalez, FL) – Style #23 is a commonly used weight.

3. Gore-Tex membrane, an expanded film of Teflon-like material (W.L. Gore, P.O. Box 1550, Elkton, MD 21921, Tel: [301] 392-4440) is available laminated to nonwoven polyester web (48 inches wide, 10 mils thick) or non-woven polyester felt (56 inches wide, 45 mils thick). Because of its low wettability and small pore size, the membrane acts as a barrier to particles such as dirt, dust, bacteria, spores, and liquid water, but does transmit water vapor and volatile organics used as dilute aqueous solutions (e.g., ammonia and water-miscible solvents such as acetone, ethanol, and propanol). The polyester web laminate transmits about 2.5 times more water vapor than the felted laminate. Dilute aqueous solutions should be pretested on Gore-Tex to determine that concentrations are low enough to avoid wetting the Gore-Tex.

4. Wet-strength paper such as Firenze (Andrews-Nelson-Whitehead).

5. Felts and blotters. See **16.3.10 E. Drying Equipment.**

B. Woven Materials

1. Dacron polyester produced in various grades for screen printing. One type in use is Pecap 76-T, made by Tetko, Inc., 333 South Highland Ave., Briarcliff, NY 10510, Tel: (914) 941-7767.

2. Finely woven ethylene-polypropylene co-polymer mesh.

3. Finely woven nylon mesh.

4. Fiberglass screening.

5. Fluortex ETFE 9-105/32 monofilament screen fabric (Teflon finely woven mesh), (Tetko Inc., 333 South Highland Ave., Briarcliff Manor, NY 10510, Tel: [914] 941-7767). It is especially helpful in supporting paper objects with media on both sides, such as a double-sided graphite pencil drawing.(LS)

C. **Plastic Supports**

1. Polyester plastic film such as Mylar (Du Pont), Scotchpar (3M), Melinex (ICI).

2. Plastic panels for rigid support, such as Plexiglas (Rohm and Haas, Philadelphia, PA 19105) and Acrylite (Cyro Industries, Box 579, Orange, CT 06477).

3. Plastic diffuser screens (often referred to as "egg crate") are produced for fluorescent lighting and available from most hardware stores.

4. Polyethylene/polypropylene extruded netting is particularly useful when stretched over a frame (manufactured by Canwed, St. Paul, MN and distributed by Internet, Minneapolis, MN).

D. **Frames** (screen washing)

1. Aluminum or sealed wooden frames. Note that wood may warp, develop fungal growth, or release discoloration.

2. Cover and materials for frame (includes materials listed under woven supports, **16.3.10 B.**).

3. Intermediate washing support is used in most washing procedures to allow the wet paper object to be moved with minimal handling and to support mechanically damaged and/or weak papers.

   a. Spunbonded polyester web such as Hollytex or Reemay.

   b. Spunbonded nylon web such as Cerex.

E. **Drying Equipment**
(See AIC/BPG/PCC **28. Drying and Flattening** 1984.) The following guidelines are to assist in selecting drying equipment.

1. **Interleaving** (see **16.3.10 A**): Absorbent materials (i.e., wet strength paper, felts, or blotters) should not be placed directly against wet media unless it is known that the media can withstand the capillary forces exerted by absorbent materials during drying. The surface pattern of any textured surface may transfer to the paper or softened media during drying (with or without weights). The texture of materials

used for drying should be carefully considered. An interleaving material such as polyester web should always be used on a drying screen to prevent the formation of a drying screen pattern on the paper support during humidification and drying. (See 16.2.7.)

2. **Blotters** used in conservation treatments should be free of components soluble in water and/or organic solvents such as dyes, optical brighteners, residual bleaching chemicals, lignin, or other acidic or colored fibers, fillers, and/or sizes. Characteristics such as absorbency, thickness, surface finish, and minimal planar distortion on exposure to moisture and during subsequent drying should be considered. Blotter sources include Ahlstrom Filtration, formerly Eaton Dikeman, P.O. Box A, 122 West Butler St., Mt. Holly Springs, PA, 17065, Tel: 1-800-233-7171; James River Paper Co., Richmond, VA, as well as various conservation retail companies. One fine blotter that is free of undesirable components, soft and absorbent, and remains relatively flat after exposure to moisture is ED 901-85 made by Ahlstrom Filtration. This 4% cotton 96% purified pulp, light, cushion blotter comes in a variety of weights; two of the most useful are the 35 point white - basis weight 500 pound per 1000 sheets and the 70 point or double-weight. Ahlstrom also markets 100% cotton blotting paper in various weights.

