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26.6 **Special Considerations.**

compiled by Robert Futernick and Debra Evans, May 1987

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26. FILLING OF LOSSES

Filling losses in a paper artifact with paper inserts, paper pulp or full paper linings.

26.1 **Purpose:** To restore aesthetic unity and structural integrity to an artifact by replacing lost parts.

26.2 **Factors to consider.**

26.2.1 **Nature and type of artifact** and its intended use in relation to handling, storage and display.

26.2.2 **Character of the paper:** thickness, density, strength, absorbency, expansivity, texture, color, flexibility, coatings, age of the paper, grain direction, mold formation (e.g. laid, wove).

26.2.3 **Nature and location of the loss(es).**

A. Size and shape.

B. Condition of edge: strength, degree of fiber extension, discoloration, presence of adhesive.

C. Amount of visual distraction caused by the loss.

26.2.4 **Media condition and characteristics:** possible problems with moisture, manipulation, placing face down.

26.2.5 **Aesthetic, ethical, and practical considerations.** Collector or curatorial input is very important in helping to decide such issues. The following are examples of questions that might arise:

A. Does the damage have some historical or cultural significance?

B. Should attributes of the artist's making (for example, tack holes) be left or repaired?

C. Will display lighting or mounting methods accentuate damage in an unacceptable manner?

D. Is it necessary to repair edge losses that will be covered by a mat?

E. Should the fill be made as invisible as possible or should it clearly show as a repair?

26.3 **Materials and equipment.**

26.3.1 **Adhesives.** Chosen for flexibility, strength, dimensional stability, visual characteristics, good long-term aging characteristics (non-darkening) and reversibility. (See 46. Adhesives)

A. Starch pastes. Wheat and rice are most commonly used. These adhesives are smooth, strong and dry relatively clear. They retain their tack when diluted to a thin consistency, are time tested and relatively reversible.

B. Cellulose ethers. Methylcellulose and sodium carboxy methylcellulose are in common use. These adhesives also dry relatively clear, have good aging properties, are relatively reversible, but do not possess the adhesive strength of starch pastes.

26.3.2 **Sizing materials.** Adhesives or other materials applied to the fill or added to the pulp

slurry to improve fiber dispersion in the fill, increase strength or improve the surface quality in preparation for the addition of compensating toning.

A. Starch pastes.

B. Cellulose ethers.

C. Proteinaceous adhesives (gelatin, parchment size).

D. Other materials such as gums, commercial products (e.g. Aquapel 380) and non-aqueous resins (e.g. B-72).

26.3.3 **Fill materials.**

A. Insert papers.

1. Western paper. Both old and new stocks are desirable, sorted by laid or wove, color, and thickness for later ease in matching. Rag content papers are generally used, however some conservators keep non-rag papers for filling losses on non-rag artifacts.

2. Oriental paper. An assortment of different weights and tones of papers is desirable. A stock of new and old papers of varying fiber type (*gampi*, *mitsumata*, and *kozo*) is useful.

B. Paper pulp.

1. Pulp source. Unprocessed cotton or linen fibers require beating. Fully beaten pulp can sometimes be purchased in small quantities from paper mills. The selection of fiber types and beating methods is critical in manufacturing fills where strength, flexibility and strong edge attachment is of primary importance (e.g. books and documents expected to withstand handling). For repairs on paper that won't undergo heavy handling (e.g. art on paper), satisfactory pulp can be generated by reprocessing paper sheets in the conservation laboratory. Pulp can be prepared from good quality rag paper of different tones or colors. Pulp made in several different tones can be mixed at a later time to achieve the color required to match a particular artifact. A few trial patches are to be made and allowed to dry to judge the color match.

2. Pulp preparation.

a. Blender method: The paper is torn or cut into small pieces and soaked. Cooking the slurry will remove old sizing and other materials yielding a lighter and cleaner product. A kitchen blender is used to process paper pieces with water until no clumps remain. Bonding characteristics of the reprocessed paper are varied by altering the water/pulp ratio and blending times. Small additions of substances such as methylcellulose can help avoid flocking of the fibers. Toned or colored papers can be used if applicable or coloring may be done at this time by adding dyes or other colorants.

b. Beating of fibers: The selection and mix of fibers and kind and degree of beating is crucial in producing fills that exhibit high strength and dimensional stability and bond well to the artifact edges. Ball mills and laboratory beaters can be used for producing small quantities of acceptable pulp. Another suggestion is to shake .5cm glass beads with torn squares of paper suspended in water in a corked flask to produce pulp.
(See Petherbridge, bibliography)

3. Pulp storage: Stock pulps may be kept in water in tightly capped labeled jars in the refrigerator. The addition of a small quantity of alcohol can serve to preserve the slurry. It is useful to attach a small patch of the pulp to the outside of its storage jar for selection purposes. Pulp may also be kept dry for long term storage. An assortment of pulp facilitates the mixing of various pulp colors and fiber types.

