LEAF CASTING CASE STUDIES

Vacuum-assisted infill techniques for paper conservation using a modular 3-D printed paper mould

Donald Farnsworth

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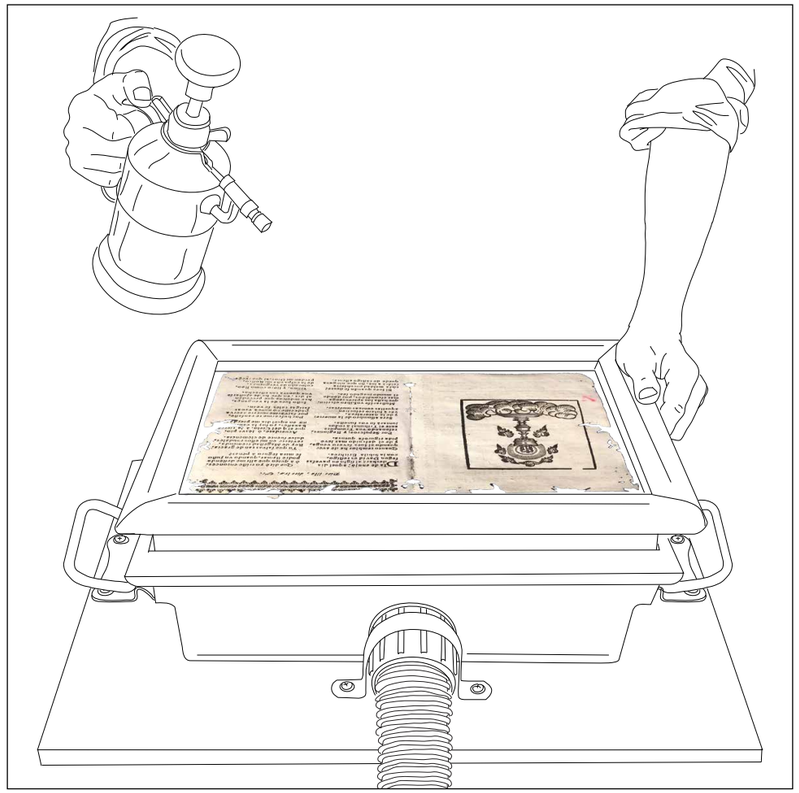

Leaf caster prototype

Donald Farnsworth

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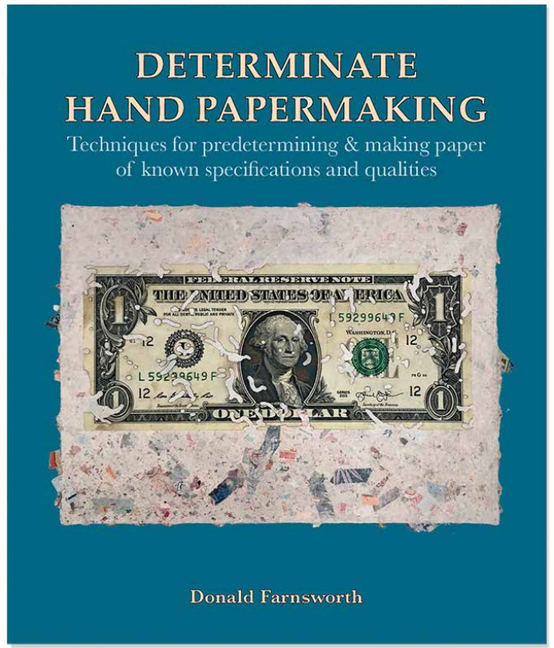


For more information on leaf casting and related techniques for making paper with specific characteristics, please see ***Determinate Hand Papermaking****, available in print or for free download at:*

http://www.magnoliapaper.com

Introduction

My interest in employing handmade paper techniques in the service of conservation began in the early 1970s while attending art school, taking chemistry classes, and working in a conservation lab in Berkeley, California. Later that same decade, working in my first paper studio, conservator Keiko Keyes and I experimented with combining sheet formation, infill and document repair, culminating in a presentation at an AIC conference*. Some 40 years later and with my papermaking knowledge greatly fortified, I revisit my roots.

Leaf casting, a relatively new, vacuum-equipped variation on the centuries-old deckle box technology, is used to strengthen and infill missing areas on damaged incunabula and other works on paper. The learning curve and meticulous effort required per leaf when using existing techniques has caused some to shy away from this otherwise effective practice. My intent here is to make leaf casting more viable and flexible by integrating both modern and traditional papermaking techniques and equipment, enabling conservators to draw on the wealth of historical sheet forming possibilities from both Eastern and Western handmade paper traditions.

Not all damaged documents require leaf casting infills; one must choose from a variety of conservation techniques depending on the artifact in question. Leaf casting can be useful when recreating the integrity of the object's original dimensions is desired. One need not be intimidated by the leaf casting process, as the steps involved are quite similar to the familiar process of making a sheet of paper.

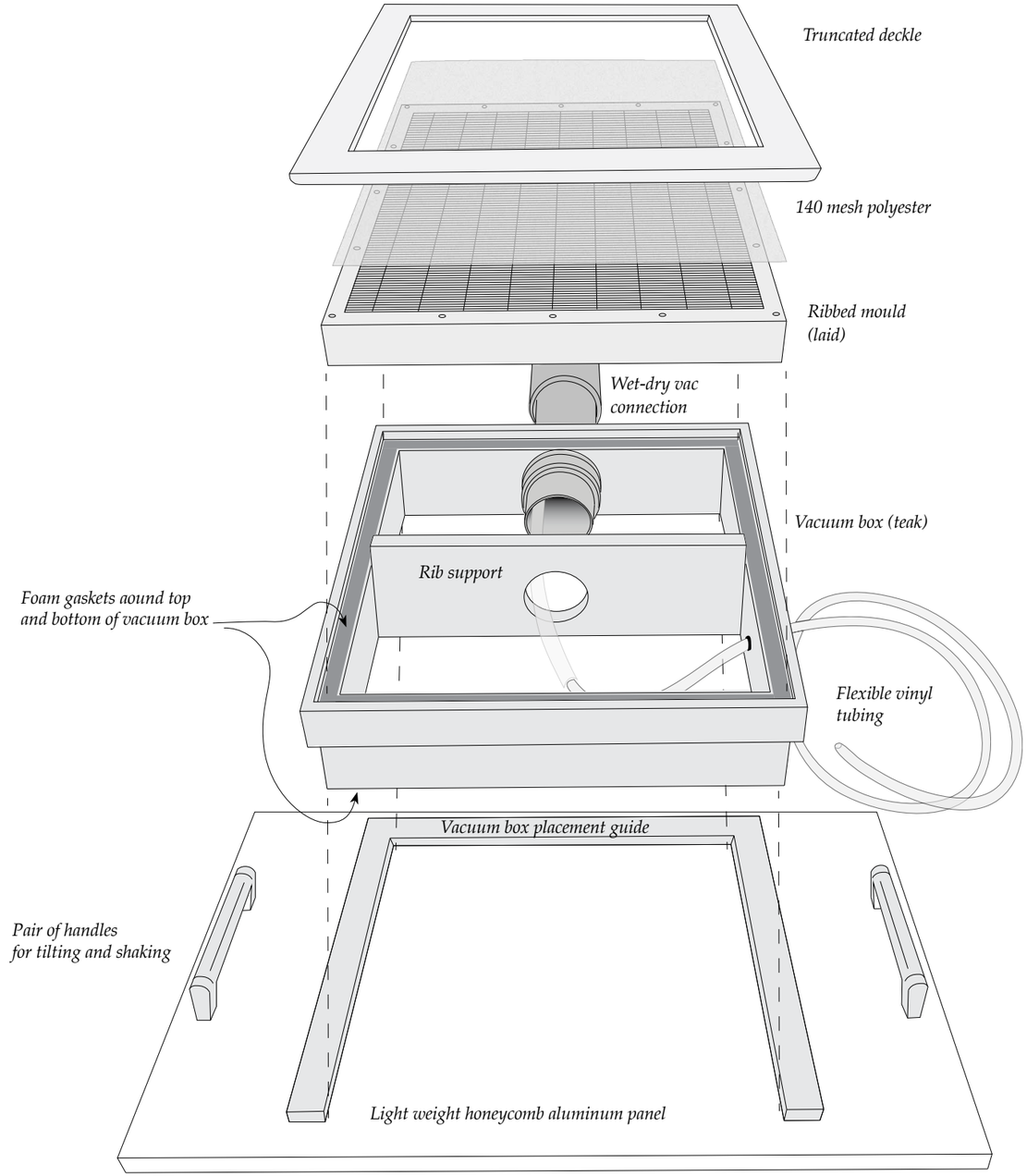
*Keyes, Keiko Mizushima, and Donald S. Farnsworth: *A practical application of paper pulp in the conservation of works of art on paper*, 1976. In AIC Preprints, American Institute for Conservation 4th Annual Meeting, Dearborn, 76–86. Washington, D.C.: AIC.

Simple leaf caster: design notes

The designs herein combine a leaf caster's vacuum deckle box with a lightweight, 3-D printed ribbed mould and deckle, enabling the user to lift and shake the mould (as in traditional papermaking) while the vacuum is turned on. As diagrammed on the following pages, our leaf casters are comprised of a 3-D printed ribbed mould and deckle (laid or wove). When assembled, the handles on either side of the support tray allow the entire box and mould to be manually agitated during sheet forming, which – in conjunction with the use of formation aid – enhances fiber cohesion and ensures that the document is not simply covered with pulp. Placing two foam gaskets – the first around the bottom of the teak vacuum box where it meets the smooth aluminum tray and the second located where the mould sits at the top of the box – enable the whole structure to sit firmly unified in place while under vacuum seal. When not under vacuum pressure, the mould may be lifted from the box and the box lifted from the tray, allowing for drainage of built-up white water.

The document is next protected with a polyester mesh and blotted while under vacuum. The mesh-document-mesh sandwich can be lifted and dried. This is the safer approach for delicate paper artifacts; forming on a 400 mesh polyester screen, then covering with another screen eliminates the need for direct handling of the moist document. Alternatively, mould and deckle can then be removed and the composite sheet couched in the traditional papermaking manner. The underlying mesh may be plain (wove), or printed with a laid-pattern and watermark.

Leaf Caster
3-D printed mould and deckle
with removable vacuum box – 11.5 x 11.5 inches



Modular leaf caster: design notes

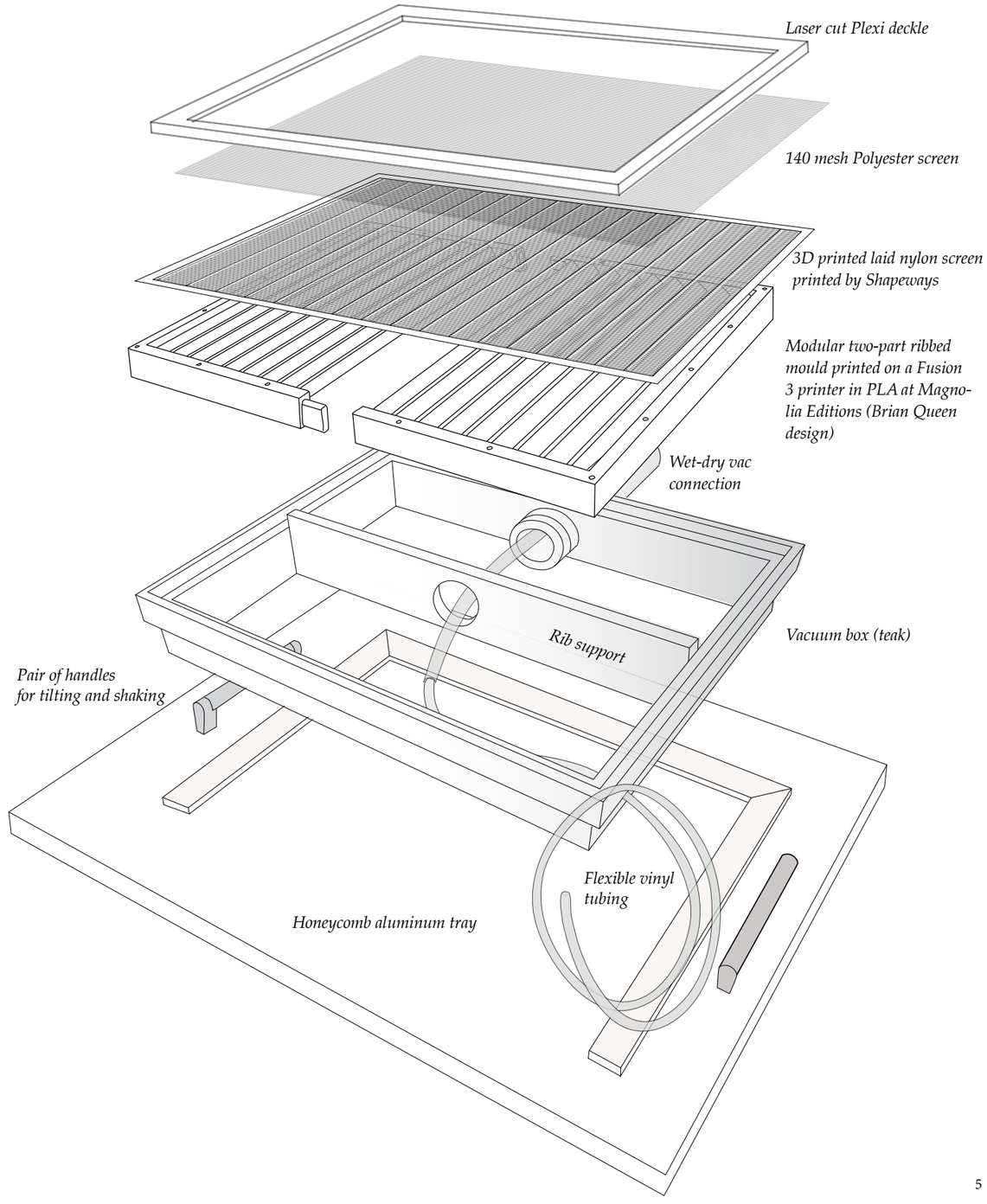
A key component of a Magnolia Editions' leaf caster is a removable 3-D printed ribbed mould. Surprisingly – unbelievably, even – this lightweight ribbed mould, printed in-house entirely of plastic, looks and behaves like a traditional mahogany ribbed mould and deckle – so much so that it can be used in a traditional European handmade paper production line. The modeled (.stl) files for these plastic moulds and deckles were created and provided by Canadian papermaker Brian Queen – surely deserving of a ***Contributions to the Field of Hand Papermaking*** award (if such an award existed).

Although 3-D models can theoretically be printed at any scale, until January of 2019 our mould dimensions were limited by our largest 3-D printer, the *Fusion 3*, which has a build size of 14 x 14 x 12 inches (355 x 355 x 315mm). In two days of continuous printing, this printer can build only one mould and one deckle with maximum sheet dimensions of 11.5 x 11.5 inches – a bit small for most documents in need of infill.

Wishing to continue my research into employing this versatile leaf casting equipment design at a larger scale, I was excited to learn that Brian had developed, modeled and tested a modular paper mould: a ribbed mould that can be printed in parts and assembled to create a larger format ribbed mould. With Brian's help, I put his .stl files to the test, printing the two-part mould on our *Fusion 3*. The laid screen (not modular and too large for my printer) a 12.5 x 18 inch (nylon) was a file Brian had uploaded and ordered from the online 3-D printing company Shapeways specifically for my leaf caster design. Next, I made vector files to laser-cut a Plexi deckle with nesting, removable rectangular masks. Cabinet maker Miguel Mendoza built the teak vacuum box and I used foam gaskets to form seals between the components.

Modular Leaf Caster

3-D printed two-part ribbed mould
3-D printed laid screen and laser cut plexi deckle
with removable teak vacuum box – 12.5 x 18 inches



Preliminary leaf casting tests

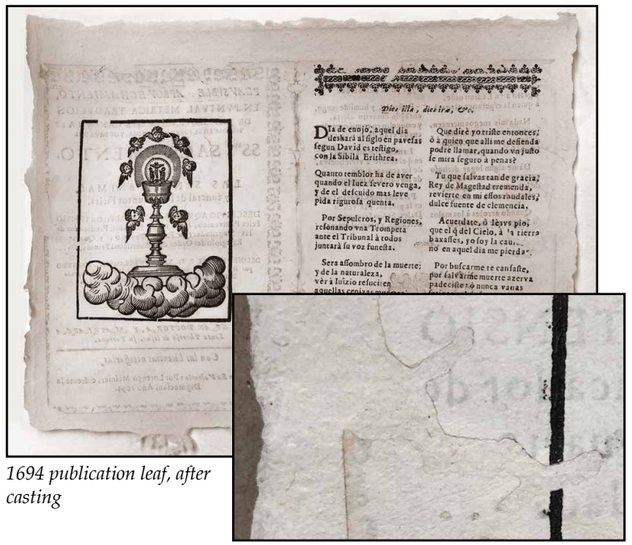
Our first 3-D leaf caster, printed and built at Magnolia's paper studio, was literally held together with bailing wire and duct tape. My focus was (and remains) to make leaf casting affordable, accessible and more similar to traditional handmade papermaking – less like a foot-treadle-deckle-box. Coaxing fibers to distribute and flow into worm-eaten voids while determined not to damage a fragile paper artifact, I found the nature of the material dictated how to proceed; specifically, the gentle sophistication of Japanese nagashizuki techniques came to the forefront as my preconceived plans of taming these fibers fell by the wayside. In these case studies, cellulose fiber, neri, and the tradition of handmade papermaking are our guides.