3. **Felts** are made for industrial use (for gaskets, etc.) and careful specifications must be given to the manufacturer to receive high-quality felts for conservation use. Some recommended felts are those used for orthopedic appliance gaskets from Western Felt and Fiber, 323 Date Ave., Alhambra, CA 91803; white felts from Commonwealth Felts, 136 West St., Northhampton, MA 01060; Aetna Felt Corp (formerly Continental Felt), 2401 Emaus, Allentown, PA 18103; Lee Scot McDonald, Box 264, Charlestown, MA 02129. All are generally made of 100% wool or wool/synthetic fiber blends. The strength of "wicking" or capillary action is determined by the amount of natural fiber in the felt, but blends of fibers may be acceptable for use. Other characteristics, including cost, may play a role. Needled felts are felts in which fibers are needled together, rather than felted by pressure. By needling, the same density of felt can be obtained at lower cost. For conservation, undyed and unbleached fibers are desirable. Colored fibers or plant fibers may be present and one must either select felts without them, choose another source, or remove the fibers.

Personal preference dictates whether hard or soft felts are used. The engineering specifications are not consistent. The surface texture of the felt should be specified since "elephant hide" or "alligatoring" caused by manufacturing and method of storing felts on large rolls is undesirable. If possible, the felts should be cut from the outer part of the roll and shipped either flat or gently rolled onto 10 to 15 inch diameter tubes. Specify cleanliness, no dye marks for cutting, no perforations at edges, no holes, no grease, and no hand or footprints. Conservators commonly use 1/4, 3/8, or 1/2 inch thicknesses depending on the amount of absorbency and cushioning desired.

4. **Racks/Screens**: Screens should be made of materials specified in **16.3.10 D.** with frames of aluminum. Sealed wood is also used, but can release colored components on repeated wetting. Aluminum frames have a tendency to oxidize and may leave dark smudges on hands. Use caution and check hands when handling the screens. Racks commonly used include those manufactured for the food service industry.

16.3.11 Miscellaneous

A. Chemically stable plastic bucket and/or glass beakers.

B. Graduated cylinder.

C. Dahlia sprayer or other compressed air system for delivering a fine mist of water. Some conservators avoid Dahlia sprayers because their brass lining corrodes readily.

D. Droppers.

E. Ultrasonic humidifier.

F. Soft broad brush such as a Japanese brush (Hake).

G. Transparent cover for washing tray. When organic solvents are used in the wash solution, heavy glass plates are useful.

H. Solvent resistant plastic gloves for use with organic solvents.

I. Fumehood and organic fume respirators when using toxic materials.

16.4 Treatment Variations

16.4.1 Immersion Wash in Water

Washing by immersion may be done when spot testing indicates that the media and paper will withstand complete wetting in a bath. Immersion washing is useful when the paper is discolored overall and is very acidic, when the object is severely disfigured by staining, and when staining is water-soluble. Immersion washing has several advantages: overall cleaning; lessening of discoloration; softening adhesives and removing attachments.

A. Select distilled or deionized water preconditioned with calcium carbonate or analyzed and filtered tap water.

B. Condition water to desired pH. Some conservators recommend that the first wash be in neutral pH water or close to the pH of the artifact, if measured. If appropriate, add surfactant or wetting agent to improve wettability, or alternately, large proportions of alcohol or other solvent to reduce water-sensitivity of iron gall inks.

C. Fill water misting equipment with conditioned water or a water/organic solvent mixture to premoisten paper.

D. Select tray or container for washing. The tray should be at least 2 to 3 inches larger than the paper object and its support in both dimensions to allow for easy, and if necessary, quick removal.

E. Pour enough water into the tray to cover the paper and its washing support.

F. Prepare blotters, felts, cotton swabs, and other materials for use after removal from bath, or for use if unanticipated sensitivities or reactions necessitate stopping treatment.