C. Cellulose powder. Cellulose powder (available from chemical supply and paper companies or generated by abrading paper) may be applied directly or over Japanese tissue as a filling material. Gradation of color tones may be achieved by cooking in an enamel or non-stick pan over low heat while continuously stirring the powder. The longer the cooking time the darker the powder. Jars of powder in a range of tones may be stored indefinitely.

26.3.4 **Toning material.**

A. Media. Sometimes used to tone pulp or repair paper prior to insertion; used on completed fill to tone and/or complete design. Water or water with a binding agent (such as methylcellulose) and other solvents may be used as a vehicle for the application of color. *It is important to consider the acidity and light fastness of the material.*

1. Pastels.
2. Watercolor.
3. Acrylic paints.
4. Graphite, charcoal, colored pencils.
5. Dye.
6. Tea, coffee or burnt sugar.
7. Dry pigments.
8. Degraded paper extract. (derived by soaking and cooking old paper in water until the liquid evaporates)

B. Tools for media application.

1. Brushes for applying media.
2. Air brush or other spray apparatus for applying liquid media.
3. Stumps, swabs, cotton wrapped toothpicks, and cotton balls for applying and blending dry media.

26.3.5 **Materials and equipment.** For preparation and application of fills.

A. Fills shaped of dry paper.

1. Light box.
2. Black paper for contrast difference.

3. Paper micrometer for gauging paper thickness.

4. Polyester film to protect the artifact while tracing or scoring the outline of the loss.

5. Weights, squares of Plexiglas or glass.

6. Polyester web or a fine linen handkerchief as casting surface beneath loss, and as release material.

7. Small blotter squares.

8. Pencil for tracing loss outline on insert paper.

9. Fine needle or other point for scoring and teasing paper fibers of edges.

10. Ruling pen or brush for scoring with water.

11. Iris or other fine scissors for cutting out insert from repair paper.

12. Tenotomy knife, scalpel or other blade for paring.

13. Rotating shaft tool as possible aid in paring insert paper.

14. Sandpaper for paring.

15. Brush for applying paste to loss or insert edges.

16. Fine tweezers for manipulating insert into place.

B. Pulp fills.

1. Light box.

2. Kitchen blender, ball mill, glass beads, or other beater.

3. Weights, squares of Plexiglas or glass.

4. Polyester web or a fine linen handkerchief as casting surface beneath loss, and as release material.

5. Mylar squares.

6. Small blotter squares.

7. String.

8. Eye dropper (with tapered end removed or inverted), plastic *ketsup* dispenser with cone-shaped top, spoon, sprayer, or other instruments for laying pulp into place.

9. Brush for applying paste to loss edges.

10. Tamping brush, hospital hand scrub brush.

11. Teasing needle or other point for separating and manipulating fiber slurry.

12. Bone folders or other burnishers.

13. Hot air gun, tacking iron.

C. For pulp fills made with leaf casting apparatus.

1. Suction table.

2. Accessories for localized leaf casting. (See Futernick, bibliography)

2. Leaf casting machine for casting fills on entire artifact. *[to be expanded]*

3. Also equipment from 26.3.4.B.

26.3.6 **Texturing Materials:** to recreate surface quality.

A. Silk screen, window screening.

B. Heavily textured watercolor papers.

C. String, Dental Floss.

D. Burnishing tools.

E. Dimpling tools, punches, carved tooth picks.

26.4 **Treatment variations.**

26.4.1 **Filling accomplished by overall lining.** (See 29. Lining)

A. Advantages: Quick. Appropriate on certain artifacts where losses are numerous and considerations do not indicate individual repair. This method works best with artifacts on thin paper.

B. Possible disadvantages: Cockling, distortion and delamination around edges of loss. Thickness variation in the laminate structure created by many losses or lining paper spanning large areas of loss can result in uneven tension. The thickness of the artifact and lining paper and the type and strength of the adhesive are important factors.

C. Lining may be used in combination with inserts.

26.4.2 **Fills shaped from dry Western paper.** This method may be appropriate when closely matching the paper is deemed necessary to re-establish aesthetic unity. It may also be indicated when the artifact cannot tolerate moisture (as required with pulp filling methods).

A. Fills are done after the artifact has been surface cleaned, bathed or solvent treated (if these operations are indicated and acceptable). Tears and planar deformations are usually straightened out before loss repair.

B. Preparation of the loss edge. Various options are available depending on the particular requirements of the individual artifact and the ethical policy of the conservator.

1. Dry cleaning only using rubber or vinyl erasers to prepare edge.

2. Teasing fibers at the loss edge of artifact (with dry or slightly moistened edge). This method improves strength of attachment and visual transition with minimal disturbance of original material. It may also reduce a darkness at the join.