My earlier attempts at leaf casting on a laid screen demonstrated the problem with pouring as opposed to the genius of the traditional papermaking technique of dipping and pulling the mould through a vat of furnish to align the screen-side fibers against the grain of the laid lines. We soon compensated by employing the use of fine 140 mesh polyester screens to stop fibers from tangling with the laid lines.

An East-meets-West approach using linen, hemp and neri furnish on worm-eaten Western papers incunabula worked surprisingly well, even using the earliest prototype. The key factors on a two-sided document where infill is desired only in the voids include not over-hydrating the furnish; using plenty of neri (formation aid); and a gentle misting while under vacuum to keep a flow of fibers migrating to the voids.

Our first leaf caster was held together with bailing wire and duct tape

A leaf from a 1694 publication – worm eaten with enlarged sewing/binding holes



1694 publication leaf, after casting

Inspecting the look-through of a leaf cast dollar bill whose portrait has been removed and cast with a light-shade watermark

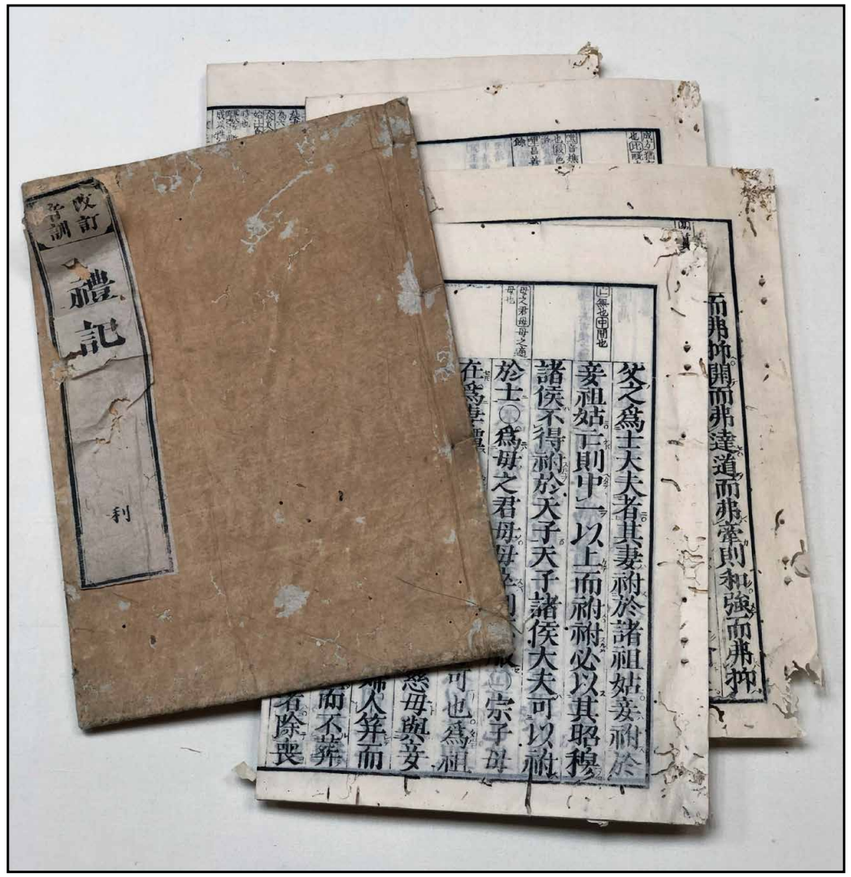
Detail of leaf cast dollar with central image replaced by light-shade watermark

Leaf cast dollar with light-shade watermark

In one early leaf casting experiment, Magnolia Editions master printers Tallulah Terryll and Nicholas Price, artist Era Farnsworth and I attempted the leaf casting of an ordinary U.S. one dollar bill whose center vignette of George Washington had been excised with a scalpel. In the same casting, the area surrounding the dollar was cast on polyester mesh printed with a laid pattern.

After spending a day with artist Guy Diehl refining the gaskets of the leaf caster V2.0, it was time to repair the now damaged bill. The following day I created a short fiber pulp by beating very dilute Celesa flax half-stuff hard and fast in a Valley Iron Works beater for 20 minutes. The reason for extreme shortening of the fiber was our desire to insert a light-shade watermark of George Washington in the center egg-shaped area. On 137 polyester mesh (supplied that day by screen printer John Ream), Tallulah and I designed and printed a dozen graphical interpretations of George with multiple layers of UV cured acrylic ink, upon which we leaf cast with the short fiber furnish until we determined which graphic would generate the most favorable light-shade watermark portrait.

We placed the laid printed polyester mesh on the leaf caster's laid paper mould surface. Next, we placed the wove mesh printed image (negative) of Washington, registered to the missing 'egg' of the bill, the perimeter of which we had trimmed smaller than the height and width of the dollar. With the suction on, we poured the short fiber furnish and settled the fibers. The laid-printed-mesh cast around the bill created a strong laid line show-through, and the wove-mesh printed portrait (laid just under the dollar) produced what I consider a fairly decent light-shade watermark, with no hint that just below it was the background laid screen.



Case #1: Japanese washi incunabula

Time note: Case studies 1, 2 and 4 were accomplished in a surprisingly short period of time. Conservator Karen Zukor and intern Solene Chazaux arrived at Magnolia's paper studio at 1:30 pm and (besides soaking the fibers the day before) work was completed promptly, finishing by 4:30 pm: a total of three hours, start to finish.

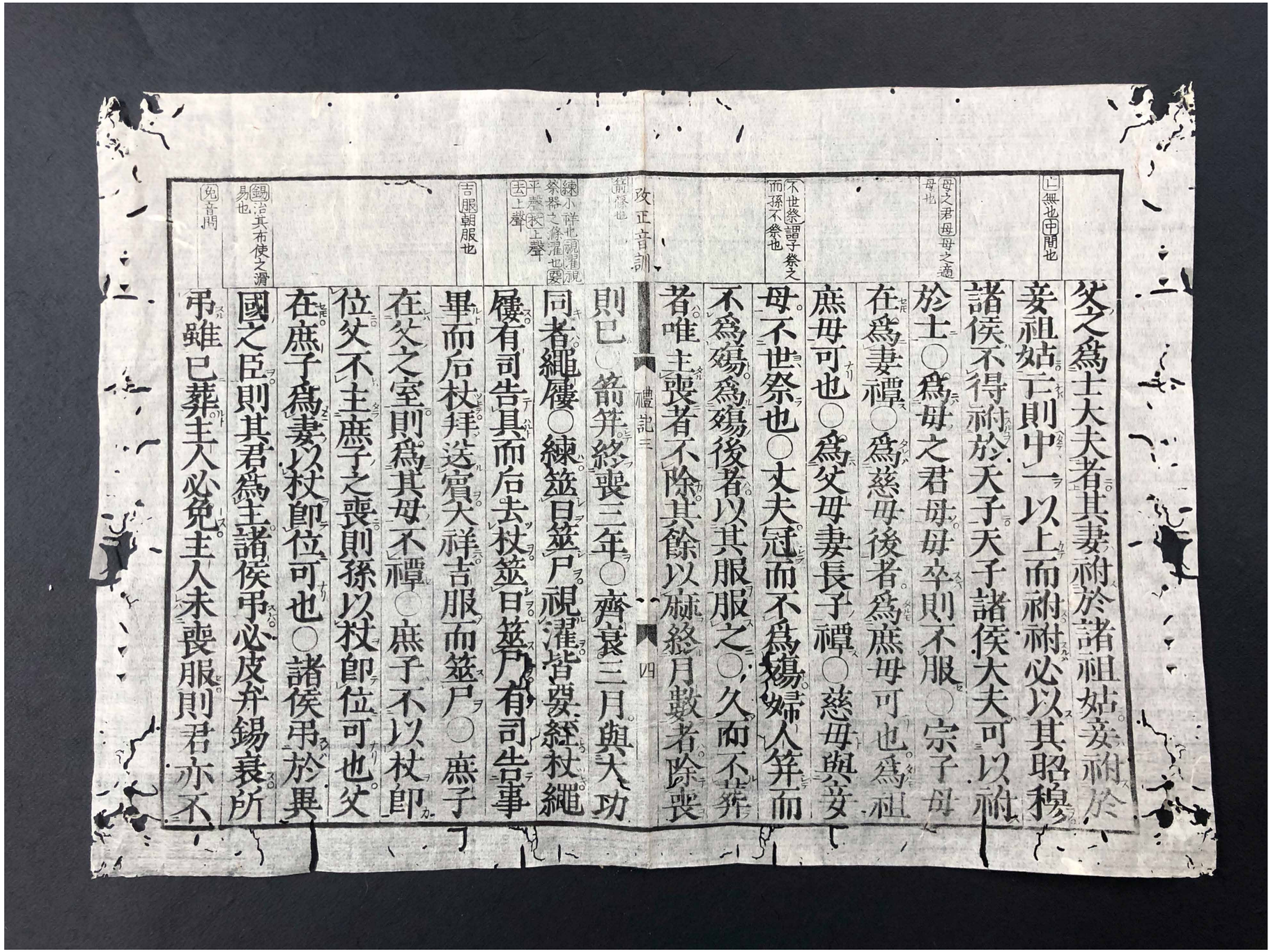
Traditional Japanese washi sheet formation

Paper conservator and friend Karen Zukor of Zukor Art Conservation allowed me to demonstrate and test my 3-D printed leaf caster at Magnolia's paper studio, using several examples from her collection of antique and worn papers, beginning with a worm-eaten Japanese incunabula. As the book was a gift, its precise age and provenance are unknown; the archaic Japanese characters on the cover translate approximately to "ritual commissions." As is common in Japanese book binding, each leaf is folded in half with printing only on the recto and nothing on the verso. All leaves are pierced and bound with stitches through the margin and, in this case, extensive damage caused by the bookworm beetle grub.

Japanese waterleaf washi, made from paper mulberry bast fibers (fibrous material from the phloem of kozo, mitsumata and gampi) respond to leaf casting quite differently than older Western papers (made from linen and hemp rags – also bast fibers). When filling the missing areas of a Japanese paper in a leaf caster, the slurry behaves as if we were simply continuing the formation process begun by a Japanese papermaker so many decades or centuries ago. With the correct fiber and adequate neri, we can agitate and slosh the furnish – shaking, tilting and throwing off kozo knots – just as if we were the papermaker, performing additional dips in accordance with the traditional washi process.

In the case of Japanese washi made in the nagashizuki* method, sheets formed on bamboo screens dipped multiple times into a slow draining furnish: the papermaker shakes the mould front to back and side to side, building up and weaving the layers of fiber as the viscous, neri-laden water drains.

** For more details see **A Guide to Japanese Papermaking** at* http://www.magnoliapaper.com



An open leaf from the incunabula

Many of the factors that make the washi formation technique so appealing are duplicated in the leaf casting process, which allows us to form a fresh gossamer layer of paper fiber on the sheet's verso and, at the same time, to fill the missing areas eaten by the bookworm grub.

Japanese washi incunabula

The positive:
We are working with a one-sided (i.e., only printed on one side), strong, unsized sheet containing a percentage of long bast fibers, naturally fortified with hemicellulose, giving our new fibers something to tangle with (literally). Its hydrogen bond potential is ready and waiting to work with our fibers.

The down side:
Although the paper is strong, it is no longer structurally sound, it is quite thin with copious bookworm (grub) damage, making it difficult to handle when wet and fully relaxed. Fortunately, a 140 mesh polyester screen can be used as a temporary support throughout this process, allowing us to transport the document without added stress.

Matching infill fiber to document color

I identified the Lab values of the dry processed half-stuff fibers I have on hand, as well as the values of the unbound book paper, using an X-rite Sphere Spectrophotometer (set to D50/2, i.e. the color viewed in 5000° light at a 2° angle of view). Next, I turned my attention to the fibers I have cataloged and archived over the years.

For this case study, I augmented my catalog of fiber colors by including two waterleaf papers from Awagami paper mill – measuring and adding Lab values for their kozo and gampi to create an expanded library of available hues and values of fiber for these infill studies. I converted this spreadsheet grouping of 27 colors (opposite page) into an .aco file (swatches) – essentially a lookup table of colors. Using a technique prescribed in *Determinate Hand Papermaking*, I translated (indexed) the book paper's Lab values into my available library of colors in Photoshop and found the percentages of kozo, hemp and gampi needed to closely match the book paper color.

Unless matching a pigmented paper, I avoid the use of pigments and dyes in my fiber library: I try to keep it simple, per the papermakers of centuries past. Fibers that have been cooked, retted, hand-beaten and/or minimally processed in a Hollander, with a touch of calcium and magnesium carbonate as a buffering agent and antioxidant can be found in my library. Pigment, however, could result in a "restoration" that, with time, no longer matches the paper artifact. I like to think that pure, natural fibers (not cut or chopped as so many papermakers do with flax roving) will age as gracefully as the fiber sources of ages gone by. (That said, a library of pigmented paper fiber half-stuff might prove useful for some projects.)

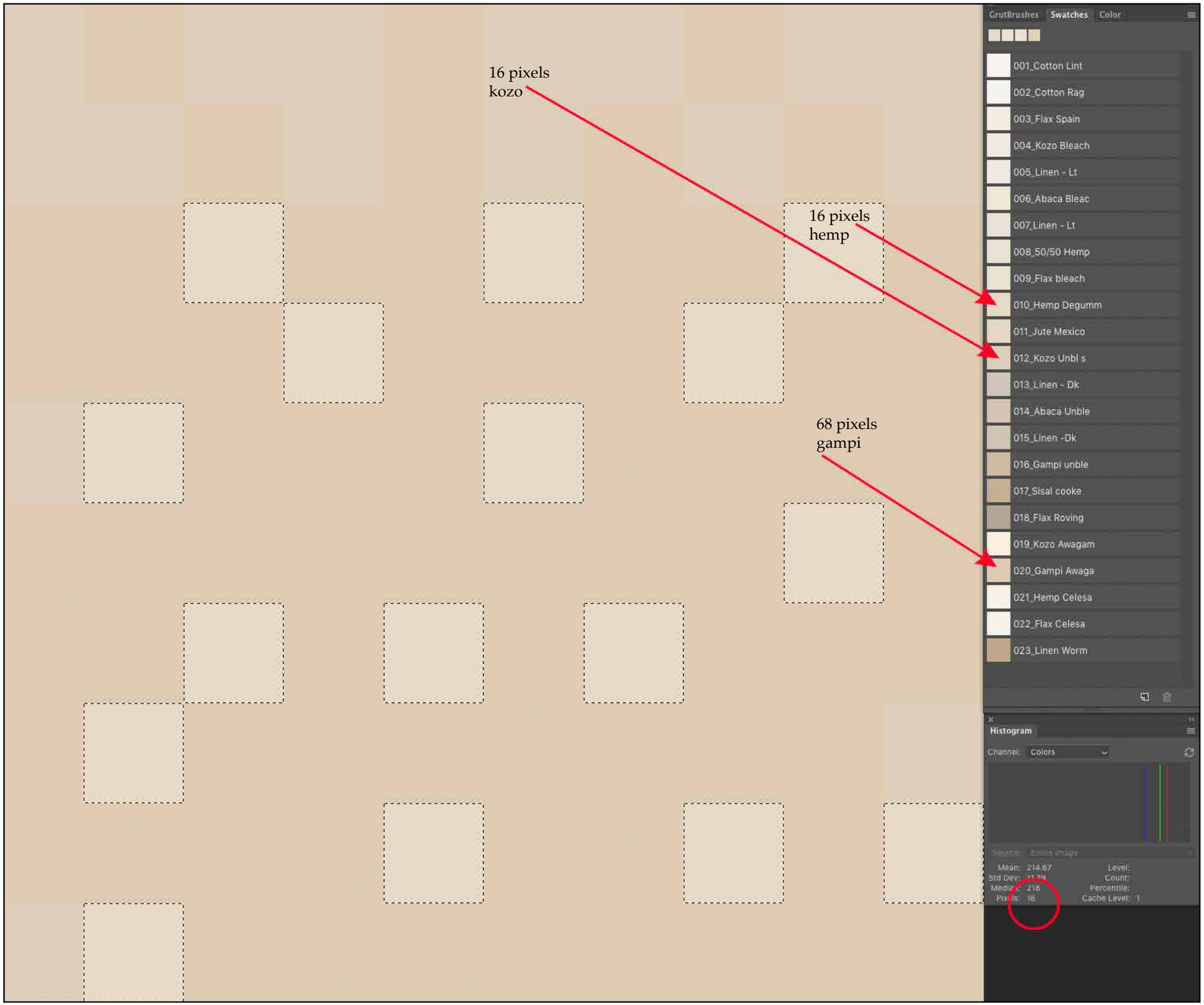
Sphere Spectrophotometer

Avoid or minimize the use of cotton rag and cotton linter:

Unless you are leaf casting to match a 19th, 20th century or contemporary Western fine art paper, cotton should not be used. For older European papers, use linen (flax) and hemp half stuff; for Japanese papers, use kozo, mitsumata, gampi and abaca. These bast fibers contain hemicellulose, an important component in the European and Japanese methods; cotton, a seed hair fiber, has no hemicellulose. In leaf casting, **hemicellulose is important for edge adhesion (without using paste) and is compatible with formation aid,** a viscous mucilage additive that promotes even distribution of fiber.