G. If the paper is calendered, heavily sized, or resists wetting for any other reason consider humidifying or treating with either alcohol or an alcohol/water mixture to facilitate wetting of the paper when it is immersed. It is important that some papers be completely wet prior to immersion to avoid tidelines.(JW) (See **16.2.4 B.**)

H. To allow controlled and even introduction of moisture, relax the paper by spraying (if humidification has not been selected). Place the object face down on a clean support material such as a polyester web and mist the verso. Turn the object over and mist the recto. Repeat as necessary to relax sheet.

I. Placing the paper in the bath

1. Carry the paper on its chosen washing support and place it face up on the surface of the water. Let the center of the object come in contact with the water first and gently lay object down moving contact out from center. Gently push down on paper to reduce the possibility of trapping air bubbles underneath the object.

   a. If the paper curls upward, mist the paper evenly with water to relax and expand the top surface of the paper, permitting the object to lie flat.

   b. Sink the washing support. Immerse the paper. Avoid touching the media. Submerge object working from one end to the other allowing air bubbles to escape. Using one of the following tools.

      1) Broad diameter glass or plastic rod with rounded ends.

      2) Soft Japanese brush.

      3) The object can be covered with an appropriate washing support web to protect the surface of the object. The object is then immersed using fingers or tools.

      4) Gently pour water over the surface.

2. Alternatively, dip one edge under water surface and quickly submerge. This technique is used to reduce risk of developing tidelines in paper during the immersion process.

J. Check for complications (see section **16.2.4-5**) including media loss or bleeding, mechanical damage to paper, and alteration of surface texture.

K. If no problems are observed, the paper is generally allowed to remain immersed for at least 15 minutes, checking frequently to ensure there are no problems. Some conservators prefer to watch continuously as solubilities of some media, such as modern inks, can radically change during immersion.(AS)

Fresh baths may be used. Depending on the amount of discoloration moving out, the bath may be changed as often as every 5 minutes.

1. Lift paper on its supports occasionally to flush out degradation products.

2. Regular, gentle agitation of the tray may facilitate the removal of degradation products.

3. Double screen/suction action (see **16.4.3**) may also facilitate the removal of degradation products.

L. To remove the object from the water

1. Align the paper on the washing support in the bath.

2. Gently, holding the paper to the support at one end, raise them together carefully from the water. Care should be taken with tears, and fragile severely weakened areas such as those caused by mold damage. To remove paper with areas of physical damage, slip a sheet of 4 or 5 mil polyester film under the object. Carefully align tears, fragile deckles, etc. Lift the most damaged area up first letting the angle of ascent control the movement of wash solution as it drains. By lifting the damaged area first, the amount of shifting of the object is reduced.

   For extra control and support, the object and polyester support can be slid onto a wetted Plexiglas or glass support which is placed at a gentle angle in one end of the tray or sink. This extra support enables the conservator to have a free hand for manipulation of damaged areas. Alternatively, damaged or fragile papers can be lifted on a washing screen, with a flexible washing support between the object and the screen to permit removal from the screen.

3. If access to reverse is required, and media permits, an appropriate support material can be placed on the face of the object and the object turned over. In this way, attachments and adhesive residues on the verso can be removed.

M. Second and subsequent baths

1. If required, the object can be placed into a second bath which may be pH adjusted (see **16.4.1 B.**). While still wet, it immerses easily. Bathing may continue, changing baths until removal of discoloration is no longer observed. Remove the paper from the water and allow to dry.

   Some conservators prefer to dry the object between immersions which allows the conservator to assess color change and the need for further washing. It may be more difficult to rewet the paper after initial drying, however the object is less likely to be bathed longer than necessary.

16.4.2 **Float Washing on Water Bath**

"The theory of washing contains the following points salient to the float-washing of paper: 1) A sheet of paper contains enough air-pockets to render it lighter than water when additionally buoyed by surface tension; 2) Water-soluble acids and other paper-decomposition products are usually heavier than water; 3) Liquid completely surrounding fibers creates what is known as a 'continuous liquid phase'; 4) In the continuous liquid phase, impurities migrate from the area of higher concentration to one of lower, finally achieving equilibrium. Accepting these statements as unalterably true, it should then be possible (given the strength of surface tension) to float a sheet of paper on pure water until a continuous liquid phase is created including both the paper and the supporting bath, then waiting until sufficient impurities exude from the paper to bring the bath and paper to equilibrium. Several repetitions of this procedure should result in a paper containing several orders of magnitude fewer water-soluble impurities than formerly. The result of the procedure should be exactly the same as that of immersion" (Eirk 1977, 4).