3. Paring loss edge of the artifact - creating a bevel to remove discoloration, increase strength of attachment and improve the visual transition from artifact to fill. This can be accomplished with a knife or scalpel, sandpaper, or rotating shaft tool fitted with an abrasive wheel.

4. Splitting paper at loss edge is especially effective with a thick, board-like paper artifact. A tissue tab is inserted into the split and layers are built up above and below the insert. This is good for missing corners of heavy paper.

C. Choice of repair paper, using the following considerations:

1. Thickness. It is possible to laminate papers, split or sand them to achieve similarity.

2. Opacity. Small quantities of pigment (e.g. chalk or clay) applied to the back can alter opacity.

3. Color as near to that of the artifact as possible or lighter (never darker).

4. Texture and such features as laid and chain lines matching as much as possible (viewing in raking light may be helpful here).

5. Flexibility and dimensional stability.

6. Grain direction.

D. Old repair paper often requires surface cleaning and/or washing prior to use as insert material.

E. Shaping of repair paper prior to attachment to the artifact.

1. The artifact is placed over a light box (as an alternative, a black paper beneath may work with thinner papers) with a protecting polyester film sheet over the loss area.

2. The repair paper is placed over the loss area; laid and chain lines and other features are matched up.

3. The repair paper is trimmed to size using various methods:

a. Tracing just along the loss with a pointed instrument, scoring the repair paper slightly. The insert is then cut or pulled apart from the surrounding repair paper. The scored lines can be moistened by brush or ruling pen and water to facilitate separation. Methylcellulose can be added to the water (1% w/v) to prevent excessive wicking.

b. Tracing outside the loss outline with a ruling pen or brush and water. The insert is then pulled apart from the surrounding repair paper.

c. Tracing outside the loss outline with a pencil. This line is then cut with fine scissors. A faint pencil outline of the actual edge of the loss may also be made as a guide for beveling later.

d. Pin prick method. A needle is used to make many small perforations following

the contour of the loss. The insert is pulled away from the surrounding repair paper. Water may be painted on the perforation line to aid the separation and cause further fiber extension.

4. The edge of the insert is beveled.

   a. Prior to insertion. The edge of the insert is beveled so that when put in place the density of the two beveled areas (edge of insert and edge of artifact) is the same as the opacity of the surrounding artifact. If the artifact is not to be beveled, the insert is beveled as thin as possible. A light table is very useful in creating the proper bevel. Various paring methods:

      1) Commonly the edge of the insert is thinned with a sharp knife or scalpel. Care must be taken to avoid cutting too deeply and chipping away paper along the join line. If the paper is hard or brittle, it can be moistened and gently scraped.

      2) Abrasive action from sandpaper can be used exclusively or in conjunction with knife methods. A rotating shaft tool (e.g. Dremel) outfitted with an abrasive wheel is useful in certain cases. The wheel must be held so that it rotates away from the edge. With the right angle, controlled and delicate thinning of even brittle paper can be accomplished without changing the contour of the edge.

      3) Beveling is usually done on the back of the insert. This preserves the color and surface texture of the insert.

   b. After insertion. The roughly cut insert paper is adhered to the artifact edge allowing the insert to overlap the join area. After pressing, the excess thickness created by the overlap is removed by paring or sanding from the reverse.

F. Alignment and attachment.

1. Alignment: An alignment system is planned so that the insert, when pasted, will fit exactly into place as planned; this is important in the case of large or complex fills. Several examples:

   a. For larger fills requiring quick pasting and rapid placement to avoid paste drying: The artifact and insert are placed on the work surface face-up. The insert is positioned and held with a small weight. The artifact is also held with weights placed well away from the loss edge. The artifact is lifted at the loss edge or rolled back onto blotting paper for paste application. Once pasted, the artifact edge is easily let down back into correct position for perfect alignment.

   b. The artifact is placed on the work surface face down. Adhesive is applied to a short segment of the loss edge. The insert is sited and pressed into the correct position. Additional paste is then applied to the unattached portion to complete the join.

   c. The artifact is placed on the work surface face down. The loss edge is pasted. Unshaped repair paper is placed well over the join area, pressed and allowed to dry. The excess repair paper is then pared away on the artifact's *verso*.

2. Pasting. Adhesive can be applied to the edge of the artifact alone or to both the

artifact and insert. To keep the join flexible, heavy adhesive applications should be avoided. Conversely, thin watery paste can wick into the artifact's edge causing tiding or darkening at the join. A very thin application of a stiff paste often yields the best results.

