
European
Hand Papermaking
Traditions, Tools, and Techniques
Timothy D. Barrett

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with an appendix on mould making
by Timothy Moore

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Disclaimer

The tools, equipment, and procedures described in this book are presented with attention to proper use. However, the reader is solely responsible for his or her own safety, and the authors and publisher assume no liability whatsoever for the success of any product, or any injury or mishap that may occur.

Dedication

Yes, I am guilty of waxing poetic about dead papermakers, but I do need to go there to give this book some important context. If you think about all you received from your parents, or whoever raised you as a child, you know that much of your outlook on life, your value system, your sensitivities, and your aspirations come from them. Even your sense of honor and your sense of humor come, in part, from them. And thus a good part of them remains alive in you. We notice their personalities and eccentricities every now and then in the things we say and do, and we marvel at how that can be so. If this is indeed the case – that the previous generation persists in the current one – then it follows that we are connected in powerful ways to those who have gone before us.

While we can't talk to papermakers long since past, a sense of who they were remains manifest in the papers they left behind. When we see and handle these sheets, we subconsciously perceive their touch and we are awed by the work they did. In the paper, still light in color, durable, and supple after centuries, we can see their skills and sense the pride they took in their work. Many of them – men, women and children – made paper their entire lives. In essence, when we consider the sensitivities they passed on over the centuries, we stand on the shoulders of giants.

So, yes, this book is dedicated to them. It is a small, small gesture in thanks for the heritage they left behind for us, and which we try to honor in our own work.

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Preface, Acknowledgments, and a Note to the Reader: Internet Links and Videos

Preface

When I first became interested in hand papermaking in 1968, I was delighted to encounter Dard Hunter's *Papermaking: The History and Technique of an Ancient Craft.*[1] But what I was really looking for was a detailed text about the actual hands-on methods of historical European hand papermaking. I wanted a book with how-to instructions and a listing of tools, equipment, and suppliers. I never found the book I was after. What follows is my attempt to fill that gap.

Because you, the reader, could easily be a beginner, an experienced papermaker, a conservator, or a paper historian, my hope is that, here and there at least, there will be bits and pieces of information of interest to you. It will be very helpful if you have had some preliminary experience with papermaking, such as a summer workshop, a semester-long course, or if perhaps you have been experimenting on your own. That hands-on knowledge provides valuable context for making the best use of this text.

That said, it is impossible to learn any craft from a book. I have been engaged in the study of hand papermaking for some forty years, and there is still a great deal I do not understand. One can make the case that the only way to attain real mastery of the craft is to be immersed in all the associated processes from a young age, as apprentices were during much of the history of papermaking. I would accept that idea. So while I have been at this for many, many years, I still consider myself a student of the craft.

So much of the important learning comes from repetition in the papermaking process itself – when something doesn't work, trying a different way. Trial and error is probably the essence of human learning. Conversations with those more experienced than you can be very valuable, but nothing matches actual practice, or, as they say, getting your hands wet.

In the end, this book is intended as a guide to learning. If it turns out to be helpful in that regard, I will be very pleased. I consider it a beginning. In other words, there are many more chapters in this story to be written, and I encourage anyone with an interest in papermaking to undertake the research and experimentation that can enrich the craft going forward.

The focus of the book is on the traditional craft of making quality book and writing papers as originally practiced in Italy in the thirteenth century, and then, of course, in the

1. Hunter, Dard. *Papermaking: The History and Technique of an Ancient Craft.* 1947. New York: Dover, 1978.

remainder of Europe. I have chosen to use the term "European papermaking" rather than "Western papermaking" in the title of the book because the former helps reference the long heritage and birthplace of the technique in Europe. And while some form of the craft is indeed practiced today in many locations in the West beyond Europe, it is also practiced in Japan, India, the Philippines, and still other non-Western countries. To reflect the contemporary use of the craft outside Europe, I use the phrase European-style papermaking.