	Magnolia Pulp Swatches				3/24/19
	Description	L	a	b	Color
1	0	0	0	0	
2	Cotton Linter	97	0	3	
3	Cotton Rag Bleached (Cheny)	96	0	2	
4	Flax Spain	94	1	6	
5	Kozo Bleached H2O2	93	0	5	
6	Linen - Lt RL Marin	93	0	4	
7	Abaca Bleached	92	1	8	
8	Linen - Lt Jacquard	90	1	7	
9	50/50 Hemp dg, Lt Linen Jacq	90	1	8	
10	Flax bleached Cave ppr 1/4" c	90	0	9	
11	Hemp Degummed	88	2	11	
12	Jute Mexico Coffee Bag	87	2	10	
13	Kozo Unbl solvent exchange	84	3	12	
14	Linen - Dk Rag jacquard	81	2	8	
15	Abaca Unbleached	81	3	11	
16	Linen -Dk RL Marin	80	2	9	
17	Gampi unbleached	77	4	17	
18	Sisal cooked hand beaten	73	4	17	
19	Flax Roving Cooked	69	2	10	
20	Kozo Awagami	95	1	10	
21	Gampi Awagami	83	4	15	
22	Hemp Celesa	96	0	5	
23	Flax Celesa	96	0	4	
24	Linen Worm Farm	70	6	18	
25	50%BA 50% UBA	87	2	8	
26	Bleached Abaca	92	1	8	
27	Unbleached Abaca	81	3	11	

Library of fiber colors



Matching fiber library swatches to target paper color

The Lab value of the book paper for this case study was determined to be: **L= 85 a= +3 b= +17**. Having previously measured and identified my library of half-stuff fiber, I used Photoshop to index a 10 x 10 pixel square (100 pixels) of the paper color (L85, a3 and b17) to the library of pulps I have on hand as an .aco table (with dither set to 100%)*. In this process, Photoshop selects the fibers and percentages for me to make the most accurate color match. Luckily, indexing into my library did not choose cotton, or I would have had to remove that fiber from my lookup table and index again.

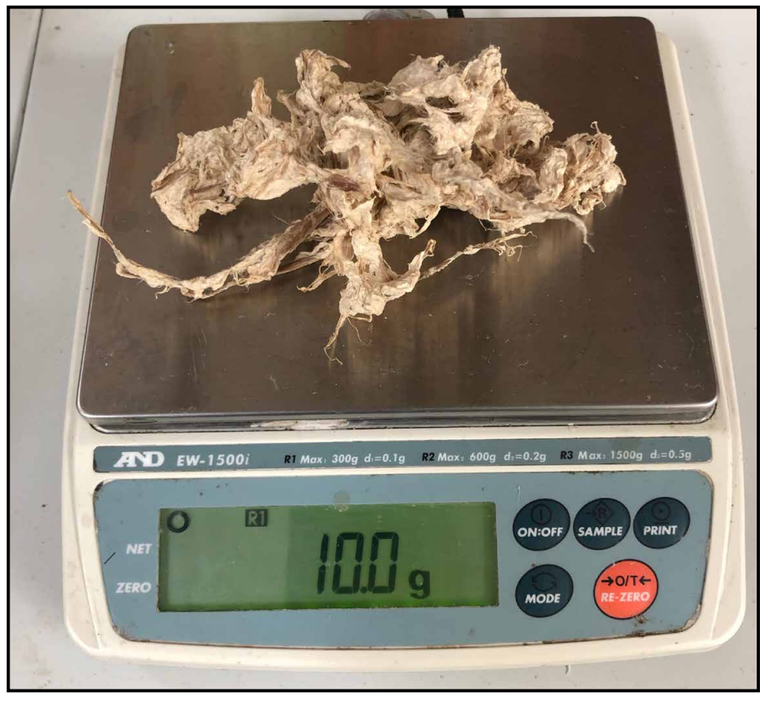
Next, I selected the chosen pixel colors one at a time, referring to the Histogram palette to determine how many of the 100 pixels were selected for each color. In the screen capture at left, we see circled in red that three colors were chosen. There are 16 pixels of *de-gummed hemp*: that is, 16% of my furnish should be ***de-gummed hemp***. By selecting the other two pixel colors I learned that the formula would also include 16% ***unbleached kozo*** and 68% ***Awagami gampi***.

In my tests using washi, the furnish disperses itself evenly across the surface of the worm-eaten leaf, bonding like a smooth gossamer network of fibers while adding strength and filling the voids. Nevertheless, once dry, this gossamer is easily reversible with the addition of slight moisture – a veritable poster child for conservation. By stark contrast, when leaf casting using Western rag papers, the furnish has little interest in evenly dispersing and adhering to the surface of a leaf of European animal-sized linen and hemp rag paper and tends to migrate to the voids. While not always desirable, this can be a useful characteristic when working with two-sided works.

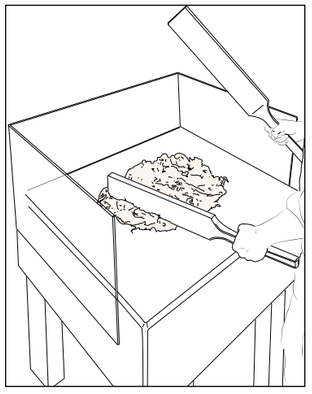
For more information on Photoshop technique, please see **Determinate Hand Papermaking, available in print or for free download at:* **http://www.magnoliapaper.com**

Preparing the furnish

In preparation for making the furnish, I weighed out 10 grams of each of the three dry fibers suggested by my indexing of my Photoshop lookup table: degummed hemp, unbleached kozo and Awagami gampi; I then soaked them in water overnight. Soaking for more than two hours is a proven and important step to ensure the quality and strength of the finished paper.



Soaking/hydrating the fiber for 12+ hours



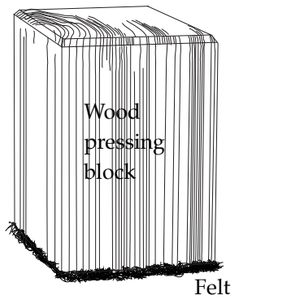
The following day, I found that the kozo and gampi required further beating by hand in order to fully disperse the fibers (about three minutes with a mallet was sufficient for this small quantity). Next, I blended each 10 gram sample in 900 ml of water, to which I added 100ml of formation aid at the end of the blending cycle. The total furnish for each of the three fibers selected, measuring 1000ml, made my concentration an easy-to-calculate 1g per 100ml – perfect for blending accurate proportions.

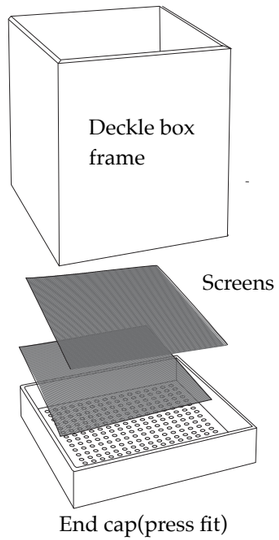
Three pulps blended and ready for mixing in the proper proportion of 68% gampi to16% hemp and 17% kozo. I use beakers with handles as neri is very slippery – get a little bit on your hand and a beaker will slip right out.

Making small test sheets to check color accuracy

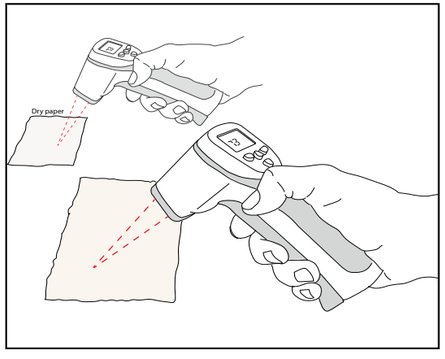
At this point I made small test sheets using a 3-D printed deckle box to verify that this fiber selection was leading me in the right direction. Using the *PaperWeight* mobile app, I verified my fiber concentration; I also tested the Lab values of the test sheets using a spectrophotometer.

For more details on the 3-D printed miniature deckle box used to make small test sheets, please see ***Determinate Hand Papermaking*** *at* **http://www.magnoliapaper.com**

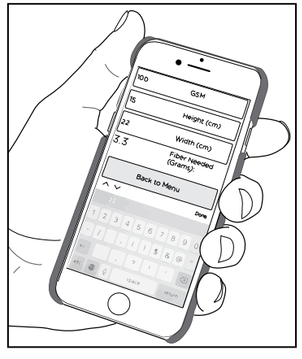




Above: a 3D Printed deckle box for making quick 4 x 4 in. paper samples. Free .stl download available at: **http://www.magnoliapaper.com** *where you can also find instructions on its use in* ***Determinate Hand Papermaking.***



Using a laser thermometer to verify test sample sheet's dryness



PaperWeight
Free download available at:
http://www.magnoliapaper.com

Adding formation aid

Adding and mixing in more formation aid

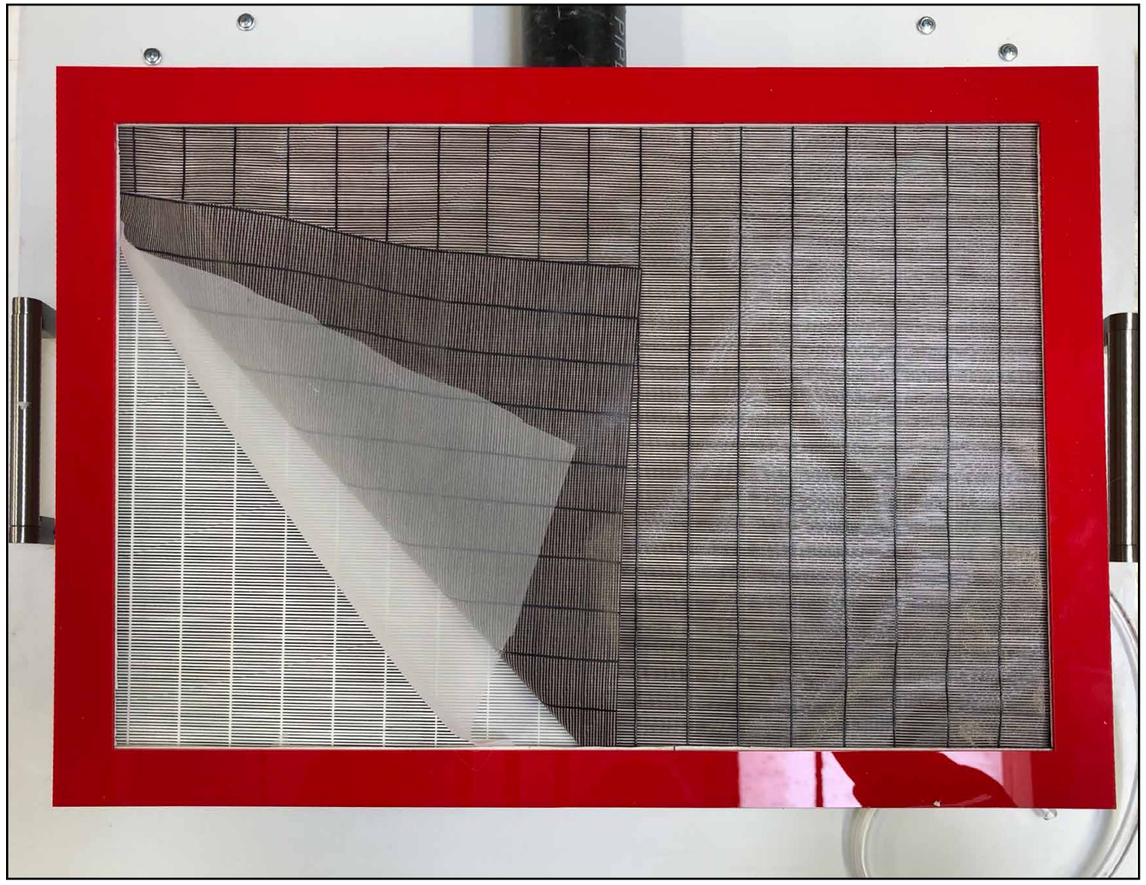
After calculating and verifying fiber concentration and color, I often mix in additional formation aid to make the furnish more pourable.

Why use formation aid?

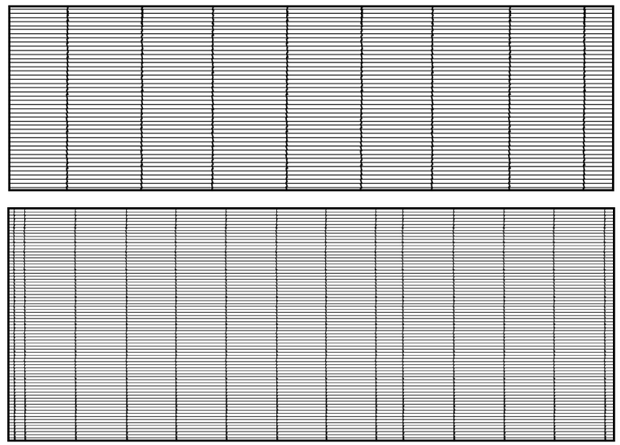
Formation aid (*neri* in Japanese) solves many of leaf casting's potential problems and frustrations. With the proper amount of formation aid, one creates a slow-moving, slippery, viscous furnish that will not displace, lift or otherwise damage the document. Additionally, the thick viscosity of the suspension allows fiber to flow to the missing areas while tending to avoid settling on the document. If the furnish drains too quickly, try again with a higher percentage of formation aid and/or reduce the vacuum pressure.

Neri has been used in the manufacture of Japanese paper for hundreds of years. The solution itself is comprised of a very small percentage of solids (one teaspoon to a gallon) and does not size or have a lasting effect on the paper besides keeping the fibers from knotting and tangling during formation.

Benefits of polyester mesh screens



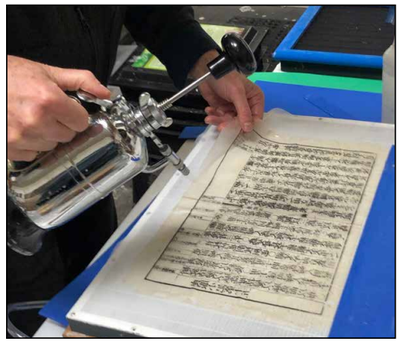
When pouring pulp on the leaf caster, where the fibers are not aligning across the laid lines, I found that a fine 140 mesh polyester screen printed with a laid pattern using a UV-cured acrylic printer gave us good "look through" while avoiding the entanglement of fibers on an actual laid screen. As an added benefit, many different spacings can be printed on multiple 140 mesh polyester screens, allowing for various options to choose from when aiming to approximate a document's existing laid pattern.