3. Pressing and drying.

   a. The filled loss is covered with a cushioning layer (such as several layers of polyester web) and burnished gently from both sides, if feasible.

   b. The filled loss is weighted to dry with release material (e.g. polyester web) and blotter on both sides and flat weight on top. This pressure remains on the fill until it is dry.

   c. An alternative is to put the sheet with the filled loss face down on release paper on a hard surface and put blotters only at the back. The idea is that this will force the fill flush at the front and force all the irregularities to the back. Plenty of weight is applied and allowed to remain until the fill is dry.

   d. Another alternative which is sometimes appropriate is to dry the adhesive in the fill by using a tacking iron over an interleaf such as polyester web or thin paper.

26.4.3 **Fills shaped from Japanese paper.**

A. Indications: Laminated fills made with Japanese paper are particularly suitable for objects where strength of join, paper flexibility and treatment speed are important considerations. Overlapping the fibrous edge of Japanese paper on both sides of the artifact creates a strong flexible join that spreads the stress of attachment over a larger area. Book leaves and other papers whose purpose requires ongoing handling are excellent candidates for this method.

B. Compatibility. Though Japanese papers don't usually match Western paper in color, texture and thickness, the differences are often not distracting especially if the fill serves utilitarian rather than aesthetic functions. By varying methods, results can be made visually acceptable.

C. Fills are generally undertaken after completion of other treatment procedures as indicated in section 24.4.2.B.

D. Edge preparation. No manipulation of the artifact other than surface cleaning is usually required. There are circumstances when extending the fibers of loss edge can improve the bonding and flexibility across the join.

E. Considerations of paper choice:

   1. Thickness. Japanese paper is selected so that two or more sheets together will approximate the thickness of the damaged artifact.

   2. Opacity. The opacity of Japanese paper is often very different even when thickness of the artifact is matched. For more cosmetic repairs, chalk or kaolin in a water suspension or watercolor may be applied to one surface of the repair paper. This painted surface when laminated to the second repair sheet becomes an interlayer which serves to subtly increase density or shift color without the distraction of an exposed painted surface.

   3. Color. Very often the natural color of the Japanese paper is acceptable for many

repairs. In instances where a closer match is needed, watercolor or pastel pigments can be applied to the surface of the fill or the entire sheet can be dyed. Another option is to "artificially age" a range of Japanese papers by toasting in an oven to various darker shades. The tone of the artifact should be matched as close as possible, however it seems better to leave the fill slightly lighter than to risk the distraction caused by repairs that are too dark.

4. Texture. The texture of Japanese paper can be modified by direct burnishing or by rubbing through other textured materials such as knobby surfaced paper or felt-like polyester web to make the object more sympathetic to that of the artifact. See 26.3.6. This optional step is usually done while the repair is still damp just after attachment.

5. Dimensional stability. Japanese papers (especially those made from *kozo*) expand less in response to moisture than Western papers. Fills made with Japanese paper do not usually impose stresses and strains and have less chance of cockling artifacts.

F. Shaping the insert paper may be done before or after attachment. When before, it is accomplished using the same tools in much the same way as described for Western paper inserts, 26.4.2E. Fiber extension at the edge may be achieved by scoring with a needle along the loss edge. When the insert is pulled away from the rest of the repair paper, the resulting edge is fibrous (fuzzy). Water, applied to the scored mark, will enhance this effect (or may be used on its own). If the loss has layered edges, layers of tissue can be scored separately to provide a stepped insert.

G. Alignment and attachment.

1. Accuracy is important in both shaping and placing the insert. Only the fuzzy part should extend onto the artifact to avoid a brittle or stiff join. Gaps can be tested by holding the attached fill up to light or over a light box or black paper.

2. Pasting. Various methods:

a. The two (or more, if matching a thicker sheet) shaped pieces of Japanese paper are prepared. The artifact is positioned on polyester web over a light box. One insert paper is selected and paste is applied with an outward brushing action to the join edge. The insert is placed onto the artifact such that only the fibers overlap. The join area is lightly burnished through an interleaf to assure contact, and the sandwich is turned over onto another supporting polyester sheet. The first polyester sheet is now carefully removed. The second insert paper is selected and pasted all over, again brushing in an outward direction to extend the fibrous edge. Small inserts can be handled with fingers or tweezers when positioning. Larger, more cumbersome pasted sheets may be set out on slightly damp plastic film. The insert paper will cling when turned upside down and clear plastic allows see-through and accurate alignment.

b. Adhesive is applied to the artifact at the edge of the loss. Care is taken to keep adhesive to a minimum and to avoid extending the pasted area beyond the very edge of the artifact. A large unshaped piece of Japanese paper is placed well over the join area such that the entire loss is covered. The artifact is turned over, the polyester sheet removed and adhesive is applied again, just onto the edge of the loss and then overall on the back side of the first insert sheet. The second insert paper is set onto the pasted portion and rubbed to achieve bonding. After pressing and drying, the excess paper extending over the join is pared away. Any unattached fibers are touched

with adhesive and set down.