In this book, the term "papermill" is reserved for large-scale enterprises running at least one vat team of three people on a daily basis. There are few such operations still working in Europe but keeping the historical reference and terminology is important. I use the term "paper workshop" to refer to workplaces hosting a much broader range of activities. They include the following:

1. Limited (less than daily) traditional sheet-production workshops
2. Personal paperworks art-making studios
3. Classroom papermaking/paperworks teaching facilities
4. Collaborative professional paperworks studios
5. Research and production paper facilities
6. Museums that host live demonstrations
7. Any mixture of the above

In America at least, the term "papermaking workshop" can also refer to a day-long, week-long, or weekend class.

The University of Iowa Center for the Book Paper Facility is an example of the fifth type. We are set up to have a three-person team working at the vat, but we only do so occasionally, not on a daily basis. If anything, we are a research and limited-production workshop where various tools and techniques can be experimented with. Our separate teaching facility fits into the third category.

In addition to methods for making book and writing papers, techniques for making letterpress and fine-printing, watercolor, and other papers are also briefly discussed, but not covered are methods for making paper from local fibers and experimental or decorated papers. There are a number of good books and other resources available on topics related to this book's and still more associated with artistic approaches to papermaking. See Appendix D. Recommended Resources for details.

Tim Barrett
August 2018

Acknowledgments

I have been blessed to work with a tremendous team of knowledgeable manuscript readers. Their comments helped change the tone, emphases, organization, and accuracy of the text. Together they made this book significantly better than it would have been otherwise. I am very much in their debt. They include Cathleen Baker, Kathryn and Howard Clark, Simon Barcham Green, Katie MacGregor, and Bernie Vinzani. Peter Thomas offered a range of helpful suggestions and supplied important images of a wooden lever-type drying system salvaged from an East German papermill by Gangolf Ulbricht.

The substance of this book has been greatly enhanced by the addition of Timothy Moore's Appendix C. Mould and Deckle Construction, with drawings by Brian Queen. The combination of Tim's expertise, accumulated over the course of forty years, and Brian's superb technical drawing skills constitute a valuable resource for anyone interested in mould making who has the necessary wood- and metal-working tools and experience. Johan Solberg took all the photographs unless an image is credited otherwise, and Nicole Cotten did the illustrations. Howard Clark graciously agreed to have the images he drew for an earlier publication be used again in this book. A fall of 2017 University of Iowa Career Development Award allowed me to devote focused time to the manuscript. A 2009 MacArthur Fellowship provided funds for photography, drawings, and the purchase of selected specialized tools and equipment that appear in the book. Finally, my special thanks to the publisher, Cathy Baker. Her own expertise on the subject matter, combined with her excellent design and organizational skills, have contributed enormously to the book you hold in your hands.

Note to the Reader: Internet Links and Videos

Throughout the book, Internet links are signified by a blue code number beginning with an X, as in X1, X2, etc. Each can be accessed via a companion website that accompanies this book, http://paper.lib.uiowa.edu/epm. A list of these codes and links appears in Appendix A. This arrangement requires having access to a computer while reading the book, but the author and publisher have decided that this is the best means of providing Internet links to references, suppliers, and other important information cited in the printed book.

At the same website, videos referenced in the text with a Z code (Z1, Z2, etc.) can be viewed at higher resolutions than the YouTube or Vimeo versions given as X numbered links. While the resources at the website are intended for use by the owners of this book, sharing with others for educational purposes is permitted, as long as the original source is cited appropriately.

Chapter 1

Traditional European Papermaking

Précis

During my career of forty-five or so years, I have found myself exploring paper science, paper history, and various hands-on aspects of the craft itself. The driver of it all, however, has been aesthetics. Why do I find one piece of paper more attractive than another? Why do some sheets from certain periods and locations seem to have an integrity, a personality, an authenticity lacking in other sheets? After many years of pondering these questions, I have decided that the papers I am drawn to were made from high-quality raw materials prepared in-house, using traditional methods, by artisans who grew up in the craft and produced paper as a utilitarian commodity rather than a specialty item. The essay that forms most of this chapter was originally written in 1989, almost thirty years ago, when I was focused on answering questions about traditional materials and techniques, and related aesthetics.