European and Japanese laid patterns printed onto 140 mesh polyester placed under the document prior to casting create laid pattern look-through
Top: 20 laid lines to the inch and 1 inch chain line spacing;
Bottom: 22 laid lines to the inch and chain line spacing based on a Japanese su

Conservation intern Solene Chazaux carefully smooths the relaxed sheet and polyester mesh support on top of the laid screen surface, removing air bubbles and wrinkles

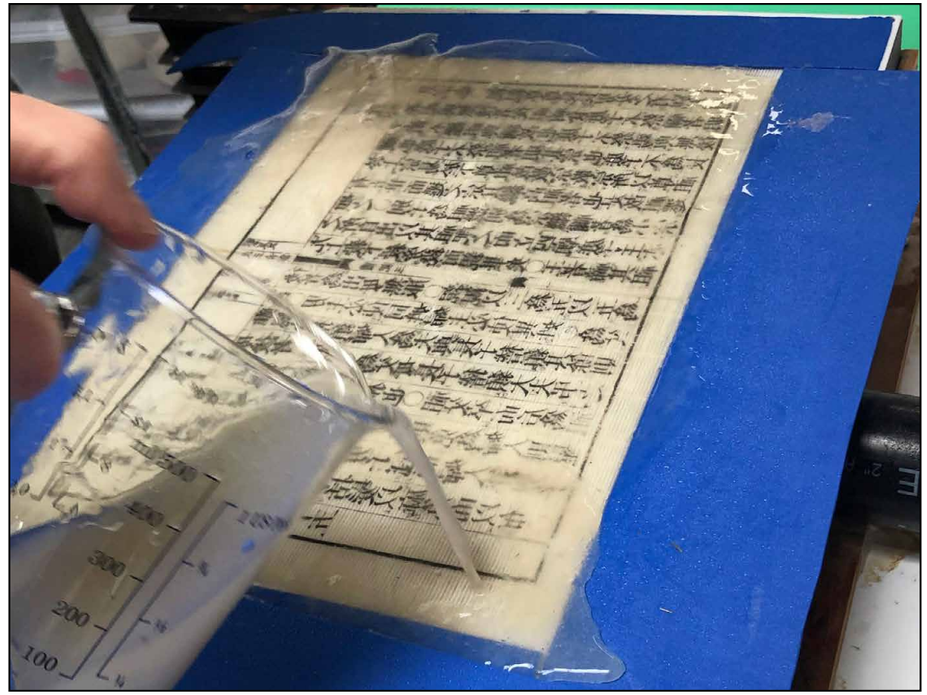
Pouring and distributing furnish with vacuum suction



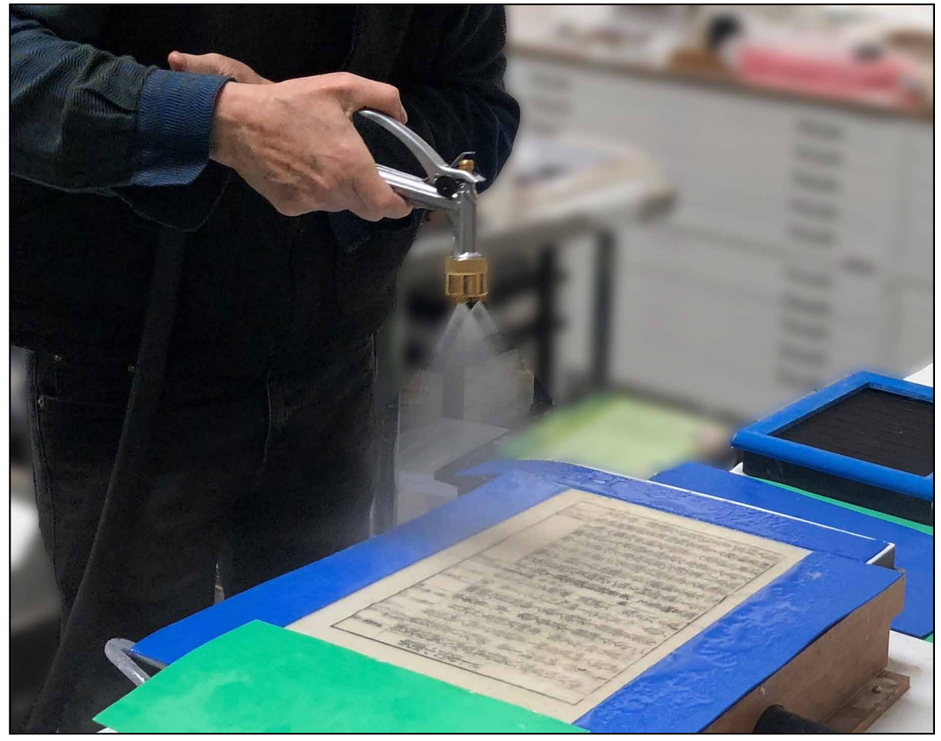
Moistening document

After moistening the document with an atomizer, and surrounding the document with ethylene vinyl acetate foam (AKA hobby foam) I turned on the vacuum – flattening and securing the sheet to the surface of the mould via suction – and began pouring the furnish, thoroughly distributing it across the sheet in thin repaetative layers. I then used the spray of a mister to further distribute the fibers, gently moving them into the wormhole voids.

Pouring furnish while under vacuum



Pouring furnish while under vacuum

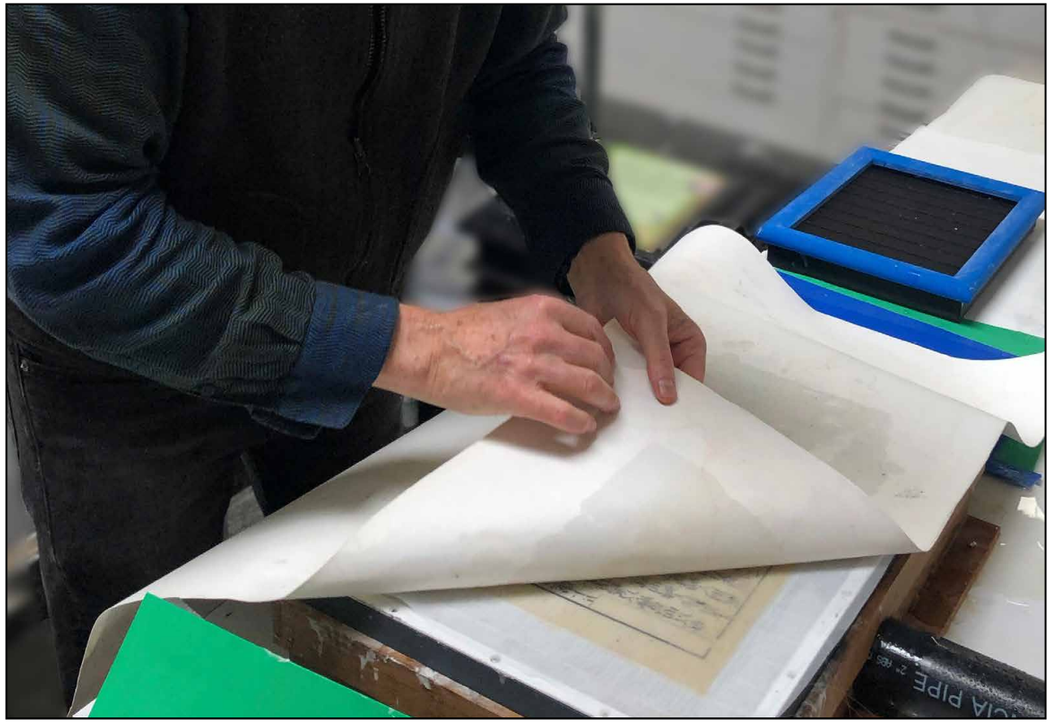


Misting furnish, allowing fibers to migrate and build up in the wormhole voids

Overlaid polyester mesh and blotting with Evolon

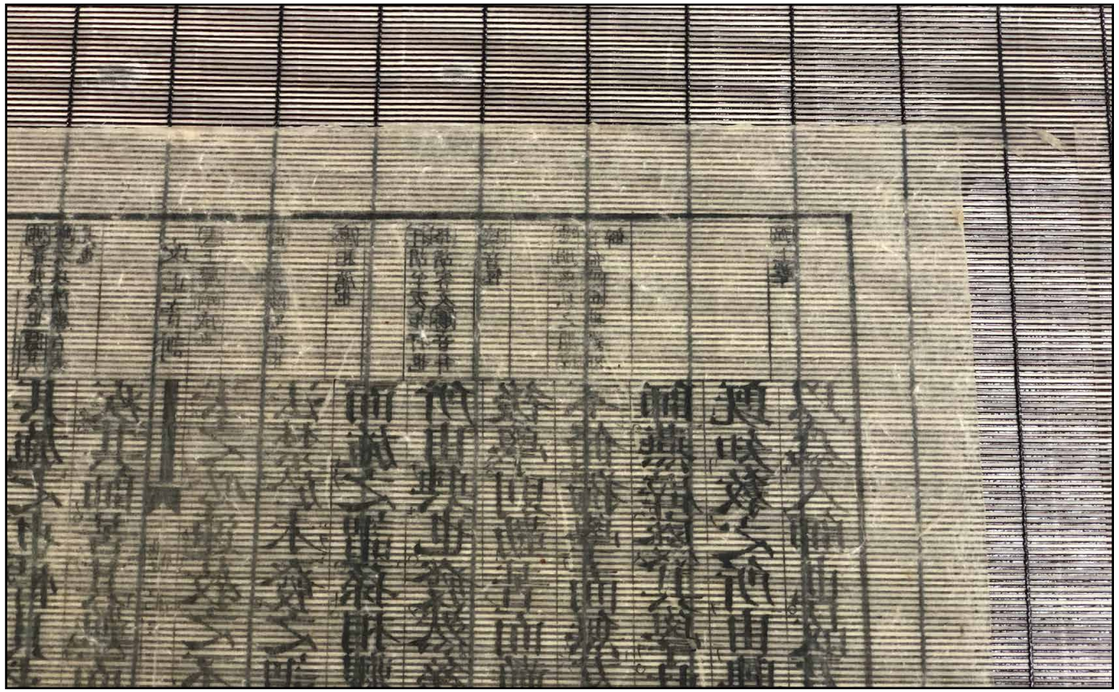
Covering the document with a 140 mesh polyester prior to blotting

The sheet was covered with a layer of 140 mesh polyester for protection during blotting and drying. The material used for blotting is **Evolon AP (168 gsm)**, a non-woven microfiber paper made from polyester and nylon. Evolon absorbs many times its weight in water and is tearproof and lint-free.

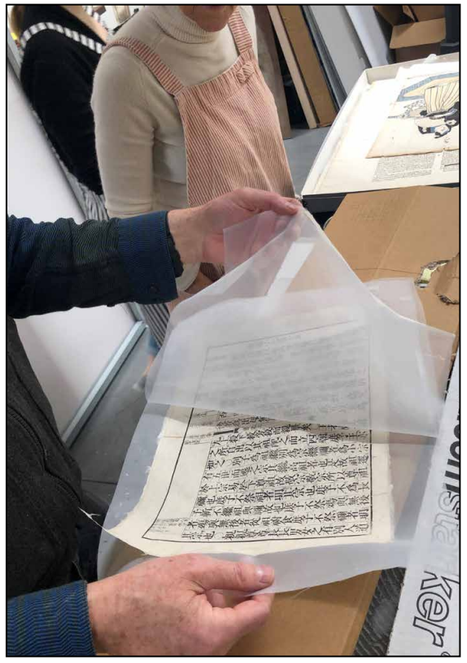


Blotting with Evolon

Handling with layers of polyester mesh



Leaf cast document on the back side of printed polyester mesh



As previously noted, the mesh-document-mesh sandwich can be easily lifted and dried. This is the safest approach for delicate paper artifacts: forming on a 400 mesh polyester screen, then covering with another screen eliminates the need for direct handling of the moist document.

Letf to right: Lightly filled, thick fill, medium filled/trimmed and worm-damaged sheets

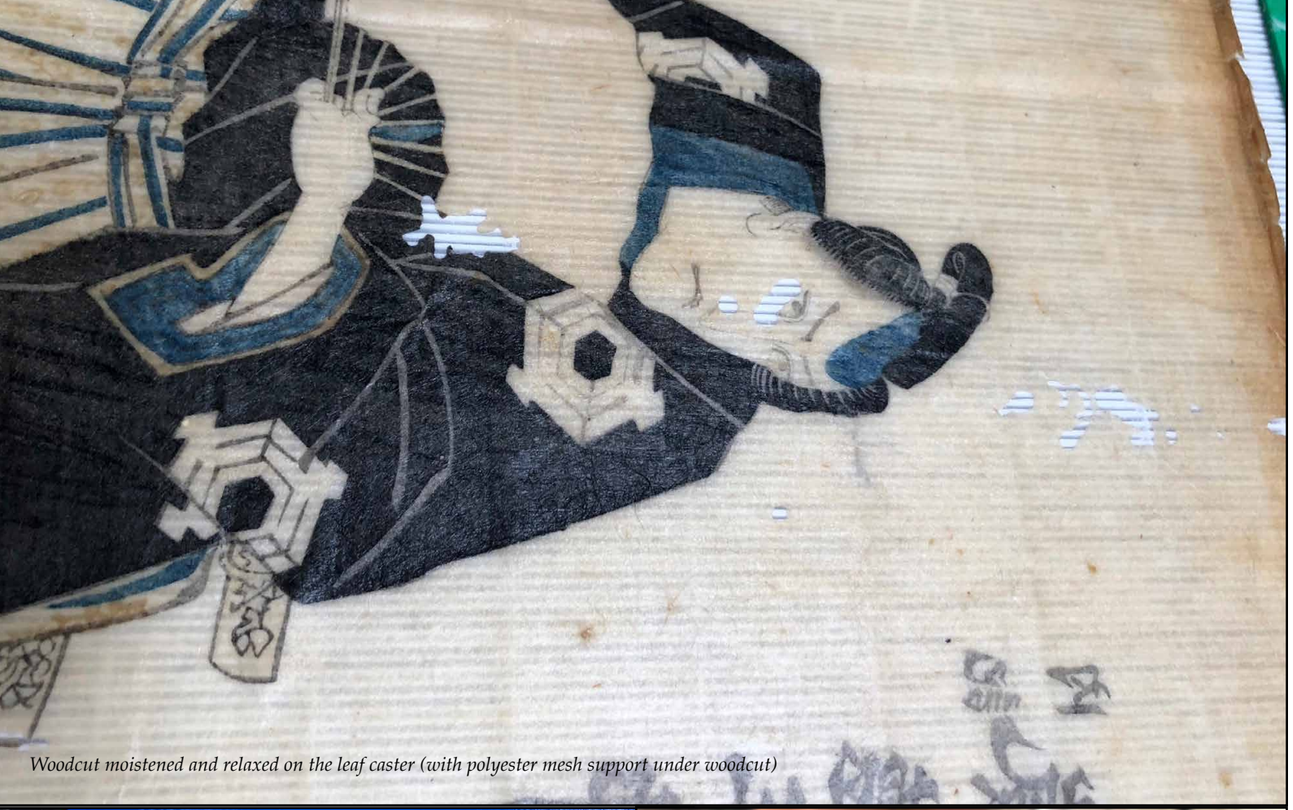
The fibers selected, processing and procedures produced results that surpassed all expectations in these tests. When strictly adhering to the indexed percentages of fiber library colors, the color matching was shockingly accurate to the original incunabula in hue and value. The gossamer of fiber distributed on the verso in the thin book paper returned the leaf to what I assume was its original rattle and strength. The infilled and dried leaf was strong, flexible and fresh, having more in common with a newly manufactured sheet of washi than a paper ravaged by bookworm larvae.

Case #2:
Japanese moku hanga

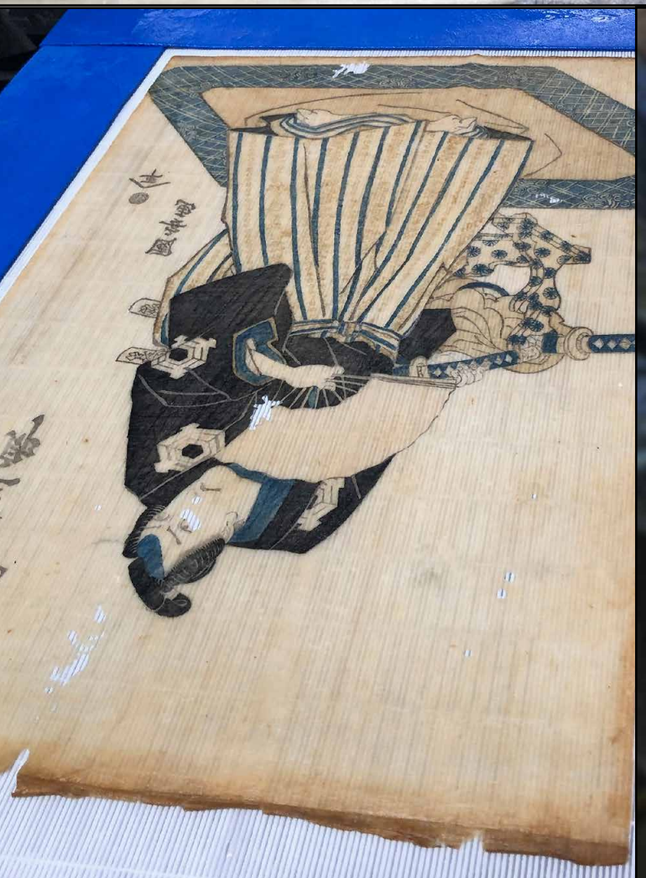
To infill the wormholes on this delicate woodcut, we used the same series of steps as described in Case #1: Lab discovery, color matching document to a library of known fiber colors, furnish blending and preparation, casting in multiple layers, blotting and drying.