c. When filling losses in thin sheets of Japanese paper (e.g. woodblock prints), a single layer of paper applied to the reverse of the artifact usually is sufficient.

d. Sheets made up of layered Japanese papers pasted together can be prepared ahead of time and used for filling losses on heavier weight papers. It is often useful to have a selection of these sheets of layered Japanese paper on hand for easy and quick filling of a variety of papers. Japanese papers are pasted together in layers of up to 8 or 9 sheets with very dilute wheat starch paste. The pasted layers are quickly immersed in a water bath and pressed between felts to dry. This leaves a minimum of paste in the paper sandwich and avoids curling and hardness. Layers of the paper can be peeled off one at a time with a bamboo or Teflon spatula to match the thickness of the paper to be filled exactly. An area of loss is marked on the top layer of the Japanese paper composite sheet with a stylus and the excess paper is pulled away at that mark in layers, leaving a slight margin for attachment on the bottom layer. A thin layer of Japanese paper can be applied to the top after the insert is in place for additional strength or better cosmetic match. The color of the insert sheets can be varied using just the natural Japanese papers.

e. Some conservators use Japanese paper previously coated with a heat sensitive adhesive. Two pieces of the heat set tissue are trimmed to follow the contour of the loss. The papers are prepared so that the adhesive coated sides face one another. The two papers are positioned and activated by heat or solvent. (See 25.4.10 Mending)

26.4.4 **Cellulose powder (dry pulp) fills.**

A. Indications: This method may be most appropriate for filling small losses in an expeditious manner. The artifact remains dry and the fill dries quickly, so this method can be used on art objects which cannot tolerate wetting.

B. Disadvantages: These fills are only appropriate for small areas because they lack the flexibility of other fills described.

C. Preparation and application.

1. Whatman cellulose powder method. The fill is made by applying Japanese tissue to the reverse of the loss area. Paste (methylcellulose or starch) is then applied to the tissue and toned powder (26.3.3.C) immediately applied to the pasted area. This procedure is repeated until the entire area of the loss is filled.

a. A dry, short fibered brush can be used to lift small amounts of dry cellulose powder and tamp it into contact with the methylcellulose.

b. Alternatively, a more even build up of the fill may be achieved by picking up loose cellulose powder with tweezers and dropping the powder on the paste moistened area. After a few seconds, the loose, non-attached powder is blown away. The attached powder is tamped into place and the procedure is repeated.

c. The surface can be consolidated with additional applications of paste and can be evened with light sanding.

d. While methylcellulose or starch paste may be used as an adhesive in this

process, methylcellulose will be lighter in tone when dry and therefore possibly preferable.

2. Scraping method. A paper of proper quality and color is locally wet and scraped to dislodge loose fibers. These fibers (or Whatman cellulose powder) are mixed with a small amount of methylcellulose or starch paste to form a "putty", which can be useful for filling small losses such as insect holes or where tears don't quite join.

3. Grinder method. A small electric coffee grinder is used to produce paper fiber fluff from good quality papers. Viscous paste is applied to loss edges. The fiber fluff is put in a strainer nested inside a funnel or a flour sifter and deposited evenly into the loss area. Fibers are tamped down and dilute adhesive is brushed over the reverse of the fill. To create texture, the newly made fill is covered with textured paper and pressed.

26.4.5 **Pulp fills (wet) applied manually.**

A. Indications: This method may be most appropriate for treatment of artifacts such as single works of art on paper or single documents that can tolerate overall wetting. The repair of multiple sheets exhibiting loss (e.g. book leaves with extensive insect damage) may be better or more efficiently accomplished using Japanese lamination techniques or mechanized leaf casting. It is difficult to manually cast even fills over larger areas. If pulp filling is desirable, leaf casting with conventional apparatus or on the suction table provide viable alternatives. Finally, there can be problems with shrinkage of large pulp fills which can result in cockling of artifacts and separation at the joins.

B. Advantages.

1. High quality repairs can be made very quickly.

2. It is possible to create a strong join of fill to artifact as well as a good visual transition from artifact to fill paper.

3. The effect of dirty edges can be minimized by flowing a small quantity of the pulp mixture over the discolored area. When dry, the thinnest deposit of pulp can camouflage a distracting edge.

4. This technique allows for careful manipulation of the slurry on a light table such that the thickness, opacity/transparency, and texture of the artifact can be closely approximated.

C. Fills are done after the artifact has been surface cleaned and/or solvent treated (if these operations are indicated and acceptable). Adequate bathing in water is essential before filling for several reasons:

1. To remove soluble products of degradation. Effective washing reduces the possibility of tide staining.

2. To swell the paper, especially those fibers at the edge of the loss. Hydrated, they merge and bond better with the filling fibers forming a stronger less obtrusive join.