Since it was written, the modern craft of hand papermaking has undergone tremendous growth and innovation. Today, while some continue to pursue traditional sheet forming with a focus on historical methods, others have reinvented the craft in a multitude of ingenious ways. New techniques have made possible compelling artist's books, two-dimensional and three-dimensional works of art, and installation and performance pieces. The Combat Paper Group and the allied Peace Paper Project work with veterans to turn uniforms into paper and finished works of art. They approach hand papermaking in a way that is cathartic for the service men and women, as well as for members of the public. All this activity makes hand papermaking relevant to the present cultural moment in new, dynamic, and important ways.

In this atmosphere, the 1989 manifesto that follows below seems in some ways short-sighted and narrow-minded. It is increasingly clear to me that it represents only one papermaking aesthetic, one school of thought among many. Even in the field of standard sheet forming, varying aesthetic points of departure are now well established. In the world of fine lithography or intaglio printmaking, the early European approach described in this work yields a paper that could easily be "too handmade," aesthetically inappropriate, or impractical in the printmaking process. Instead, a bright-white, circular sheet might be the perfect solution. For a certain work of calligraphy, an extremely smooth, plate-calendered, lime-green paper could be the only right paper. In short, it is a sign of robust health in the field of papermaking that many schools of thought and aesthetic pursuit have developed and continue to thrive and inspire one another.

Introduction

Excelling at any craft requires focused attention on the accomplishments of the best craftspeople who went before us. Their accumulated experience can be very valuable to those of us working today. Unfortunately, except in rare instances there are no written details about how they practiced the craft. Nevertheless, their excellent papers remain. We just need to learn how to decipher the messages locked within them. This is not a new idea. In 1947, Dard Hunter, who inspired so many of us working in the book arts today, wrote (with paraphrasing),

> [Changes in raw materials, fiber preparation equipment, mould surfaces, and finishing tools] caused changes in the character of paper throughout the ages. To the casual observer these changes are insignificant, but to the student of papermaking they are clues that, followed, lead to the secrets of the craft he loves.[2]

Hunter was, of course, referring to holding a piece of paper up (to a light source so it can be viewed by transmitted light) and observing the mould surface and other watermark evidence, formation quality, approximate fiber length, freedom from debris, knots, etc., and other details. He also was considering the feel of the sheet, its sound (because a stiff hard sheet with "rattle" may indicate the presence and quantity of surface sizing in the paper), the degree of surface polishing, and any other evidence of interest.

Today we have nondestructive analytical techniques, such as those described at the *Paper through Time* website, that also can help lead the student of papermaking to a new and deeper appreciation of the craft; X1, X2. The point is that paper specimens themselves can be a portal to understanding earlier papermaking methods.

The following essay describes the materials and techniques used to make paper by hand in Europe between 1300 and 1800. Some have questioned ending at 1800 when the real trouble with paper stability was just beginning. However, the 1300 through 1800 period represents for me the rise and the slow but certain decline of hand papermaking as a major industry. In the late 1700s traditional methods were still in use in many mills. Soon after 1800, however, with the arrival of the paper machine, handmade paper ceased to be the ubiquitous utilitarian commodity it had long been. Once a part of daily life, within a decade or two the definition of "paper" was changed not just by the paper machine but by various other innovations, including chlorine bleach, rosin and alum internal size, and by the mid-nineteenth century the introduction of wood-pulp fibers as a substitute for rags. These changes were not always bad from the standpoint of paper permanence, printing quality,

2. Hunter, *Papermaking*, 202. The full quotation is: "To be able to determine the locality and period of old papers it is necessary to make a minute study of the ancient papermaking appliances, as the succession of innovations, occurring in different countries at various periods, caused changes in the character of paper throughout the ages. To the casual observer these changes are insignificant, but to the student of papermaking they are clues that, followed, lead to the secrets of the craft he loves."

and certainly not wider access to the printed word, but the look and feel of what people considered "paper" was changed forever.[3]