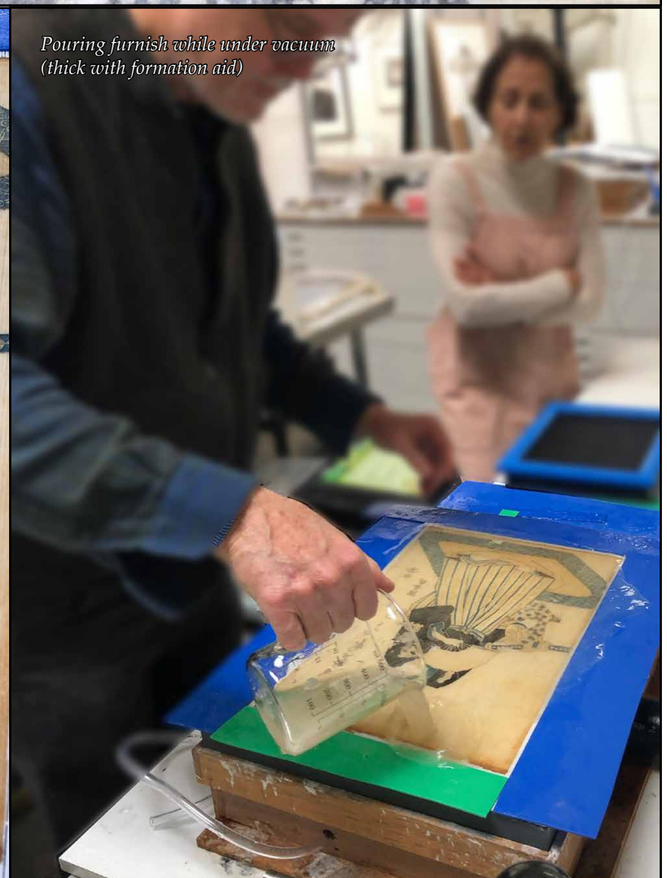
Moistening woodcut placed face down on leaf caster

Pouring furnish between beakers to keep fibers suspended just prior to pouring

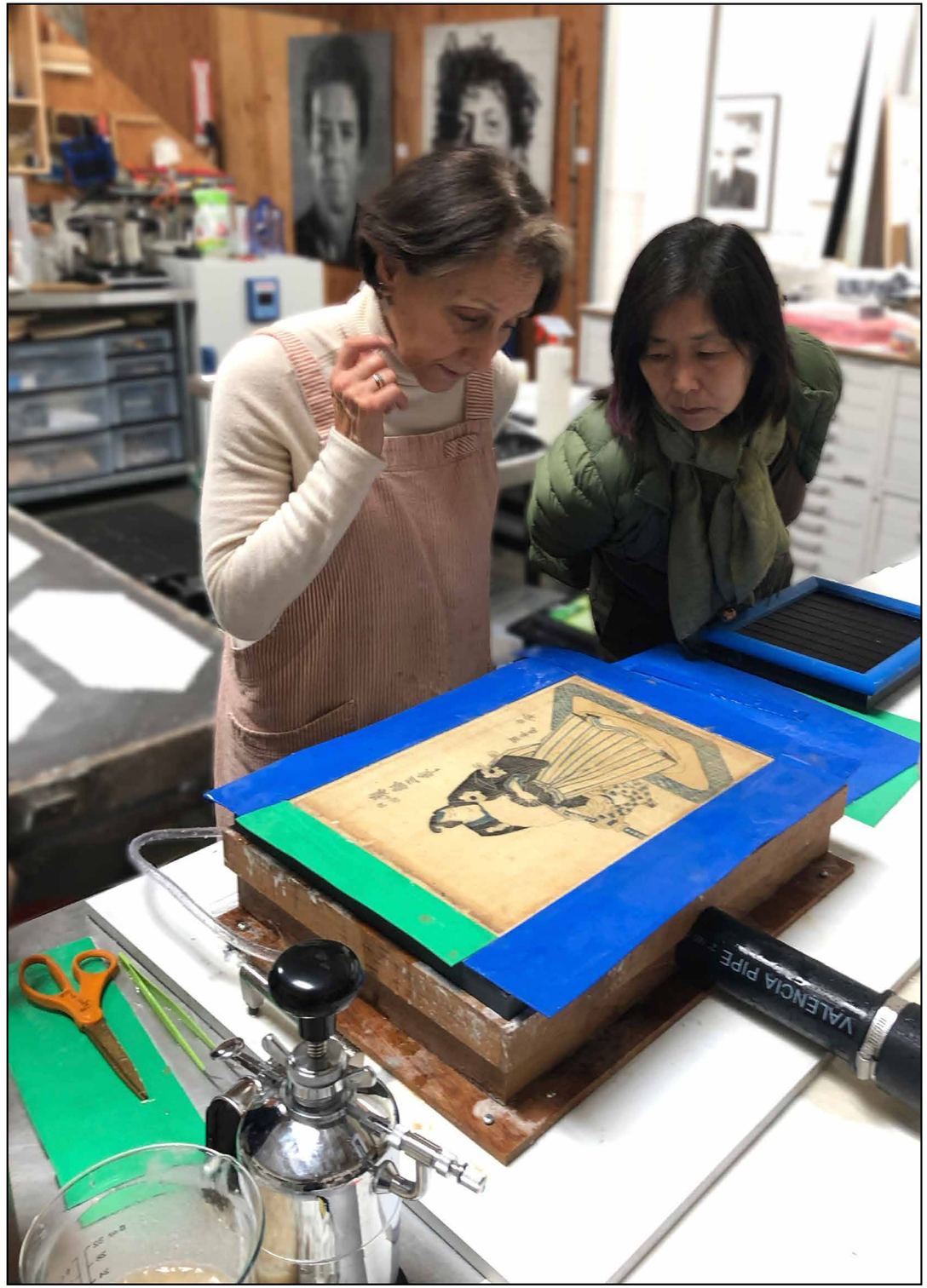


Woodcut moistened and relaxed on the leaf caster (with polyester mesh support under woodcut)





Pouring furnish while under vacuum (thick with formation aid)



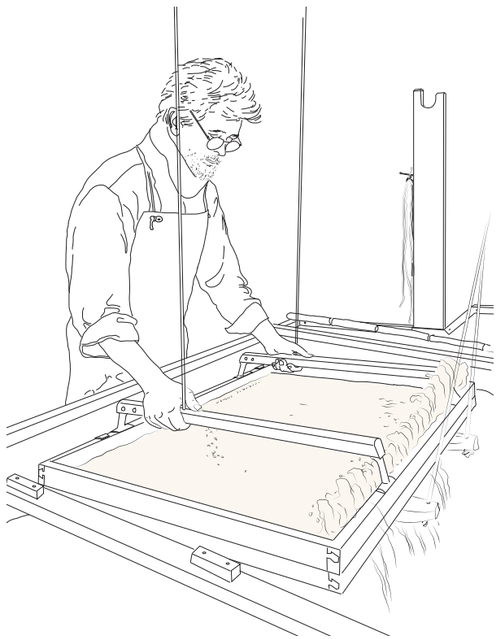
Conservator Karen Zukor and Magnolia Editions' Era Farnsworth inspecting newly poured infill still under vacuum

Multiple pours to build up an even sheet – pouring method

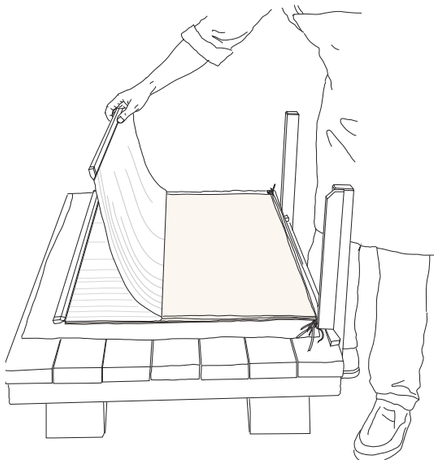
Controlling how fibers wash across the surface of a bamboo screen in the first second of sheet formation is very important in traditional washi practice. Without this sealing dip (*kumikomi*), couching is impaired if not impossible. In the technique of leaf casting described here, where the furnish is poured directly onto the mould's screen surface, there is no sealing dip; the first pour lands as a swirl of fibers on the document as well as on the screen. This pouring technique demands a mould laid surface screen be covered with a fine polyester mesh that prevents the fibers from entangling in to laid lines. With a polyester mesh covering the laid screen, the traditional sealing dip is not necessary.

But we can take inspiration from and emulate other aspects of the washi making method – especially the multiple dipping technique used in Japanese papermaking (in this case, multiple pouring). With each successive pour we lift the leaf caster by the two handles and shake waves in cross directions as the furnish slowly drains. As the mould is shaken front to back and side to side, these waves of furnish lay down fiber in opposing directions, "weaving" the fibers as they settle. Towards the end of each dip cycle, a Japanese papermaker will throw off the what little furnish is still being agitated as the knots found in the furnish are the last to settle out. In the photo on the opposite page, a wave can be seen washing over the leaf caster's foam deckle.

Japanese papermaking techniques we can adopt for use in leaf casting:

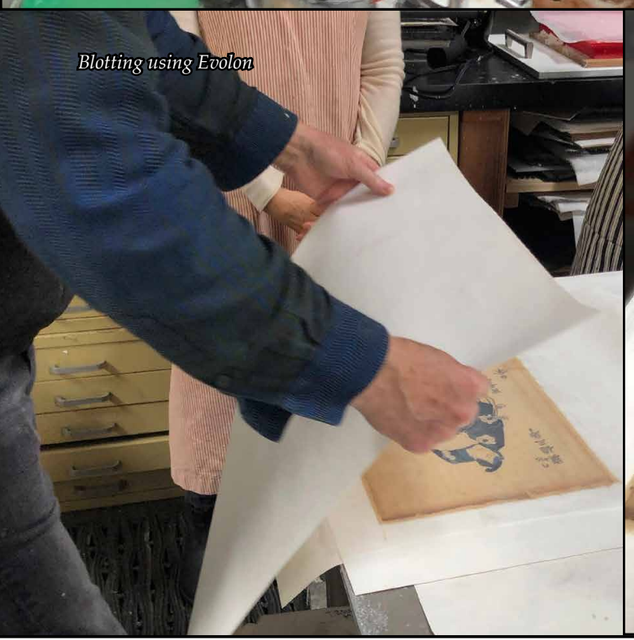


- *Bast fiber cooking, rinsing and beating*
- *Formation aid (neri) additive*
- *Sealing dips for easier couching*
- *Multiple dips "weaving" the fibers*
- *Couching using a flexible screen*
- *Drying on boards and hot surfaces*



Using handles to throw off furnish, removing floating knots of fiber

Aggressive atomizing while under vacuum can help the fibers migrate to the voids



Blotting using Evolon

After blotting and ready for constrained drying

The filled woodcut, dry and untrimmed

Case #3:
Japanese moku hanga

Here we used the same series of steps as described in Case #1: Lab discovery, color matching document to a library of known fiber colors, furnish blending and preparation, casting in multiple layers, blotting and drying. In this infill we intentionally used a lighter value blend of fibers in our furnish to accentuate the conserved and infilled areas.

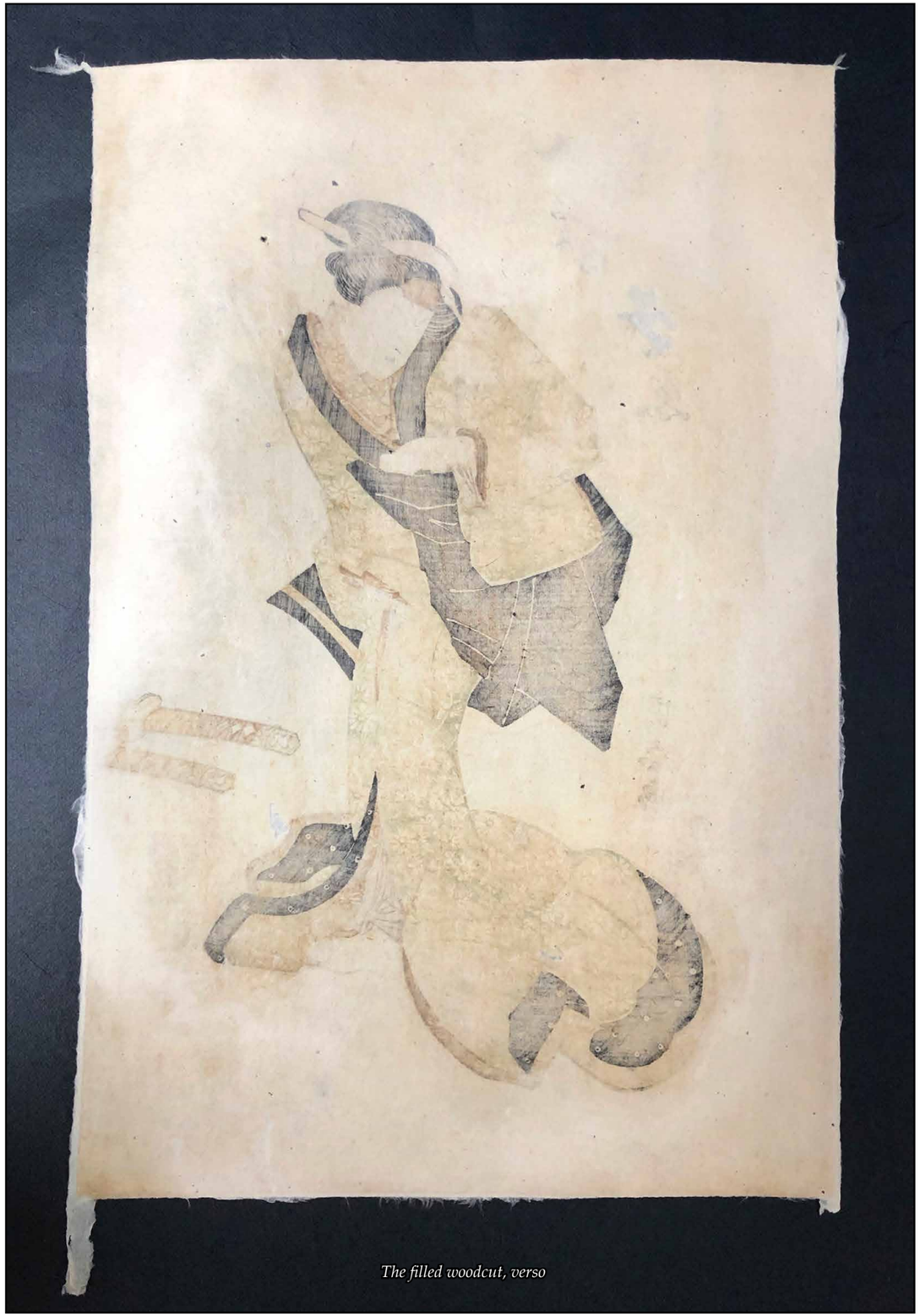
Spectrometer displaying Lab values of the worm eaten woodcut after averaging multiple readings

Woodcut moistened and relaxed on the leaf caster (with polyester mesh support under woodcut)

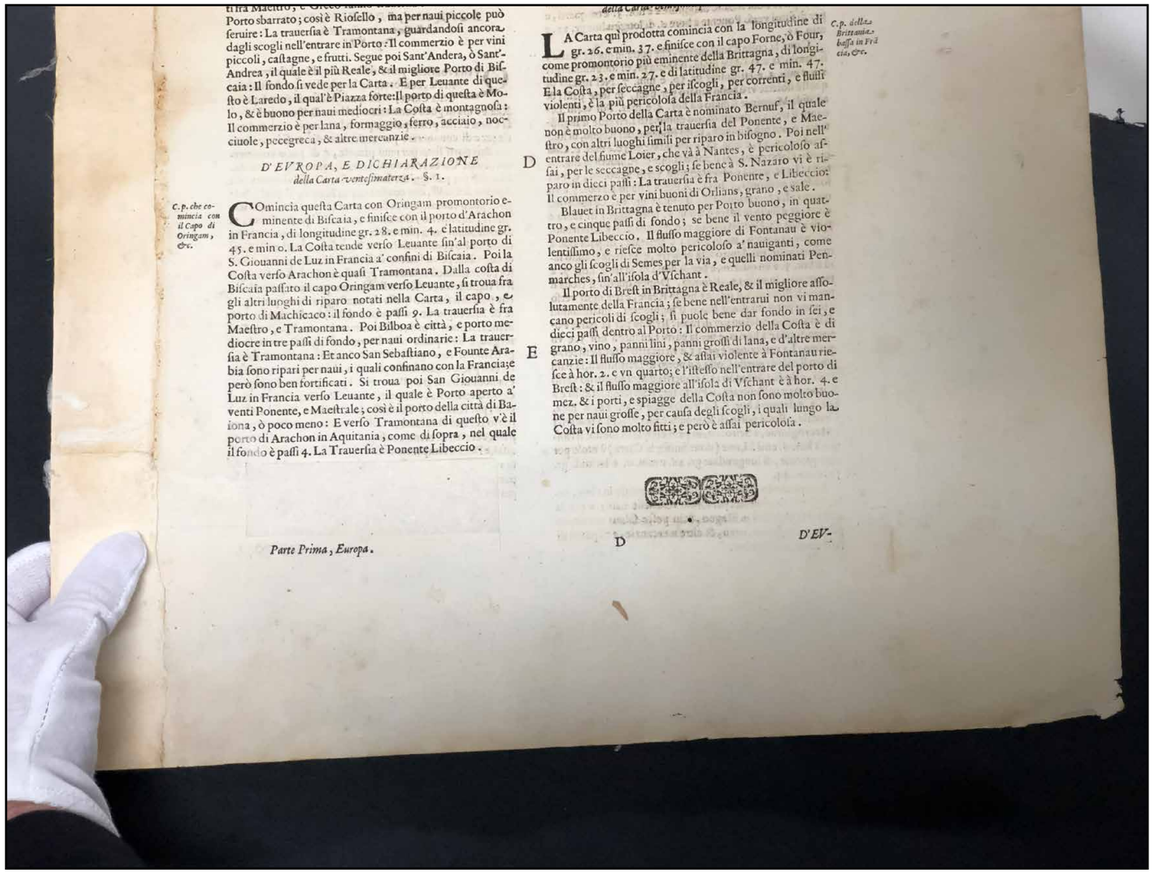
Detail of worm holes filled with furnish

Conservator Karen Zukor examines the consolidated finished woodcut

The filled woodcut, recto



The filled woodcut, verso



Porto sbarrato; così è Rioſello, ma per naui piccole può ſeruire: La trauerſia è Tramontana, guardandoſi ancora dagli ſcogli nell'entrare in Porto: Il commerzio è per vini piccoli, caſtagne, e frutti. Segue poi Sant'Andera, ò Sant-Andrea, il quale è il più Reale, & al migliore Porto di Biſcaia: Il fondo ſi vede per la Carta. E per Leuante di queſto è Laredo, il qual'è Piazza forte: Il porto di queſta è Molo, & è buono per naui mediocri: La Coſta è montagnoſa: Il commerzio è per lana, formaggio, ferro, acciaio, nocciuole, pecegreca, & altre mercanzie.