Float washing can be used when a paper object requires washing, but the media will not tolerate immersion. This treatment may not be possible if the paper has too many tears, holes, etc. There will be insufficient surface tension in these areas to prevent water from flowing over the surface of the object. Some conservators believe that float washing still presents more risk of solubilizing the design than suction table washing and is best used with media that are only moderately water sensitive. During the early stages of float washing soluble deterioration products tend to form discolored droplets on the surface of the paper. Usually the moisture eventually wicks back into the paper and the water bath. It may be necessary to blot the discoloration with swabs or small blotter pieces. Also consider covering bath with Plexiglas to slow the rate of evaporation occurring on the paper's surface. During float washing, margins or other areas of the

object not sensitive to water may be submerged to facilitate washing. Again, there is a risk of forming tidelines.

Defacto local washing occurs when a non-wetting sheet with foxing stains is float washed. Sizing in the stained areas has broken down so water can penetrate and clean the stains. A small brush (with the end sharpened to hold a tiny cotton swab) can be used to wet and tamp the surface to remove solubilized discoloration products. Remove the sheet to the suction table for final removal of moisture/discoloration from the spots.(JW)

A. Follow similar steps (**16.4.1 A-H)** as those used in immersion washing up to the point of submerging the object. To protect objects from sinking, a screen can be placed in the tray and the water level in the tray brought up to the surface of the screen. The paper object, on a washing support, is placed on the screen surface. If a washing support is not used, it may be difficult to remove the wet object from the screen and it may be necessary to dry on the washing screen, though there is a danger of leaving a discolored pattern of the drying screen. Before it is placed on the water surface, the paper may be humidified or misted with conditioned deionized water. Avoid use of a surfactant or wetting agent because the paper will sink.

B. If no problems are observed, allow the paper to remain on the surface of the water until overall cleansing or stain removal is achieved. Careful monitoring is recommended.

C. Remove paper from bath using appropriate procedures as used in immersion washing (see **16.4.1 L.**). This procedure is facilitated by using a screen below the support for the object.

D. The object can then be:

1. Placed onto a second bath of wash water;

2. Placed on a suction table (see AIC/BPG/PCC 27. **Suction Table Treatments**, to be published). The suction table should be set up for use prior to float washing in case discoloration moves to the surface of paper and tidelines develop. Washing can then be completed on suction table if the media can withstand suction without sinking into or penetrating the paper support. Place on a uniformly damp blotter. The damp blotter will promote intimate contact with the object; and therefore, uniform absorption of soluble discoloration.(LS)

E. Allow the paper to dry in the appropriate manner (see AIC/BPG/PCC **28. Drying and Flattening** 1984).

16.4.3 **Screen Washing on a Water Bath**

Screen washing is especially useful for artifacts with fragile supports or friable media (e.g., tears or detached pieces). It is also an option when spot testing does not show solubility, but the media are still suspected to be vulnerable to the washing process. Screen washing is thought to facilitate the removal of stains and deterioration products from the paper due to the mild suction created when top and bottom screens are pulled apart. This technique is considered by some to more successfully retain original surface characteristics of the paper. For a description see Stirton 1987.

A. Follow steps **16.4.1 A-B.**

B. Select two screens, of the same size, covered with synthetic woven or net materials at least 4 inches larger in both directions than the paper to be washed. The screen cover should allow water through, but at an even, slow rate.

C. Select tray for washing larger than both dimensions of the screens chosen.

D. In an empty tray, place the two screens face-to-face, with their webs touching. Bring the water level up to the bottom of the top screen, this allows for an evenly wetted surface. Alternatively, one screen can be used, supported on plexi blocks or weights so that the water level is even with the bottom of the screen.(HK)

E. A washing support larger than the paper is placed on the screen.

F. The paper may be prewetted by humidification or water or water/alcohol mist.

G. Transfer the paper to the washing support on the upper surface of the top screen in the water.

H. Repeatedly lift the top screen away from the bottom screen (as though it were hinged on the far side) to create a mild suction. This pulls water and degradation products from the paper to the bath.