What follows is an attempt to give a detailed picture of the tools and techniques used by early European papermakers to make high-quality book and writing papers. The text draws on my earlier and current research, my own experience as a papermaker, and the sources cited in the footnotes. The latter sources are generally well known to paper historians. In a number of instances scholars working in related fields have offered especially interesting references or made other important contributions. John Bidwell, Howard Clark, Richard L. Hills, and Leonard Rosenband gave especially generous support on the occasion of the original 1989 publication and their help remains much appreciated in the context of this new publication.[4]

Published details on papermaking technique are sparse until the mid-eighteenth century when the French writers Joseph Jérôme Jean Le Français de Lalande, Louis-Jacques Goussier, and Nicolas Desmarest began documenting the craft in their country.[5] The absence of details from earlier periods is no doubt a result of trade secrecy, the habit of passing skills directly to family members or in-laws rather than to outsiders, or the lack of ability, time, or need to document the craft in writing. It is also certainly possible that important written references do exist but have not yet been found in the archives.

As a result, what follows cannot help but be part generalization and part hypothesis. Generalizations are dangerous. Attempting to describe the methods used to make paper in Europe between 1300 and 1800 in a relatively short essay, such as this, is like trying to describe the methods used to make cheese throughout the continent during the same period. The raw materials, local conditions, routines, and traditions were almost certainly very diverse. But a generalization, once understood as such, is probably the best way we have of looking back

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3. See Baker, Cathleen A. *From the Hand to the Machine. Nineteenth-Century American Paper and Mediums: Technologies, Materials, and Conservation*. Ann Arbor, Mich.: The Legacy Press, 2010; this book provides an excellent overview of the complex interrelated changes that occurred during the 19th century.

4. Barrett, Timothy. "Early European Papers/Contemporary Conservation Papers," *The Paper Conservator* 13 (1989): 1–108.

5. Lalande, Joseph Jérôme Jean Le Français de. *Art de faire le papier*. Paris: Académie royale des sciences, 1761 (*Descriptions des arts et métiers*, vol. 4). Atkinson, Richard MacIntyre, trans. *The Art of Papermaking*. Kilmurry, Ireland: Ashling Press, 1976; Goussier, Louis-Jacques. "Papeterie." In *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers*. Vol. 11. Paris: Briasson et al., 1765, 834–845; Desmarest, Nicolas. "Premier mémoire sur les principales manipulations qui sont en usage dan les papeteries de Hollande, avec l'explication physique des résultats de ces manipulations." In *Mémoires de l'Académie royale des sciences de Paris*. Paris: Imprimerie royale, 1774; Desmarest, Nicolas. "Second memoire sur la papeterie." In *Mémoires de l'Académie royale des sciences de Paris*. Paris: Imprimerie royale, 1778, 1–89; Desmarest, Nicolas. "Papier (Art de fabriquer)." In *Encyclopédie méthodique: Arts et métiers mécaniques…*. Vol. 5, pt. 2. Paris: Chez Panckoucke, Libraire, 1788, 463–592. Note: Citations for the references above are from John Bidwell's "Recommendations for Further Reading," a bibliography given to students in the History of European and American Papermaking, a Barrett/Bidwell course offered at Rare Book School, University of Virginia.

over the past, especially if the subject is new to us. To hypothesize is dangerous as well, but if the hypothesis is based on knowledge and expertise, it can add considerably to our general sense of what actually happened.

In summary, what follows is my surmise, based on limited research, about what may have been the routine in a mill producing high-quality papers somewhere in Europe between 1300 and 1800. If this text broadens the reader's view of the craft only a bit, raises new questions, and inspires new research, it will be ample reward for the effort.

Please note that with regard to gender roles in the papermaking craft, I try to respect the historical reality while acknowledging contemporary changes in roles. For example, I might say: "For much of the history of the craft a vatman was expected to work until his quota for the day was finished. Today a vatperson can adjust his or her workday to suit production goals." Vatmen, layers, and couchers as well as those in charge of fermentation and stamping or Hollander beating were typically men, and the apprentices were boys. Women and children worked in the rag house (or rag room) and finishing areas of the mill, exchanging, pressing, burnishing, counting, and packing paper. Paper hanging and drying work may have been shared.