D'EVROPA, E DICHIARAZIONE della Carta ventesimaterza. §. 1.

C. p. che comincia con il Capo di Oringam, &c.

COmincia queſta Carta con Oringam promontorio eminente di Biſcaia, e finiſce con il porto d'Arachon in Francia, di longitudine gr. 28. e min. 4. e latitudine gr. 45. e min 0. La Coſta tende verſo Leuante ſin'al porto di S. Giouanni de Luz in Francia a' confini di Biſcaia. Poi la Coſta verſo Arachon è quaſi Tramontana. Dalla coſta di Biſcaia paſſato il capo Oringam verſo Leuante, ſi troua fra gli altri luoghi di riparo notati nella Carta, il capo, e porto di Machicaco: il fondo è paſſi 9. La trauerſia è fra Maeſtro, e Tramontana. Poi Bilboa è città, e porto mediocre in tre paſſi di fondo, per naui ordinarie: La trauerſia è Tramontana: Et anco San Sebaſtiano, e Founte Arabia ſono ripari per naui, i quali confinano con la Francia: e però ſono ben fortificati. Si troua poi San Giouanni de Luz in Francia verſo Leuante, il quale è Porto aperto a' venti Ponente, e Maeſtrale; così è il porto della città di Baiona, ò poco meno: E verſo Tramontana di queſto v'è il porto di Arachon in Aquitania, come di ſopra, nel quale il fondo è paſſi 4. La Trauerſia è Ponente Libeccio.

Parte Prima, Europa.

C. p. della Brittania baſſa in Fiandra &c.

LA Carta qui prodotta comincia con la longitudine di gr. 26. e min. 37. e finiſce con il capo Forne, ò Four, come promontorio più eminente della Brittagna, di longitudine gr. 23. e min. 27. e di latitudine gr. 47. e min. 47. E la Coſta, per ſeccagne, per ſcogli, per correnti, e fluſſi violenti, è la più pericoloſa della Francia.

Il primo Porto della Carta è nominato Bernuf, il quale non è molto buono, per la trauerſia del Ponente, e Maeſtro, con altri luoghi ſimili per riparo in biſogno. Poi nell'entrare del fiume Loier, che và à Nantes, è pericoloſo aſſai, per le ſeccagne, e ſcogli; ſe bene à S. Nazaro vi è riparo in dieci paſſi: La trauerſia è fra Ponente, e Libeccio: Il commerzo è per vini buoni di Orlians, grano, e ſale.

Blauet in Brittagna è tenuto per Porto buono, in quattro, e cinque paſſi di fondo; ſe bene il vento peggiore è Ponente Libeccio. Il fluſſo maggiore di Fontanau è violentiſſimo, e rieſce molto pericoloſo a' nauiganti, come anco gli ſcogli di Semes per la via, e quelli nominati Penmarches, ſin'all'iſola d'Vſchant.

Il porto di Breſt in Brittagna è Reale, & il migliore aſſolutamente della Francia; ſe bene nell'entraui non vi mancano pericoli di ſcogli; ſi puole bene dar fondo in ſei, e dieci paſſi dentro al Porto: Il commerzio della Coſta è di grano, vino, panni lini, panni groſſi di lana, e d'altre mercanzie: Il fluſſo maggiore, & aſſai violente à Fontanau rieſce à hor. 2. e vn quarto; e l'iſteſſo nell'entrare del porto di Breſt: & il fluſſo maggiore all'iſola di Vſchant è à hor. 4. e mez. & i porti, e ſpiagge della Coſta non ſono molto buone per naui groſſe, per cauſa degli ſcogli, i quali lungo la Coſta vi ſono molto fitti; e però è aſſai pericoloſa.

D'EV-

Case #4: Full sheet Italian leaf

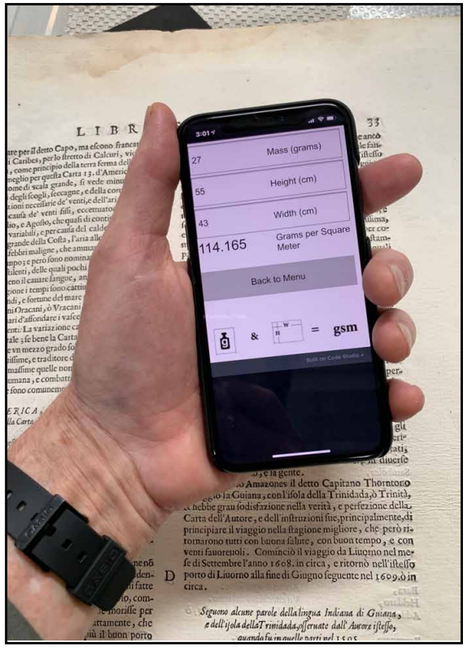
Infill on this early 17th-century document followed the same series of steps described in Case #1: Lab discovery, color matching document to a library of known fiber colors, furnish blending and preparation, casting in multiple layers, blotting and drying. This leaf was larger that our leaf caster but only had voids on the lower half. We built a platform to support the document, only infilling where necessary. Days later we tested for reversibility as described below. Note the back mark passing through the center of the sheet, precisely as described and predicted in *Renaissance Paper Textures* (available at **http://www.magnoliapaper.com**).

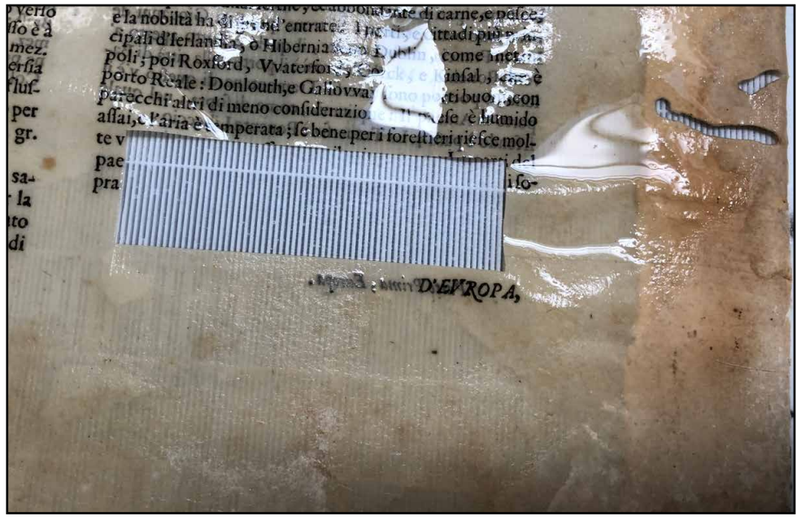
Case study #4 - first try

Towards the end of a productive three-hour infill session with Karen Zukor, we performed an infill on a formerly tipped-in leaf from a large Italian folio. The missing areas included two worm holes and an odd, rectangular aperture void, apparently cut with a knife.

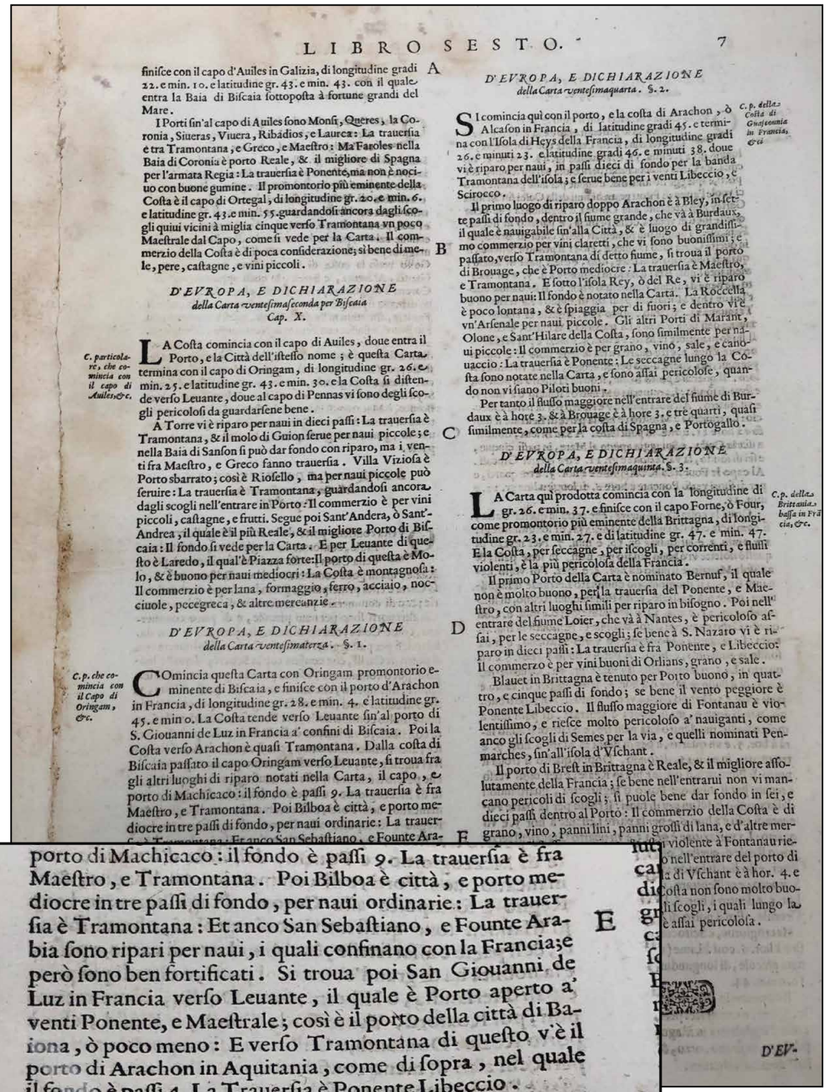
We weighed and calculated the g/m2 using *PaperWeight* installed on an iPhone and quickly arrived at 114 g/m2. We found the dimensions of the 3 x 10 cm rectangular void and (again using *PaperWeight*) calculated the pulp required for casting at 114 g/m2 in the small 3 x 10 cm void, arriving at .3 grams of fiber (or 33 ml of my blended furnish).

After calculating the percentages to match the color at hand, we were ready to proceed. Rather than using a blender to mix the percentages of hemp and linen necessary to make the correct color, I stirred the pulps together by hand. Sadly, this lack of blending caused the resulting infill to appear mottled.



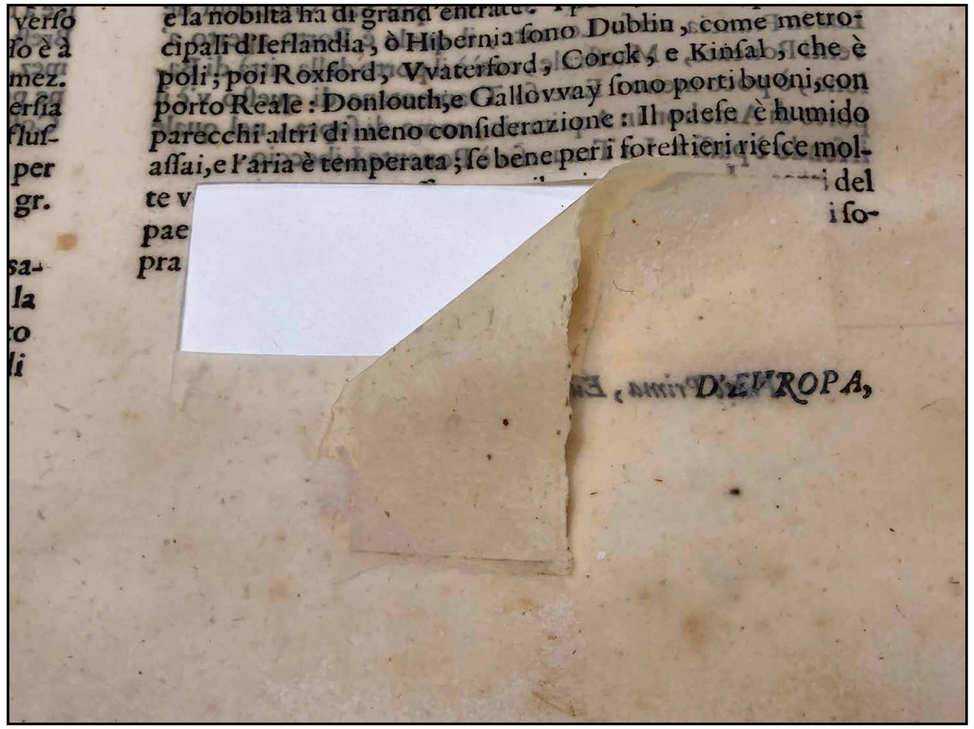


Aperture and wormholes (verso) prior to leaf casting

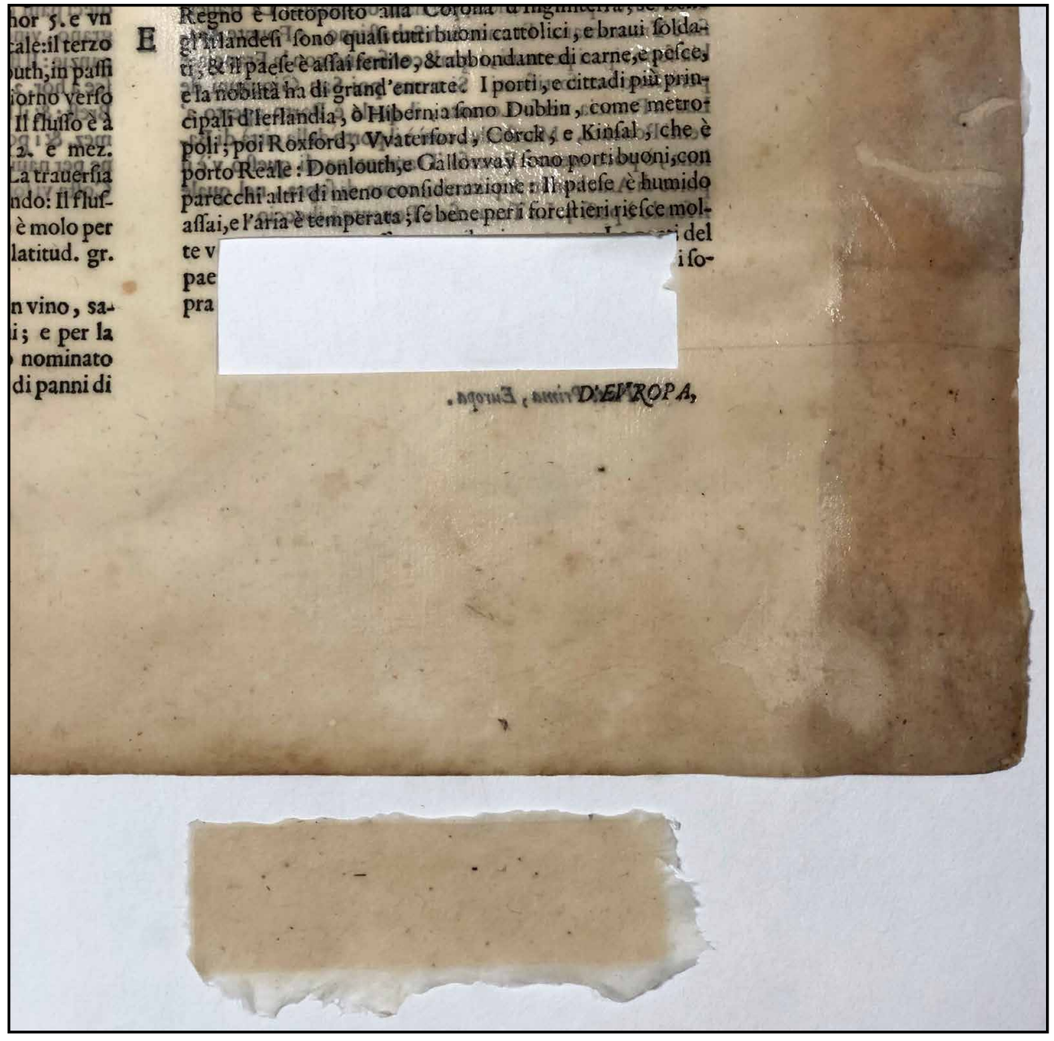


Aperture and wormholes (recto) after leaf casting

Testing reversibility



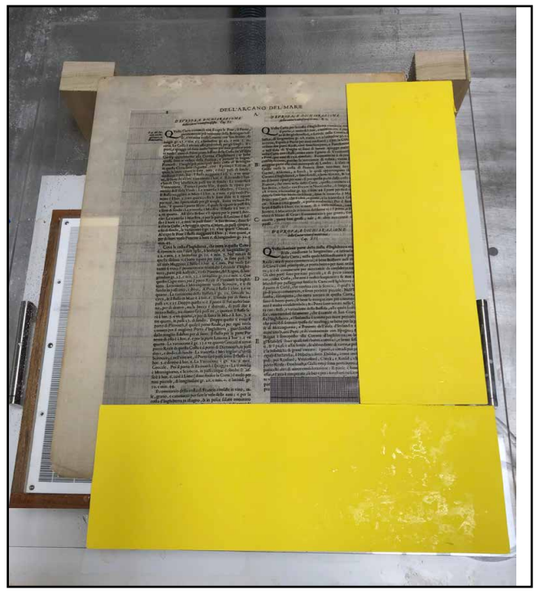
Although somewhat pleased with the results, I was not satisfied with the mottling and in any case wanted to test reversibility. A few days later, I moistened and relaxed the rectangular infill and easily peeled it from the void: reversibility had been achieved. I left the wormhole infills as they were satisfactory. I was also pleased to find that, despite its mottled color, the edges of the removed infill section were beautifully and naturally chamfered.