D. Edge preparation.

1. Paring. Conservators sometimes thin the edge of a loss from the reverse. This action serves to clean a dirty edge and allows for greater overlap of filling material

without increasing paper thickness across the join. This action can render a join stronger and in some cases, almost invisible. This may be desirable in certain instances, but ethical questions arise about the removal of original material, and these must be carefully considered.

2. Manipulation with a probe. This is usually done just after bathing. Paper fibers at the loss edge are teased out with a needle. Magnification may be useful to conduct this without causing additional loss. This method is also very effective in improving bonding and reducing the noticeablility of the resulting join.

3. Adhesion. Bonding of the new fill fibers to the loss edge will vary depending on the quality of the artifact paper, the degree of fiber extension at the loss edge, and the fiber type and preparation (beating method and duration) of the fill fibers. While pulp fills may often be accomplished without any added adhesive, in certain instances a small quantity of starch paste is applied to the loss edge while the artifact is damp. This can help with join strength when other factors are not sufficient to provide an adequate bond.

E. The process.

1. One sheet of polyester web is placed on a light table and sprayed with water. Light from below is needed to achieve proper thickness when adding pulp. Occasional viewing with top or side light is also useful during application.

2. The wet artifact is set on top, usually face down. All wrinkles are smoothed. Flooding the sheet with water is helpful to float sections of a very damaged artifact into proper alignment.

3. Edge preparation can also be undertaken at this time if desired.

4. Pulp in water is applied to the area of loss. The water to fiber ratio is a matter of experience and conservator judgement. Overly thick mixtures result in clumping and unevenness. Thin slurries are difficult to confine to the loss area.

5. Spoons, plastic squeeze bottles, and sawed-off eye droppers can be used to aid in application. Whatever method is chosen, it is important to work with plenty of water (a puddle).

6. Some conservators use a string circled around the loss to confine pulp.

7. When the fill appears even, well placed and the proper thickness, excess water is removed. Blotters can be placed at the edges of the fill to wick up excess water. When the fill has lost enough water to hold together, the whole sheet can be lifted (holding the polyester support) onto a blotter or a blotter square can be inserted under the polyester web for additional absorption. It may be useful to use a same-size stack of blotters (like a card deck) held tightly together on their ends to tamp the excess water out of the fill without disturbing the fiber arrangement.

8. Some conservators place a sheet of mylar below the polyester web before beginning the pulp fill. After placement and manipulation of the pulp, a blotter is slipped just beneath the mylar. The mylar is then pulled out (magic tablecloth technique) to allow for rapid drainage.

9. Pressing. Polyester web may be placed over the fill and additional blotter squares can be pushed against the fill to compress the fibers and take away additional moisture. When trying to match dense smooth paper, burnishing the damp fill

area with a bone folder will further compress the fill, improving fiber to fiber bonding, smoothness and strength at the join. This may be preferable to overall pressing because a textured artifact is especially vulnerable to surface alteration when wet.

10. When filling thick paper, it is easier to achieve even results by repeating the application/water removal cycle two or three times instead of attempting it with one thick application.

11. Drying. Drying without weight (beyond that provided by a felt cover) is preferable for initial drying. In this way, the various and different portions of the sheet can contract unrestrained. This may result in slight cockling, but disengaging at the join location is usually avoided. In some instances, it is necessary to place a plastic film mask over the artifact with holes cut out to match fill locations. This serves to dry the relatively slow drying fills first which may prevent disengaging at the join and reduces the chance of tide stains from water retained in the fill wicking into the artifact.

12. For final flattening, the repaired sheet can be evenly humidified with a minimal quantity of water and then lightly pressed between felts under weight of glass.

13. For added strength, Japanese tissue mends may be added along fill edges on the reverse if the area will be subjected to stress.

14. Artifacts that cannot be wet. Mylar, serving as a moisture barrier, can be placed over an object positioned on a light table. Wet pulp is applied in the loss area and slightly over the edge to allow for shrinkage of the insert on drying. The shape of the new paper will match the contour of the loss and can be affixed using conventional technique.

26.4.6 **Pulp fills made with leaf casting apparatus.**

A. Many artifacts which are good candidates for pulp repair call for a more mechanized approach.

1. Large losses. Evenness of density is difficult to control in manually applied fills of larger size. Leaf casting provides an alternate approach that can create extremely regular results.

2. A collection of items where treatment speed is important. A collection of many damaged sheets (e.g., leaves of a book) might be more efficiently repaired using leaf casting technology. Good judgement in artifact selection coupled with high quality equipment and materials (casting and beating machines and well selected and processed pulp) can result in excellent repair requiring shorter treatment times.