Readers interested in the briefest introduction to how sheets of paper were made by hand, pressed, and dried may wish to jump to the "Sheet Forming" section below. Alternatively, or in addition, they can view excellent short YouTube videos showing papermaking by hand; X3, X4.[6] Another related site gives an interactive view of the spread of papermaking and printing across Europe during the fifteenth century; X5.[7]

Raw Materials[8]

Water

For anyone who has tried to make paper free of specks and other debris, it is not hard to imagine the concern about water quality in any mill where high-quality white paper was in production. For papermakers of any era, stray bits of foreign matter seem to enter the pulp no matter how much care is taken to keep them out. Diligence and attention are the only ways

6. The X3 link is a short film, made by Anglia TV, describing all the processes in making paper by hand, including a section devoted to making and fitting a watermark to a mould. Simon Barcham Green narrates the film, which was shot at Hayle Mill, his family business, located in Maidstone, Kent. The film was made in 1976 when Hayle Mill was the last full-scale production papermill in operation in England. Hayle Mill continued in operation until 1987, when production ended following the deep economic recession of the early 1980s. The second link, X4, takes you to a 2013 recreation of early papermaking work routines undertaken by Tim Barrett and his student coworkers.

7. X5 was developed by Greg Prickman, previously head of special collections and university archives at the University of Iowa. Click on "Paper Mills," and "Show Pre-1450 Locations," and then adjust the chronological slider at the top of the screen. Click the "Spread of Printing" radio button or others as you wish.

8. What follows to the end of this chapter is a slightly edited version of the text that appears in the *Paper through Time* website at X2. The essay was originally published in Barrett, "Early European Papers," pt. 1, 7–27. Reprinted here with permission of the original publisher.

to win the battle. Clear, fresh water is, and was, of the essence. Lalande describes eighteenth-century water-treatment systems consisting of settling tanks and sand filters used to clear particulates from incoming process water.[9] In another mill, says Lalande,

> the water arrives in the stamping-troughs only after having passed through a wicker straining basket from the canal, a water-outlet designed to precipitate the dirt, a strainer in the large settling tank, a water-outlet and a very fine grid in the small settling tank, often several piles of rags, and finally through the strainer of the small feed tank: all of these precautions have their use; one can never be too careful when it is a question of the purity of the water used on the rags and in the making of the paper.[10]

Alfred Shorter, in his work on papermaking in the British Isles, cites "plentiful, pure and clear or 'fair' water" as one of the essential ingredients in producing white paper of good quality.[11] Separating process water from water used for power was an alternative, and often a routine necessity. A nearby spring might offer top-quality water for actual papermaking, while the immediate river would be used only for power. (This was the normal working arrangement at Hayle Mill in England for some time, until use of the waterwheel was discontinued.[12])

While it is unlikely that papermakers were knowledgeable about the contribution of calcium and magnesium carbonate to paper permanence, they would easily have noted the ill effects of water high in iron content by the reddish or brownish cast it gave their paper. The historical papers with lighter and less red colors analyzed during the *Paper through Time* research contained higher calcium and lower iron concentrations; X6. Calcium compounds,

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9. Lalande, *Art of Papermaking*, 10–12. Note: This reference is occasionally viewed with a reservation because neither Lalande nor the work's translator, Richard Atkinson, was a papermaker. Without a working knowledge of the craft of the era, the argument goes, the document may contain unintentional but crucial mistakes. While this is a valid concern, it is also worth noting (as Henk Voorn carefully points out in his introduction to the Atkinson translation) that Lalande was a scientist. Presumably then, we can be fairly confident of his ability to observe and record carefully what he was seeing or being told. As a papermaker and researcher of Japanese and other papermaking techniques, I have been much impressed with Lalande's attention to relevant details. As to Atkinson's translation, portions of it can be checked against a partial translation into English recently discovered in several issues of *Universal Magazine* (1762) by Colin Cohen and Geoffrey Wakeman. It has been reprinted; Cohen, Colin and Geoffrey Wakeman. *The Art of Making Paper*. Loughborough, England: Plough Press, 1978, 5–31. In the end, although caution is warranted, the Atkinson translation is a valuable source for researchers unable to read the original French.