I. The water screen can act as a wet table for surface treatments. The paper remains saturated and supported throughout operations.

J. Some ways to remove the paper from the water.

1. Lift the top screen and place over a blotter, allowing the water to drain. Lift the washing support and object and place both on a blotter. Always return top screen to tray before refilling in order to be sure of bringing the water up to the proper level.(LSA)

2. Lift the washing support from one end (see **16.4.1 L.**).

3. Add enough water to the bath just before removing the object that the paper floats off screen. This saturates paper further and may "pull out" more discoloration.(LSA)

K. Allow the paper to dry in an appropriate manner (see AIC/BPG/PCC **28. Drying and Flattening** 1984).

16.4.4 Damp Blotter Washing

Blotter washing is useful when the media are friable or moderately water sensitive, when float washing is considered to be inappropriate, and it is felt that capillary action will enhance the removal of stains and deterioration products from the paper. Blotter washing provides a firm support to badly torn or otherwise mechanically damaged works on paper and allows them to be washed in a manner similar to float washing.

A. Select a washing tray at least 3 to 4 inches larger than the paper in both dimensions.

B. Cut a sheet of blotter at least 2 to 3 inches larger than both dimensions of the paper object. Dampen the blotter with conditioned water, to the extent considered appropriate for the object, and place in the bottom of the tray.

The more water used in the blotter, the more similar the technique can be considered to float washing, in which case discoloration may move to the surface of the object and tidelines may occur. Dampening the object somewhat more than the blotter seems to take better advantage of the blotter's capillary draw. Heavier moistening of either the top or the bottom blotter can selectively loosen attachments or linings on an object.

C. Precondition the object as in **16.4.1 G-H.**

D. Place the object on its washing support on the blotter surface. Lay the object down so that no air bubbles are trapped between the object and the blotter.

E. Cover the tray with a transparent material so the object can be observed during washing. The cover helps keep the paper object from drying out during the procedure. If the object begins to dry, repeat the preconditioning steps.

F. Carefully observe the paper object. If no problems develop, the object can remain on the blotter for a few minutes up to one hour. Discoloration should be observed to move into the blotter.

G. Second and subsequent blotter washing. If the blotter absorbs discoloration, the paper object can be removed on its washing support, a fresh blotter wetted and placed in the tray, and the object laid down on the fresh blotter. Alternatively, a stack of wet blotters can be used. As discoloration is drawn into the top blotter, it can be exchanged for the one below. Capillary pull can be considerable.(NA)

H. The paper is then removed from the tray (see **16.4.1 L.**) and allowed to dry in an appropriate manner.

I. Blotter washing is also possible on a flat surface under glass or plexi sheet or between two sheets of clear polyester film.

J. In cases where media is very stable a second damp blotter can be placed over the surface to enhance washing.

K. If the work of art is very fragile and manipulation or lifting to a clean blotter is too dangerous, blotter washing on a slant with a "soaker" hose behind the blotter dribbling water slowly down the tray will carry the discoloration out of the blotter, always keeping the area behind the print clean. The "soaker" hose can be made by drilling holes along clear plastic tubing which fits over the nozzle of the deionized water tap. This can be attached to the top of the tray with clips, and the edge of the blotter folded over. Care should be taken that the water flows evenly and slowly so the print doesn't slide down the blotter.(JW)

16.4.5 **Gore-Tex Washing** (NA)

This technique is similar to that of blotter washing except that Gore-Tex controls the amount of moisture passing into the object. The moisture passes through the Gore-Tex as a vapor rather than as a liquid. If the object is placed under Gore-Tex with a wet blotter over the Gore-Tex and then placed under light weight, the moisture from the blotter will keep passing through the Gore-Tex until the moisture in the object is in equilibrium with the wet blotter above the Gore-

Tex. The amount of moisture allowed to enter into the object can be better controlled in this way.(MW)

Note: Gore-Tex leaks when it has been creased. Keep it rolled, do not flex it, and be prepared to use a fresh piece on the most sensitive objects.(JW)

This technique allows soluble discoloration to be gently drawn out of a moisture-sensitive object. It is particularly useful with sensitive watercolors, but it should be noted that objects with impasto or glazes are most likely to offset onto the Gore-Tex. Gums in fraktur, for example, may stick to the Gore-Tex. The less weight used with such objects the better.