B. Calculating pulp to casting liquid ratio for use with leaf casting apparatus: Too much pulp yields a thick, irregular, uneven casting and too little will produce transparency and thinness. There are a number of methods in use for determining area of loss and appropriate pulp quantities and the following techniques apply to both leaf casting on the suction table and with a leaf casting machine.

1. Graph paper is placed below the loss area and those squares revealed are counted to approximate the area. This measurement is multiplied by the artifact thickness to determine the volume of the loss, which is equal to the volume of dry pulp needed for the fill.

2. The artifact is placed on top of a computer graphics tablet. The loss is traced with the electronic stylus and a computer program calculates the area. When the thickness factor is entered, the volume of pulp to fill the missing area is computed.

3. The damaged artifact is placed on a black easel (larger than the size of the sheets that will be measured). A computer with a lens attachment is pointed at the artifact and differentiates the black background revealed through the losses from the more reflective paper surface. Thickness is measured and entered into the computer to determine loss volume. (See Mazel & Mowery, bibliography)

4. Fast and accurate technique for loss calculation of many objects of the same paper and size (e.g., leaves of a book). A control (undamaged) sheet from the group is weighed and measured for thickness.

   a. Where all of the damaged leaves are the same thickness as the undamaged control: Weigh the damaged leaf and subtract that value from the control weight to find the amount of pulp necessary to make the damaged paper whole (e.g., 5.21 grams{undamaged control} - 4.11 grams {page with losses} = 1.1 grams pulp).

   b. Where all the damaged leaves are the same length and width but there is significant variation in thickness: Compare the thickness of the damaged sheet to the control (e.g., 0.002cm {damaged sheet} ÷ 0.001cm {undamaged control} = **2** {*correction factor*}). Multiply the *correction factor* times the control weight to find what the sheet would weigh if it were whole. Then, subtract the weight of the damaged sheet from this value to determine the weight of pulp necessary to do the proper repair (e.g., **2** {*correction factor*} x 5.21 grams {undamaged control} - 9.22 grams {actual weight of the damaged leaf} = 1.2 grams).

5. Seat of the pants approach: This method is very direct and practical when only a few repairs are required. Guess at the amount required and record how much is used in the first casting. Immediately after filling, take the leaf casted paper to the light table to estimate how much more (or less) pulp slurry is required to achieve a proper fill. Quickly remove the first casting and redo the fill with the corrected quantity of pulp slurry. Experience and skill often yields acceptable results with the first try.

C. Leaf casting with a leaf casting machine. *[to be expanded]*

D. Leaf casting on the suction table. With only slight modification, many vacuum/suction table designs may be used for leaf casting. A major issue is the ability of the system to handle safely a gallon or more of water at one time. The liquid should be disposed of before it reaches the suction motor. Note that this method does not differ in principle from the conventional method except that the casting fluid is contained only in the area directly above the loss. (See Futernick, bibliography)

   1. Indications for leaf casting on the suction table:

      a. Absence of conventional leaf casting apparatus.

      b. The artifact is larger than the dimensions of the leaf casting machine.

      c. When the losses are large and/or numerous and the results from hand pulp filling are too irregular.

2. Advantages of suction table casting.

   a. Pulp deposition on the artifact paper is avoided, since very little liquid is used and only a small area of the artifact is exposed.

   b. The entire sheet does not always have to be completely wet (flooded) before casting.

   c. When water-sensitive media are present, another liquid such as alcohol may be utilized to carry the pulp into place. This variation requires later selective water wetting of the fill area to effect fiber bonding.

   d. The use of a mechanized approach should not rule out hand methods. "Late additions" of pulp along either or both sides of an area of join can improve both the appearance and strength of a repair.

   e. Leaf casting on the suction table can yield very even results.

3. The process. (For more complete description, see references cited in the bibliography.)

   a. Pulp container construction: A pulp container is made using a short length (approx. 4") of plastic tubing left open at both ends. Various convenient sizes are readily available (2" to 6") at most plumbing supply stores. Containers for larger losses are easily fashioned by heating and bending Plexiglas sheeting into circular or rectangular shapes. Thin plastic film (.002") is cut into a rectangular shape several inches larger than the dimension of the container and attached to the container's edge with silicone adhesive or two sided tape. A hole, larger than the loss but slightly smaller than the opening is cut in the center of the rectangle. When suction is applied, this pulp container will temporarily seal itself above the loss area without harmful downward pressure of the container on the paper artifact. A collection of different sizes of pulp containers can be used again and again and will accommodate the variations in loss dimensions.