10. Lalande, *Art of Papermaking*, 17.

11. Shorter, Alfred H. *Paper Mills and Paper Makers in England, 1495–1800*. Hilversum: Paper Publications Society, 1957, 23; or Shorter, A.H. *Papermaking in the British Isles*. Newton Abbot, England: David & Charles, 1971.

12. Personal communication between Simon Barcham Green and the author, ca. 1992.

such as lime, are known to have been used in early papermaking. Józef Drabowski and John Simmons cite F.M. Grapaldo's 1492 description of the addition of lime to the stamper pits.[13] This was likely done to help swell the cellulose and expedite fiber shortening and fibrillation during stamping. Ground chalk might have been added in small amounts as a whitener to counteract the yellowing effects of retting or iron in the water. Limed skins and other animal parts used to make gelatin size may have been another source. Finally, at least a portion of the calcium compounds entered the paper via the water supply. Calcium and magnesium carbonate can appear as sources of hardness in ground and surface water. During papermaking, cellulose fiber very rapidly accumulates metals dissolved in water, be they favorable or unfavorable to the permanence of the paper.

While Lalande and other writers seem to indicate a preference for soft water free of iron and other hardness-promoting components because of its apparent ability to degrease the rags more readily and dissolve sizing, it is likely that much of the available water had a degree of natural hardness. The analyses I reported on in 1989 showed considerably more residual metals in historical specimens than in modern handmade sheets produced in a laboratory with soft (deionized) water.[14]

In summary, if the early papermaker took care to obtain a supply of fresh water free of iron and debris, he was, more often than not, on the right track to making quality paper. The makers of many of the better-quality sheets studied during this research had to have been very aware of the quality of the process water entering their mills.

Fiber

To appreciate the nature of the rags used as raw material in early European papermaking, we need to consider textile manufacture of the period. Raw flax and hemp fibers are both naturally dark in color as a result of the encrusting plant material that remains attached to the fiber after its separation from the inner stalk, or straw, of the plant. Since strong chemicals and bleaches were not available at the time, it required time, considerable handwork, and patience to produce a very light-colored fabric from material woven of these fibers. A revealing chart by Th. Mareau (as cited by A. Proteaux) gives an indication of the work and loss occurring during the gradual transition from raw flax plants into paper.[15]

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13. Dabrowski, Józef and John S.G. Simmons, "Permanence of Early European Hand-Made Papers," *Fibers and Textiles in Eastern Europe* 11, no. 1 (January/March 2003): 8–13. Conor Fahy confirms the practice in 17th-century Italy in Fahy, Conor. "Paper Making in Seventeenth-Century Genoa: The Account of Giovanni Domenico Peri (1651)." *Studies in Bibliography* 56 (2003–2004): 243–259; X6a.

14. Barrett, "Early European Papers," 80–86.

15. Proteaux, A. *Practical Guide for the Manufacture of Paper and Boards*. Trans. Horatio Paine. Philadelphia: Henry Carey Baird, 1866, 194. This reference is worthy of special note. Much of the text, including the translations cited here, was written during a period that marked the twilight of the hand-papermaking industry and the dawn of the machine-papermaking trade. The book seems to sit on the divide between two eras, and as such it makes fascinating reading for those interested in this

Loss in weight of raw flax during the transition into paper

Condition of the Material	Kilograms
Raw picked flax	100.00
Dry flax	25.00
Rippled flax	17.50
Retted flax	4.40
Combed flax	4.18
Spun thread	3.55
Linen cloth	2.84
White linen	2.41
Papermaking	1.69

Ignoring the steps involved in processing raw flax into linen cloth, the following account by Dr. Francis Home, from John Horner's *Linen Trade of Europe*, gives some idea of the work required to produce white linen fabric using "the old Dutch method." (Abbreviated by the author.)