A. The Gore-Tex and blotters should be at least 2 to 3 inches larger than the object on all sides in order to allow more even wetting of the object and to provide an outer margin for wicking of discoloration. Most conservators use felted Gore-Tex.

B. Spot testing of an area for treatment may be carried out with small Gore-Tex strips. Testing, however, may not reflect true treatment potential as the area to be treated has to be surrounded by the Gore-Tex environment.

C. The object is placed between two sheets of Gore-Tex, membrane sides against the object. A variant mentioned by Keiko Keyes is to place thin Japanese tissue paper inside the package on either side of the object, both to protect the surface of the object and to provide a place for discoloration to be drawn.

D. Damp blotters are placed outside the Gore-Tex. Gore-Tex treatments seem to be most effective when the moisture comes from both sides of the object, but the amount of moisture in each blotter can vary. The degree of wetting depends upon the sensitivity of the object. One might begin with blotters that are lightly misted, just enough to relax them evenly. The object is checked from time to time. If more moisture is needed, and if the object can take it, the amount of moisture in the blotters is increased.

E. Very light weight is all that is needed to ensure good contact between the object and the Gore-Tex and blotters. Some conservators feel that heavier weight may actually close down some of the pores in the Gore-Tex laminate.

F. The gentle washing action may take place over a period of hours. The progress of the washing can be monitored in the

discoloration that wicks to the outer edges of the Gore-Tex and blotters. Flexibility of the paper may also be increased.

The way that water vapor is imbibed in Gore-Tex treatments seems to cause the water to move out of the paper quite rapidly when it is uncovered. Too frequent checking may reduce the efficacy of the treatment.

G. For reduction of residual paper and adhesive left after backing removal on a moisture-sensitive object that cannot be washed, overall softening of residues in a Gore-Tex package may be gentler than moistening the verso section by section for mechanical removal. When using the Gore-Tex package in such a manner for removal of residual mounting materials, unintended washing action is sometimes noted in discoloration that wicks outward into the Gore-Tex and blotter edges.

16.4.6 **Felt Washing (KL)**

Felt washing can be used for any media when it is felt that capillary action will enhance withdrawal of stains and deterioration products from the object.

A. Plain Water Washing

1. Fill tray with water to a depth of approximately the thickness of felt. Place felt in tray and allow to wet out completely. Do not place felt in tray and then fill with water as this allows air to be entrapped in felt and causes irregular saturation and flow patterns.

2. Place washing support on felt and allow to wet out completely. At this time water level may be lowered by tilting tray. Alternately, the object may be placed on washing support, then water level adjusted to suit. The degree of saturation for felt, support, and object is a matter of judgement based on condition, type of paper, pigments involved, and familiarity with this technique.

3. If desired, precondition object by humidification.

4. Position object approximately 2 inches in from edges of washing support at corner diagonally opposite drain outlet. Placing the object with the grain parallel to the short side of the tray is thought to facilitate water flow parallel to the paper fibers. Edge tears should be parallel with tray's short side and with open end of tear facing toward drain to insure that water moves parallel to tears and does not well

up over a tear edge. If both of the above conditions cannot be met, orient open ends of tears toward drain outlet.

5. Allow object to soak as long as practical, keeping watch for pigments being pulled down through paper by capillary action.

6. To remove degradation which has soaked into felt from the object, the tray is blocked up, tilted toward drain, and water is directed under the support with a hose as often as necessary. Rinsing may be done on four levels – over object (if media allows), under object, under support, or under felt. Folded polyester strips can be inserted under edges of the object to insure no water washes over it. Brayers are used, while tray is tilted, to squeeze out felt in the margins below object, creating a slight suction on the object. Lower tray and refill to desired level. It is not necessary to move the object during any of the above operations.

7. Soak and rinse until satisfactory cleaning results.

8. Tilt tray toward drain and allow water to drain off using brayers to squeeze excess. Lower tray and remove object. Follow normal drying practice.

B. Alkaline or Solvent Bath

1. A similar approach can be used for a solvent bath or an alkaline solution bath (e.g., alcohol or other solvents, or very dilute ammonia water). Felt must be completely dry. Close tray drain and fill tray as before with solvent or alkaline solution. Place dry felt in tray and allow to wet out completely. Place support and object as described for plain water wash. Adjust level of solution bath to desired saturation.