   b. Arrangement of materials on the suction table. A piece of thin plastic film cut larger than the top of the suction table is placed on the surface so that the extending edges hang over the table. A hole in this film is cut centrally, its dimension slightly larger than the opening of the container mask. Two layers of nonwoven spunbonded polyester fabric are placed over the opening to provide a surface on which to cast. Reemay (#2014 or #2114, from Dupont), an especially suitable material, aids in creating very even pulp formation and imparts a texture much like that achieved by contact with papermaker's felts. (Sometimes this is not desirable with smooth textured paper; tightly woven silk screen fabric provides a good alternative.) The damaged artifact is set on the Reemay so that the loss is located over the opening in the table. The container can be set directly on the surface of the paper.

   c. Delaying drainage. An interval of time is needed for filling the container with water and pulp. A removable plug can be fashioned using plastic film, cut so that it just fits in the container tube. A string or narrow strip of plastic affixed to one edge of the plug facilitates removal. The plug, inserted inside the container just prior to applying suction, is pulled tightly against the container mask to form a temporary bottom to the container when suction is activated. Lifting the attached string removes the plug, allowing the slurry to be pulled into the area of loss. Larger areas of loss are plugged better if several pieces of plastic film (each with a tail) are placed to overlap each other slightly.

Multiple plug removal becomes a louvre action, thus avoiding tidal waves.

d. Casting: Suction holds the container and plug in position while the pulp solution is poured into the container. Vacuum pressure is then adjusted. The tail of the plug is quickly pulled. This action opens the bottom of the container, enabling the liquid to drain.

e. Texturing and drying: The casting is quite wet and much water can be removed by slipping a sheet of blotting paper between the first and second layers of Reemay. Acting as a support, the Reemay can then be lifted to move the paper to a hard-surfaced table. Rubbing over the fill with a bone burnisher while it is still wet serves to compact fibers and improve the join. Using plastic film, polyester fabric or rough surfaced material as an interleaf during burnishing will help to achieve a more sympathetic match of textural qualities. Subsequent drying of the sheet in open air is often preferable to pressing even under light weight. Remoistening for final pressing and flattening is accomplished with controlled, even water application. By this time, the joined areas are more secure and not as susceptible to detactment.

26.4.7 Considerations applicable to manual or leaf cast pulp fills.

A. The quality of the join between pulp and artifact can be improved in cases where strength is especially important by casting half the fill's thickness and then turning the sheet over to complete the fill. This creates an actual encasement or overlapping of the edge on both sides. This variation is not only strong but offers the additional advantage of obscuring a dirty edge.

B. The quality of a casting and its adhesion to the artifact is dependent on many factors: the type of fiber, the nature and duration of processing, and the method of casting and drying. Pulp selection and beating is a complicated issue and experimentation and experience is invaluable here. In some cases, it is possible to obtain very satisfactory results by using pulp derived from old, good quality papers beaten in a kitchen blender. The use or addition of linters or commercially processed pulps can provide special advantages in terms of bonding strength and textural quality. Additions of colored fibers or toned pulp to a slurry can help achieve a more pleasing match. Adding cellulose powder, which acts as "fines", is useful when attempting to imitate a smooth surface.

C. See 26.3.3.C.

26.4.8 Toning fills to match surrounding artifact.

A. Pulp. While ideal pulp color can usually be obtained by selecting and/or mixing paper stock for processing, watercolors, acrylics, dyes, tea or toasted cellulose powder may be added to the fiber slurry in the blender during pulp preparation for additional coloring. Colored pulps should be thoroughly rinsed to remove any traces of unattached pigment or dye. Tests should be done to insure that the colored pulp will not color the surrounding artifact during the wet process of pulp filling. Paper may also be colored prior to pulping, however paper of the appropriate color may lighten when repulped and be too light as a fill.

B. Fills shaped of dry paper, prior to trimming or insertion.

1. The paper insert can be immersed in a bath of watercolor, acrylic paint, dye or tea. Rinsing may be appropriate. Considerations should be given to the acidity and light fastness of some of these colorants.

2. The paper insert can be heated in an oven until it darkens to the proper color (keeping in mind that this will degrade the paper).

3. The paper insert can be brush coated with a sizing material (see 26.3.2) to give a matching surface reflectance or to prepare for compensating toning.

4. The paper insert can be painted with watercolor, acrylic paint, dye or other liquid media, using a brush, roller or airbrush. When using a brush, much control of the media can be exerted by working with the media very dry.

5. The paper insert can be stroked or brushed with pastels, colored pencils or dry pigments using a variety of tools including brushes, fingertips, stumps, swabs, cotton wrapped toothpicks and cotton balls for applying and blending media.

C. Fills shaped of dry paper, after insertion.

1. See 26.4.7.B.3, 4 and 5.

2. It is often best to save final toning until the insert is in place in order to making the toning match local variations in coloration.

3. For edge fills, an illusion of continuation can often be achieved by darkening the extreme edge of the insert, since edges of paper are often dark.

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