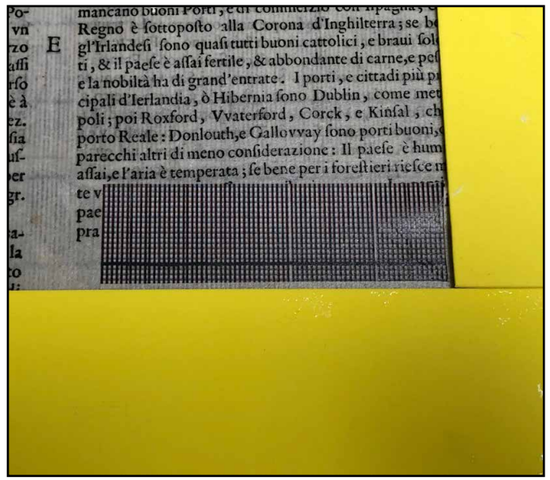
Removed infill section

Case study #4 - second try

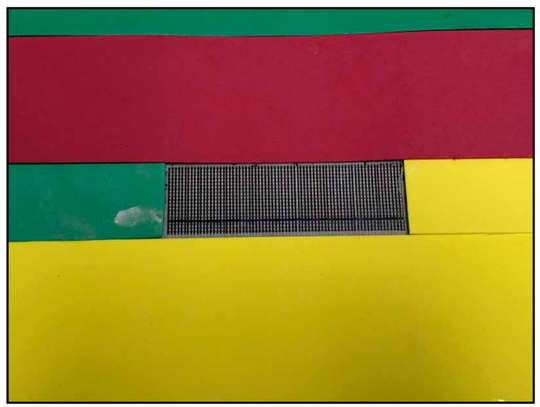
For my second try, I re-cast only in the damaged area, masking off the document and placing it on a clear Plexiglas platform for support (since the document was larger than the leaf caster's surface). I also blended the fibers more carefully in an attempt to more closely match the color with a less mottled result. Having realized that the degummed hemp component was exceptionally fibrous, I found it required more processing than anticipated, calling for an additional minute or two of hand beating and longer blending times. While it could have benefited from processing with a modern beater as well, heavy processing equipment like a Hollander beater would threaten the dimensional stability of the cast sheet. In general, when conserving older documents, retting, hand beating and blending is preferable to Hollander beating – a subject covered in more detail in *Determinate Hand Papermaking* and deserving of further investigation in the future.



Partially masking a document that is larger than the leaf caster, supported by a clear Plexiglas platform



Detail of partial masking: here we see chain lines agreeing with the laid lines of the document

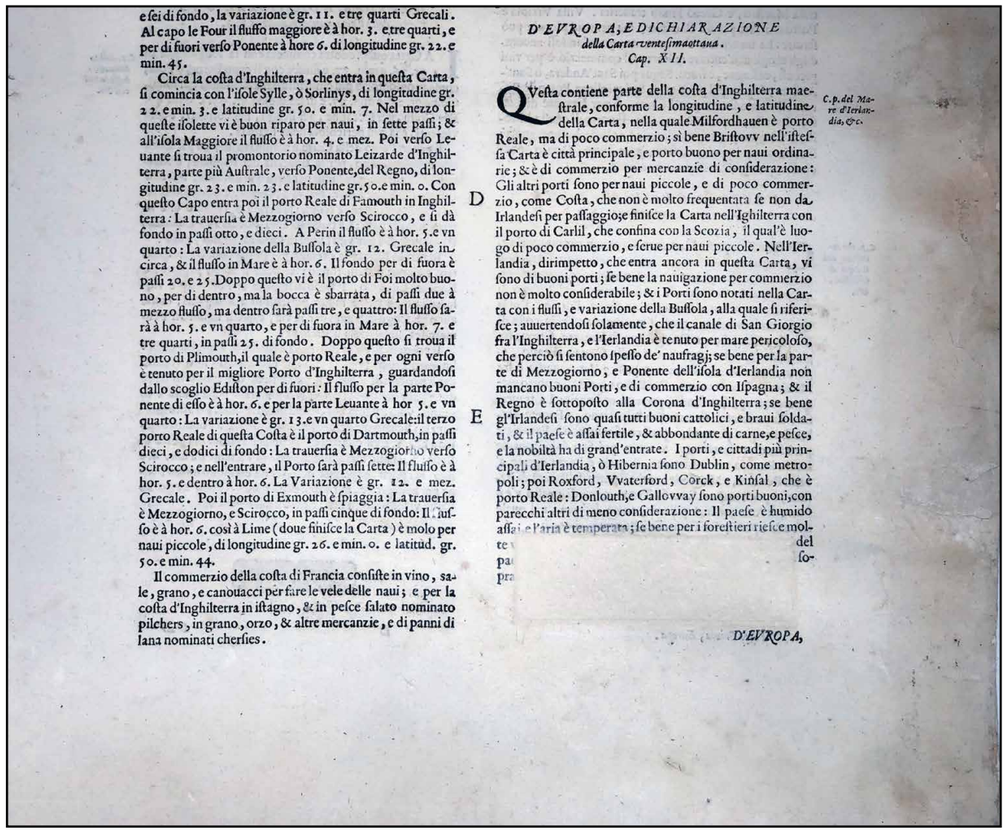


Masking to delimit the infill area including a 1/8 inch document edge

Pouring furnish while under vacuum

Glossy areas are still wet; vacuum has removed moisture from matte areas

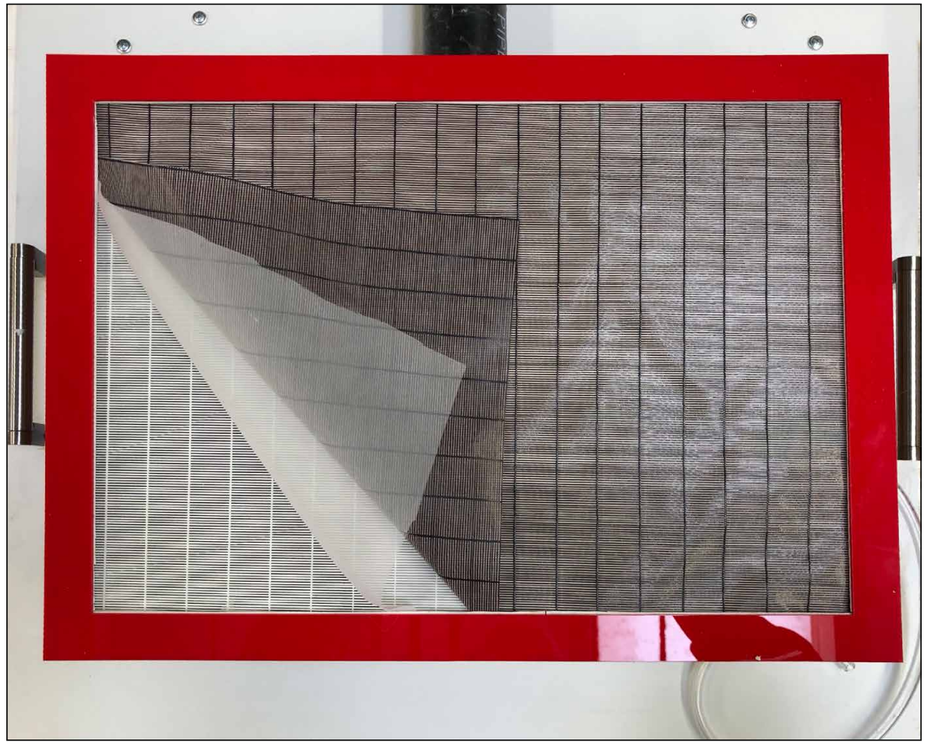
Using additional suction to remove excess furnish from foam masks



Second attempt after leaf casting

Reference:

General instructions for using a modular 3-D printed paper mould leaf caster



The mould dimensions can be scaled up according to the output capabilities of one's 3-D printer – Brian Queen's modular approach to 3-D printed moulds allows us to create larger moulds from smaller interlocking pieces printed on a modestly-sized 3-D printer

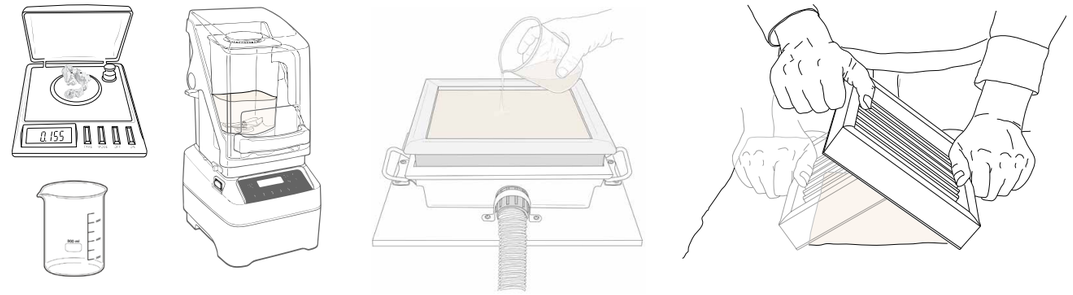
Example case: leaf casting an 81 GSM sheet

Using a 8.5 x 11 in. (22 cm x 28 cm) mould

Terminology: (raw material –> half stuff –> pulp –> furnish –> paper)

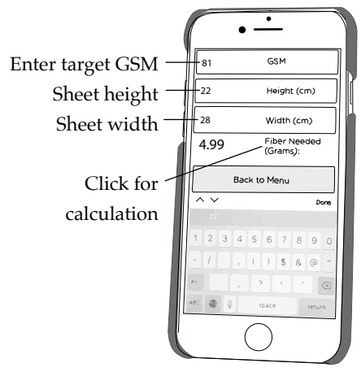
- **Half stuff:** *partially processed paper fiber, usually dry (aka: first stuff, lap, wet lap)*
- **Pulp**: *aqueous processed fiber - retted, cooked, beaten; hydrated and fibrillated (aka: stuff, stock)*
- **Furnish:** *dilute pulp with additives (e.g. CaCO3, MgCO3, formation aid), ready for sheet formation (aka: charge)*

– Overview –



Calculate – Measure – Blend – Pour – Form – Vacuum – Couch – Press/Blot – Dry

To perform initial calculations such as determining the dry weight of fiber required for this size sheet, use the PaperWeight app:



Here we learn that **5g** dry weight of fiber will create an 81 GSM sheet of paper 22 x 28 cm.
If prepared (blended) in **400** ml H_2O with **100** ml of formation aid, we get **500** ml of furnish, which nicely works out to **1g** of fiber per **100** ml of furnish.

> ***Note:*** blending 1 liter at the concentration **1g per 100ml** creates a very convenient suspension for formulating different weights of paper, as adding or subtracting 100ml of pulp solution will correspond to an addition or reduction of 1 gram of dry fiber.

In this example, the target GSM of 81, height of 22 cm, and width of 28 cm in the PaperWeight app yield a result of 5 grams (4.99 g) of dry pulp. Blend in 400 ml of water; add 100 ml of formation aid at the last 5 seconds of blending.

As you might expect, there is some loss of fiber in the determinate papermaking process, e.g. fibers stuck to the blender blades, white water fines passing through the screen, etc. Therefore, it is wise to err on the plus side of any fiber weighing equation; in other words, too much is preferable to not enough.

Preparation overview

• Clean the surface of document chosen for infill
• Weigh the document (example document = 4.1 g)
• Test for aqueous solubility – gently roll a moistened cotton Q-tip on pigmented area and inspect for fugitive colorant
• Prepare formation aid (*neri*) in advance and let sit overnight

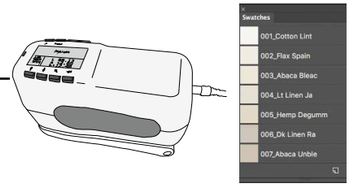
• Download and install *PaperWeight* app: www.magnoliapaper.com
• Determine document's square centimeters: scan document on a contrasting background alongside a 1 cm^2 white square and dividing pixel count per instructions on p. 22 (8,570,075 ÷ 17,283 = **496 cm^2**)

• Calculate document weight, GSM (Grams per Square Meter) using PaperWeight's *Manual Area Entry to GSM* menu. (enter the data we have collected: mass: 4.1 g and square centimeters: 496 = **82.7 GSM)**

• Subtract sq cm of document from interior deckle dimensions to determine sq cm of the paper that will be made (22cm x 28cm = 616 cm^2 - 496 = **120cm^2** infill)

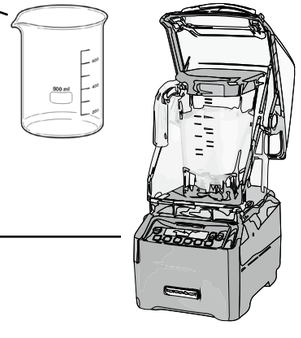
• Calculate dry weight of pulp required for matching the document's GSM and the surface area of infill using PaperWeight's *GSM to Pulp Required (Area) menu* (in our example, 82.7 GSM and 120 cm^2 = **1 g of pulp**)

• Calculate the percentages of pulp needed to match document color from your library of pulp colors (p. 36) and weigh and prepare in calculated proportions – 10 grams (Example doc Lab= 90, 0, 9)

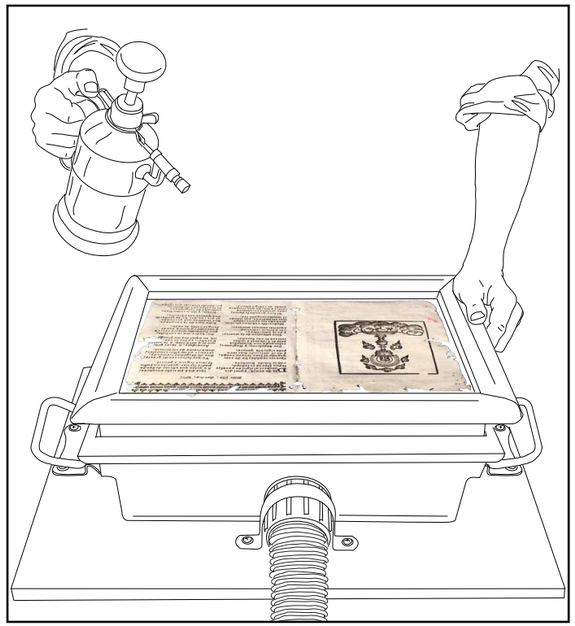


• Add 500ml of filtered water and allow to soak for 3 to 24 hours

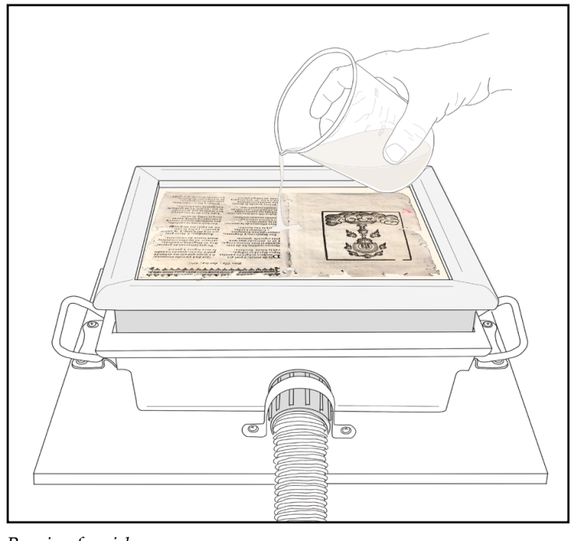
Prepare Furnish:
• Blend the 500 ml and 10 grams of fiber for 1 to 3 minutes being sure there are no lumps
• Add 450 ml of additional water (total 950 ml)
• Add 50 ml of formation aid and blend for 5 more seconds
We now have 1 lt of furnish equal to 1 g of fiber per 100 ml of furnish. This makes the quantity needed in this example easy: 100ml
Let air bubbles subside, transfer to beaker, stir by hand prior to pour