2. Soak as long as desired, with drain closed, occasionally tilting tray to allow foreign matter to drain toward edge.

3. Rinse only when operation has gone as long as practical. Rinsing out treated solution will leave felt saturated with plain water and not reusable until felt is dried out completely. Remove as above.

C. **Useful Tips**

1. Before using new felt, rinse thoroughly to assure removal of any dirt and foreign matter.

2. Practice with scrap paper in order to get a feel for how water flows through felt under different conditions during rinse cycle. A little experimenting with water levels and quantities used to achieve the desired levels, particularly for treated water washes, will save start up time.

3. Felts being used for plain water washes may be kept under water in tray for two or three days for convenience, but should be rinsed out thoroughly before use.

4. Never wring out felts, squeeze out excess water. Drying felts is best done by rolling felts, standing on end, and allowing to drip. When drip stops, unroll felts, and place felt on a tilted drying rack. Felts hold a great deal of water so it is advisable to provide a pan to catch drips.

16.4.7 **Washing on a Slanted Solid Support**

This technique can be used for rinsing or for alkalizing after initial washing. It can be used to stop the action of locally applied bleaches, enzymes, or surfactants by flushing the reagent out of the paper as soon as the desired effect has been achieved. It can be used to rinse the verso of an object when adhesive residues, previously loosened with a brush, are removed.

A. Moisten the paper object to be washed and place on a glass or Plexiglas sheet that is larger than the paper in both directions.

B. The wet object should be flat against the support which is then inclined in a sink.

C. Pour water slowly and gently over the surface of the paper from a flask, beaker, or from a hose hooked directly to the faucet.

D. Removing adhesive and other soluble deposits: After the deposit has softened and swelled, the paper object can be transferred from the bath to a solid support to remove residue. Working on such a support reduces stress and strain on the paper support. Soft-haired Japanese stippling brushes (made in a range of sizes), worked in a circular motion with constant or occasional flushing of the area, can remove deposits with minimal alteration of the paper's surface.

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16.4.8 **Brush Wetting**

Marilyn Kemp Weidner distinguishes wetting from washing as the controlled introduction of water into the paper after the cellulose fibers have reached "the fibers' saturation point" (Weidner 1985, 128). Wetting can be considered a preparatory phase to washing.

A. An Oriental technique, brush wetting can be used for wetting-up large objects such as posters. Place the object face down on a blotter and brush water over the reverse, letting the stains and discoloration seep out into the blotter. Change the blotters as often as necessary until as much discoloration as possible is removed.

B. Alternatively, a very fragmented or damaged object can be placed face down on clear polyester film (Mylar) and brush wet on the reverse (through polyester web if the object is badly torn). Blot up water and discoloration from verso with blotter squares. The polyester acts as a facing, holding the paper pieces in place while the discoloration is removed by blotting from the reverse. When the paper fragments are flooded with water, they become mobile and can be readily realigned. Blotting up excess water immobilizes the fragments against the polyester film. Alignment can be checked by viewing recto through the lifted polyester. This treatment is generally followed by Japanese lining of the still wet object. This technique was developed to permit aqueous treatment of very fragile or damaged large posters.(KN)

16.4.9 **Suction Table Washing** (See AIC/BPG/PCC 27. **Suction Table Treatments**, to be published.)

16.4.10 **Local Treatment Methods**

A paper artifact may be washed in a restricted area when overall washing is not required, safely possible, or otherwise desirable, or when local treatment is required before overall washing. When media are sensitive to, or soluble in water, local washing allows cleaning of the paper support where the media is not present. Examples of objects that might be candidates for local washing are artifacts with water-sensitive components such as seals, collage elements, and/or water-soluble adhesives associated with these attachments.

With local washing, it is likely that there will be a formation of tideline stains or distinctly lighter areas, especially in papers containing large amounts of water-soluble discoloration. Extreme care must be taken to prevent these occurrences as well as to prevent the migration of water to sensitive areas of the artifact. Ethanol or solvent mixtures with water can be used to feather the edges of locally washed areas to prevent or minimize tideline formation.