> After the cloth has been sorted into parcels of an equal fineness, as near as can be judged, they are...steeped in water, or equal parts water and lye...from thirty-six to forty-eight hours.... The cloth is then taken out, well rinsed...and washed.... After this it is spread on the field to dry. When thoroughly dried it is ready for bucking or the application of salts. [The liquor used in bucking was made from a mixture of ashes in water.] This liquor is allowed to boil for a quarter of an hour, stirring the ashes from the bottom very often, after which the fire is taken away. The liquor must stand till it has settled, which takes at least six hours and then it is fit for use.... After the linens are taken up from the field, dry, they are [immersed in the lye] for three or four hours.... The cloth is then carried out, generally early in the morning, spread on the grass, pinned, corded down, exposed to the sun and air and watered for the first six hours, so often that it never is allowed to dry.... The next day in the morning and forenoon, it is watered twice or thrice if the day is very dry, after which it is taken up dry again...fit for bucking.... This alternate course of bucking and watering is performed for the most part from ten to sixteen times, or more, before the linen is fit for souring....
>
> Souring, or the application of acids...is performed in the following manner. Into a large vat or vessel is poured such a quantity of buttermilk or sour milk as will sufficiently wet the first row of cloth.... Sours made with bran or rye meal and

period of papermaking history. It is most valuable to the present study, however, in its discussion, in a single text, of fermentation and cooking, rag and wood fiber preparation, rosin and alum internal and gelatin surface sizing, loft and machine drying, and hand and machine papermaking. The coverage of gelatin sizing techniques is especially thorough.

> water are often used instead of milk.... Over the first row of cloth a quantity of milk and water is thrown, to be imbibed by the second, and so it is continued until the linen to be soured is sufficiently wet and the liquor rises over the whole...[and] just before this fermentation, which lasts five or six days, is finished...the cloth should be taken out, rinsed, mill-washed, and delivered to the women to be washed with soap and water. [Then it was carried outdoors to be bucked yet again.] From the former operation these lyes are gradually made stronger till the cloth seems of a uniform white, nor any darkness or brown color appears in its ground.... From the bucking it goes to the watering as formerly...then it returns to the souring, milling, washing, bucking and watering again. These operations succeed one another alternately till the cloth is whitened, at which time it is blued, starched, and dried.[16]

Horner adds:

> This process, including the field bleaching, required from six to eight months to complete. At Haarlem this industry continued large and lucrative until the end of the eighteenth-century, when the modern system of bleaching by the agency of chlorine practically stifled it.[17]

Doubtless, many rags that found their way into paper did not receive this sort of attention during their original manufacture. Rough or off-white rags, and tough and strong waste material, such as old ropes, sails, and canvas, certainly ended up in the sorting rooms of papermills, but such materials were set aside for making rougher-quality papers, wrapping paper, or board. Rags of the finest quality used for making better-quality paper, however, very likely started off being bleached using the "old Dutch method" described above. Thereafter such items were repeatedly washed, and used again and again, until they became too weak to be serviceable and were finally collected as rags and sold to the papermill.

The excellent formation quality apparent in some of the better historical specimens and rather short fiber lengths encountered during the 1989 research suggest that great care was taken in sorting the raw material.[18] Less attention was necessary if a poorer-quality or thicker paper was being made. Caustic chemicals and high-pressure cooking equipment were not available to weaken a strong raw material. The stampers, though shod with iron teeth and quite capable of cutting, were slow, and prolonged time in the stamper pits cost money. Therefore, a fine-quality white paper with good look-through (examined in transmitted light) was most readily and economically made by first selecting well-worn white rags of a similar strength.

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16. Horner, John. *Linen Trade of Europe*. Belfast: Linenhall Press, 1920, 368–371. Special thanks to Jesse Munn, formerly book conservator at the Library of Congress, who provided this reference.
17. Horner, *Linen Trade*, 368–371.
18. Barrett, "Early European Papers," 40–41.