Leaf casting with removable mould – step by step



Moistening document



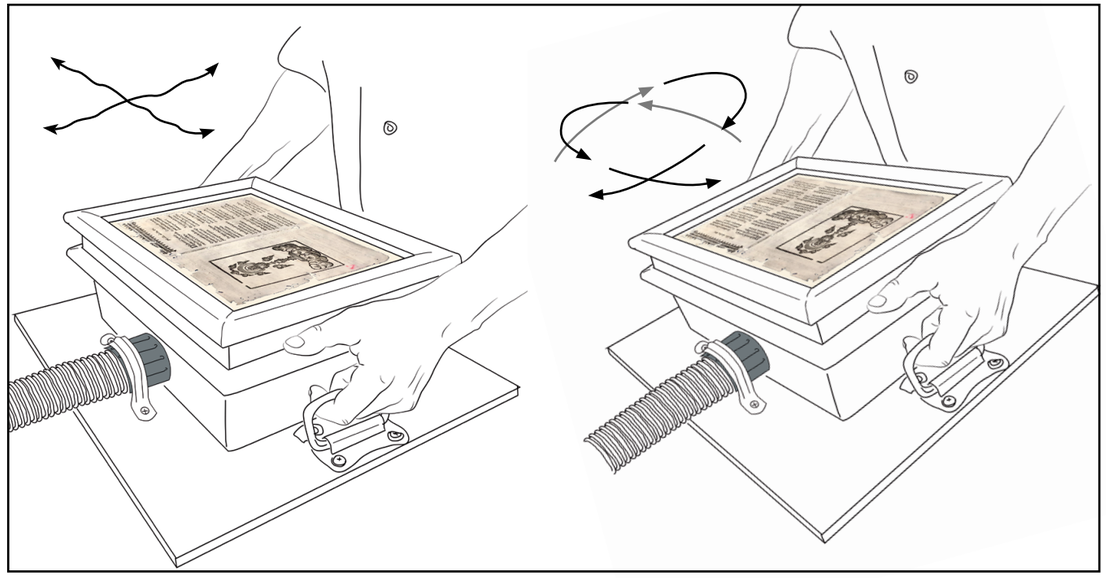
Pouring furnish

1. Moisten (prepped/cleaned) document and let relax until flat on the mould surface. Place the document verso up / recto down: consider that the end result will display a harder-edged definition conforming to the shape of the document apparent on the wire side (the face down side of the document that touches the screen) and softer edges are present on the felt side (the upward facing side). For example, given a document with a blank verso, it is best to place the document recto down on mould surface (verso up).

2. Try a test pour to ensure that the pulp solution quantity is sufficient to fill the deckle. If it is not, dilute the calculated GSM of pulp with water and formation aid (for example, 100 ml of furnish diluted to 800 ml total volume). Include formation aid when diluting furnish; with formation aid as a component in the furnish, more time is available for pouring, forming, shaking and couching. **Do not pour if the furnish is still foamy from the blender; transfer to a beaker, let stand and stir before pouring.**

3a. Turn on the vacuum and ensure it is drawing air through the mould surface and that the document is gently pulled flat to the mould surface.

3b. Pour the 800 ml of dilute furnish (with formation aid, the consistency should be as viscous as cream) onto the document while the vacuum is on, filling to near the capacity of the deckle (as tested earlier). Due to the formation aid in the furnish, this technique allows for direct pouring onto the document without damage.



The lightweight design of this 3D printed leaf caster gives the maker complete control of the pulp flow: start with initial shakes and vibrations, then tilt to slide furnish off document

4. Immediately after pouring the furnish (filling to the height of the deckle), use the handles to lift the leaf caster, first shaking using longer strokes front to back and side to side with slight up-tilt at the end of every shake so as to prevent wave from spilling. Then switch to more of a vibration shake, watching and assessing that your shakes are successfully aligning and smoothly setting the fibers.

When the replacement areas have drained and while there is still liquid furnish on the document, slowly tilt in all directions and allow the furnish to slide off the document and into the document voids.

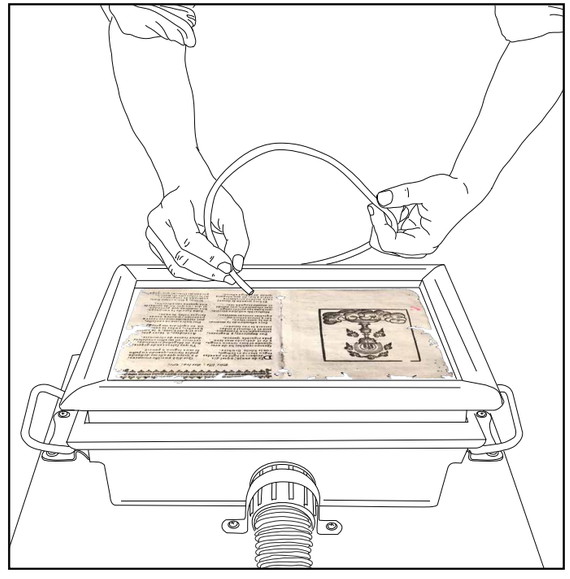
Japanese techniques may also be used; one can go as far as "throwing off" excess pulp during formation and employing multiple pours to build up a sheet.

5. Carefully remove any small areas of excess or unwanted furnish using a length of ¼ inch flexible vinyl tubing that passes through the box and into the vacuum tube. Maximum suction can be achieved by running the ¼ inch vinyl tube into successively larger gauges of tubing on its way to the vacuum.

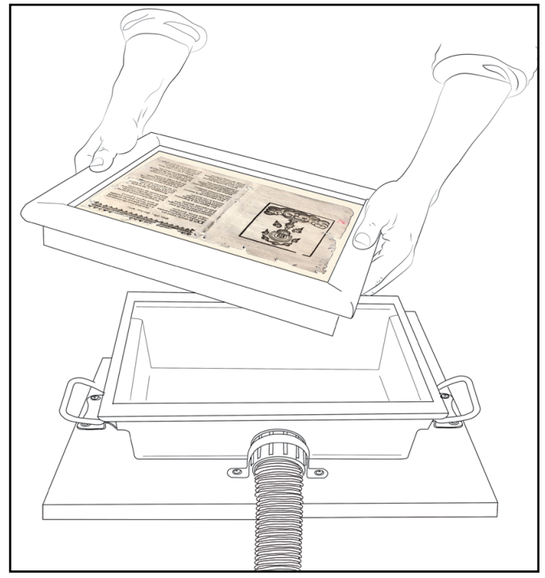
6. Turn off the suction, lift the mould from the vacuum box, and remove the deckle in preparation for couching.

Alternative to traditional couching:

My preferred method is to protect the document with a polyester mesh and blot while under vacuum. The mesh-document-mesh sandwich can be lifted and dried. This is the safer approach for delicate paper artifacts; forming on a 400 mesh polyester screen, then covering with another screen eliminates the need for direct handling of the moist document.



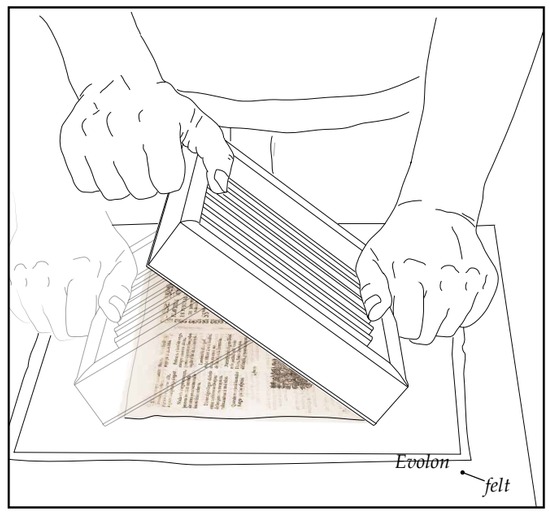
Use vinyl tubing inserted into the box and 6 inches down the vacuum connection tube to carefully remove excess furnish. Moisten with Dahlia sprayer to re-moisten and suck unwanted/drained fiber.



Remove moulds and deckle from vacuum box

If performing a traditional couch, do not over vacuum-dry the sheet, as moisture is necessary for a good couch. (See following pages for more on alternative couching method with polyester mesh screen.)

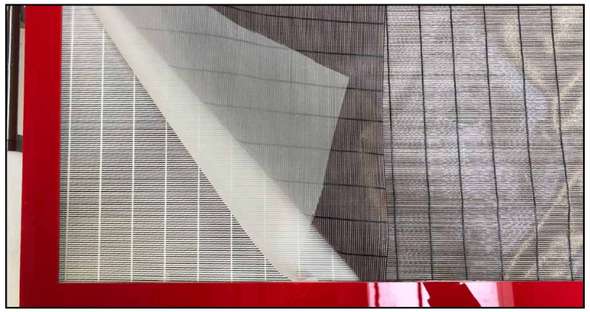
7. Holding the center of the long sides of the mould, couch the cast sheet and document onto a layer of Evolon atop a felt. Rather than rolling the mould from left to right in the traditional single motion, stop when the mould is flat on the couching surface and press on the ribs. When you press on the ribs, moisture should be seen seeping up through the back side of the screen; this water, when pressure is released, will "wash" the fibers off the screen surface to make the couching transfer from mould to felt (Evolon). If no moisture appears, the sheet was overly vacuumed and may need re-wetting.



Couching on Pellon or Evolon laid on a felt

Note: Evolon AP (168 gsm) is a non-woven microfiber paper made from polyester and nylon. Evolon absorbs many times its weight in water and is tearproof and lint-free.

Watermarks & laid screen printed in acrylic on woven mesh

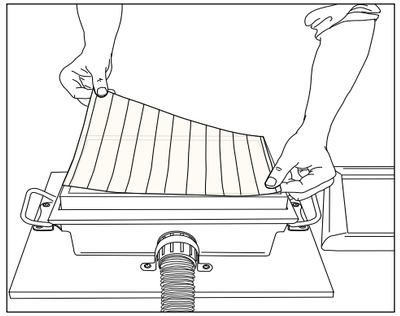


A laid pattern printed onto 140 mesh polyester screen can create a "modern laid" pattern in the look-through of the paper. Place mesh printed pattern side down so the artifact lays on the non-printed side.

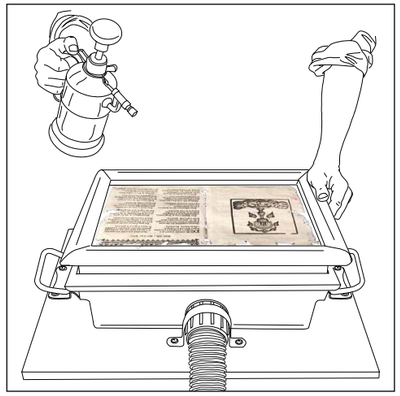
An entanglement problem often occurs when pouring furnish directly onto a laid screen when leaf casting. All western laid moulds are pulled through the vat perpendicular to the laid lines in order to align the wire side fibers across the gaps of the laid line surface (thereby forming a micro-screen on which a more random fibers of the felt side form). Pouring, on the other hand, creates a chaotic swirl of fibers on the wire side and are prone to tangle in the gaps of the laid wires, making couching difficult if not impossible.

One solution that can tolerate a random swirl of pulp on a laid screen is to print the laid pattern onto a woven screen (like a modern watermark). After designing the pattern in Photoshop, we printed it onto a **140 mesh polyester screen** using a UV-cured acrylic inkjet printer. For improved results, we printed the laid pattern multiple times to build up ink thickness. We made the polyester screen correspond to the outer dimension of the mould so that the deckle, once in place, helps hold it down. Custom chain widths were chosen so we could more closely align the chain lines of the mould covering with the document's chain lines.

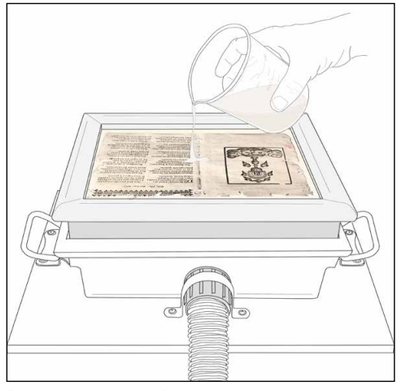
As we were not performing a traditional couch (see opposite page), we allowed the vacuum to pull for a longer duration, making the sheet easier to handle. Dewatering was augmented by first covering the wet document with a protective polyester screen then laying dry Evolon sheets on our newly cast sheet (deckle removed), taking advantage of the suction to evenly pull the Evolon in contact with the work. As the laid pattern is printed on flexible mesh, the screen can simply be lifted off the mould to allow for further blotting and drying of the cast sheet.



1. Place 140 mesh polyester (with or without laid-printed-pattern) on wove mould and moisten, smooth and remove air bubbles.

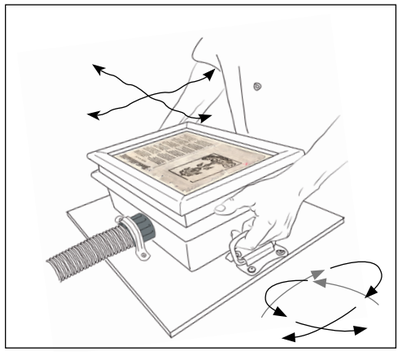


2. Place and moisten document.

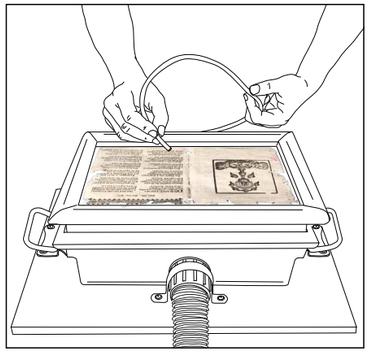


3. Start vacuum and pour furnish.

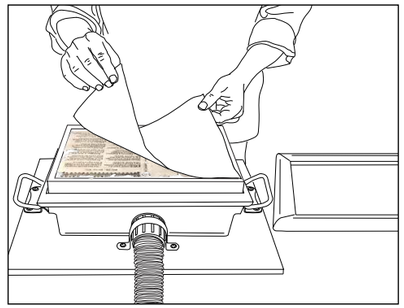
Note: Directly pouring furnish on a document while under vacuum requires the use of formation aid and works best with furnish made from bast fibers.



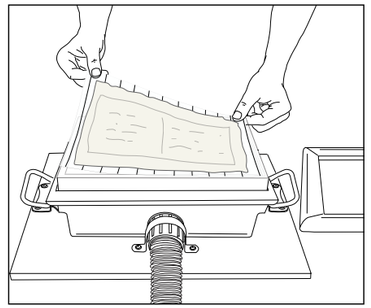
4. Shake and settle fibers while under suction – finishing shakes with short vibration. Stop shaking while furnish is still flowing.



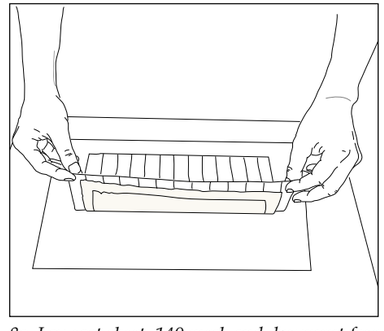
5. Use ¼ inch vinyl tube to carefully remove excess furnish. Moisten with Dahlia sprayer to re-moisten and suck unwanted/drained fiber.



6. Place 140 mesh polyester screen over document then blot with Evolon while under vacuum.

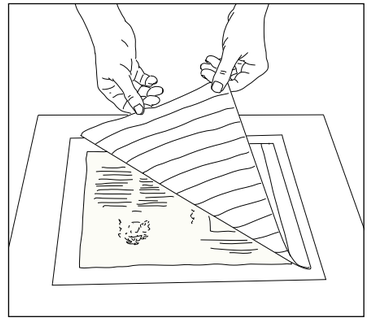


7. Turn vacuum off, lift mesh-enveloped-document from mould.



8a. Lay cast sheet, 140 mesh and document face down on Evolon atop a felt.

8b. Cover with a blotter and with moderate pressure, allow for absorption to continue the dewatering of the composite.



9. Artifact may be blotted and dried between the polyester mesh (my preference) or carefully lift printed mesh from cast document; gently free one edge and pull away from that edge while lifting slowly and carefully. A deckle edge is usually of little concern, as edges will be trimmed. Transfer cast composite to Evolon for blotting and drying.

Note: *Keep cast paper areas from adhering to blotting material (e.g. Pellon, Evolon or Zorbix) when dry by placing a layer of 140 mesh polyester beneath the document when casting and on top when blotting and drying. This is especially relevant when using drying methods using heat. Test all methods before repairing any document of value.*

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