Local treatment may result in physical and chemical differences between treated and untreated areas; such as dimensional changes, planar distortions, reduced concentrations of degradation products, and increased concentrations of treatment reagents (surfactants, solvents, buffers, etc.). Theoretically, it is possible that even with the best intentions and greatest care, tidelines can develop in areas of local water treatment after natural aging.(JS)

A. **Local Blotter Washing**
Areas wetted locally with a brush, dropper, damp blotter, airbrush, sprayer, steamer, or ultrasonic humidifier may be blotted on the recto and/or verso to remove stains and/or discoloration. Swabbing or brushing may be done through Japanese paper and polyester web fabric placed over the wet area to minimize alteration of the paper surface. Blotting materials include cotton swabs, analytical filter paper pulp, and other absorbent materials.

B. **Local Washing with Poulticing Materials**
Moisture may be applied with poultice materials such as Kaolin powder (hydrated aluminum silicate, "Fullers Earth"), cellulose powder (Whatman, CF11), paper pulp, cotton, or cellulose ethers. In some cases, poultices can be used to prevent the development of tidelines around local washing areas. Care must be taken to remove the poultice completely. Some may become embedded in the paper fibers and difficult to remove. Use of a barrier sheet such as lens tissue or polyester web between the paper and Fuller's Earth can prevent embedding in the paper.(PDS/YS)

C. **Local Washing with Surfactants**
Thin methyl cellulose solutions can be applied locally and worked in a circular manner with a soft, flat-faced brush to work up a foam. Solution works into crevices, reduces stain, discoloration, surface dirt, etc. Remove excess with cotton swabs and blotter. This technique allows one to work near moisture-sensitive media and can also be used to remove embedded dirt using soaps and detergents. Alternately, dilute methyl cellulose can be applied locally to ingrained dirt and allowed to dry. On subsequent rewetting with a damp swab, the methyl cellulose film will be redissolved, lifting up with it much ingrained dirt.

D. **Local Washing with Alkaline Solutions**

E. **Local Washing with Chelating Agents**

F. **Local Washing on the Suction Table**
The object, usually preconditioned as in **16.4.1 G-H**, is placed on the suction table, with or without a blotter interleaf. Water or other water/solvent mixtures may be applied locally to the area with a brush, dropper, damp blotter, airbrush, sprayer, steamer, ultrasonic humidifier, or combination thereof. Areas not to be washed may be shielded with polyester film or other plastic masks. Masks are especially useful when sprays or ultrasonic humidity are used. It may be possible to prevent tideline formation during local treatment on the suction table due to the physics of washing on this equipment (Michalski 1981). Suction table tops may impart a surface texture to an object even through layers of interleaving.(YS)

G. **Local Enzyme Treatments**
Enzyme solutions can be mixed into viscous cellulose ether solutions or into agar gels and applied locally. Carefully select an agar with a low gelling temperature to prevent denaturing heat-sensitive enzymes. Take care to rinse treated area thoroughly after enzyme use and to denature.

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16.6 Special Considerations

16.6.1 A Brief Historical Background to Washing (concluding in the 1930s)

In regard to art on paper, the term washing has several historical meanings. As early as the seventeenth century it was used to refer to the resizing of paper. The practice of hand coloring intaglio prints with watercolor had widespread appeal among hobbyists and art enthusiasts in the seventeenth and eighteenth centuries. "Washing" is the name most frequently given to this popular pastime.

The immersion of paper-supported art works in water to remove stains and discoloration is a restoration technique used at least since the mid-seventeenth century. By the nineteenth century, when published instructions for aqueous immersion treatments became common, approaches to bathing varied widely. Bath temperature could range from cold to boiling and immersion times from one half day to two days or more. The addition of surfactants, such as oxgall or soap, to the bath water is rarely suggested. However, early in this century, particularly in Germany, vinegar was added to water to make it weakly acidic. Paste washing was encountered in the nineteenth century and was recommended for its expediency. Several coats of wheat paste were applied to either side of the print which was then placed in a bath of warm water to remove the paste. Around the turn of the century instructions were published which entailed suspending prints on a muslin screen over boiling water. Once the rising steam had "loosened" the dirt, boiling water was poured onto the back of the print and allowed to seep through the paper and carry away the stain.

It is not uncommon in nineteenth and early twentieth century restoration instructions for aqueous immersion to be disregarded and for reagent bleaching to be the only means used to reduce discoloration in a sheet of paper.(MS)

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