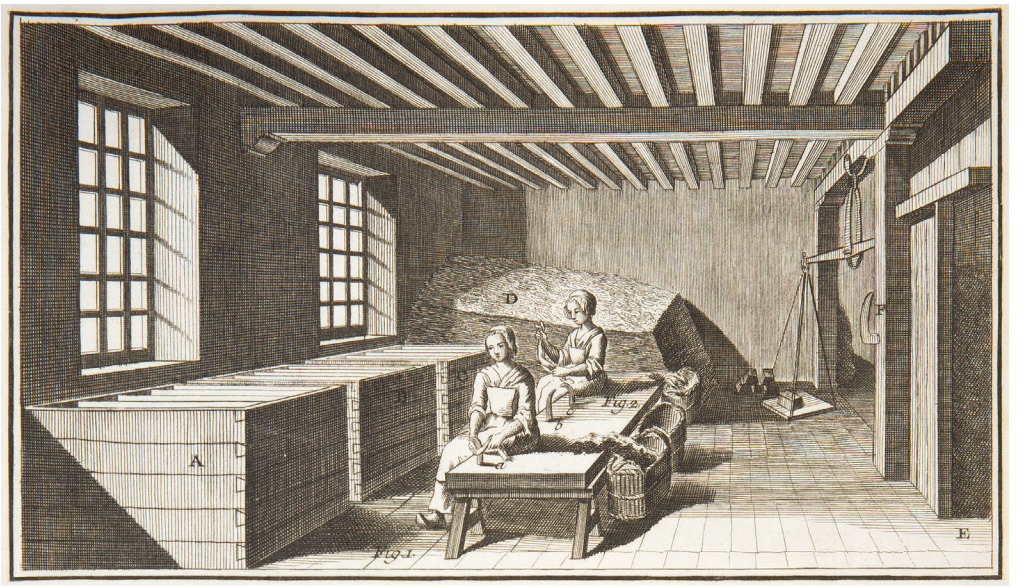

Fig. 1. Sorting rags into grades of varying quality and strength; Diderot, *Encyclopédie*.

This step in the process, like all those that followed, required skill and experience. Women and girls worked in the rag-sorting rooms of papermills, and the younger ones learned from their mothers or other relatives. Important sensitivities were passed from one to another while working together day after day, year after year. Fig. 1. Note: This and the historical plates that follow are all from Diderot's *Encyclopédie* published in Paris between 1751 and 1765.[19] No images have come to light that show the same steps in fourteenth- or fifteenth-century European papermaking, and therefore these rather idealized depictions of the steps in eighteenth-century papermaking workplaces will have to suffice. Lalande indicates that the women in mills in the Auvergne sorted rags into three grades: fine, medium, and coarse. However, he adds, "Those [mills] who wish to take even more care over the sorting have up to six compartments for six grades of rag: superfine, fine, fine seams, medium, medium seams and coarse, without taking into account the extremely coarse matter which is discarded."[20] Poorly sorted rags, stronger than the rest in a graded lot, could cause those in charge of retting and stamping tremendous headaches. With regard to retting, Lalande warns that

> Rags with varying degrees of strength and wear react in different ways to the retting process. Some are already spoilt when others have not yet shown the effects of the first fermentation; it is necessary, therefore, to put rags of similar qualities, chosen

19. Diderot, Denis and Jean le Rond d'Alembert, eds. *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers, par une societé de gens de lettres.* Vol. 5 (Plates). Paris: Briasson et al., 1751–1765.

20. Lalande, *Art of Papermaking*, 5.

> with great care, to work together if one does not wish to run the risk of ruining the whole [batch] by the inclusion of cloth which differs radically from the remainder.[21]

At stamping, remaining bits and pieces of the stronger material would force the crews to prolong the stamping, to clear up the pulp, risking its ruin. Unlike the Hollander beater, in which the roll-to-bedplate opening could be adjusted to minimize damage to already separated and shortened fiber, the stampers continued to work on every fiber caught under their blow. The secret of success was therefore to start with a carefully culled batch of rags of similar weight, color, and tenderness. The entire lot of fiber had to finish in the stampers at the same time. Without access to rags in a range of qualities, and skilled workers in the sorting rooms, a mill would have had no choice but to make only rougher-quality papers. Henk Voorn describes an eighteenth-century Swedish attempt to hire skilled workers from Dutch papermills. One of the first workers to be located, Voorn tells us, was "a highly skilled sorter," since the high quality of Dutch paper was considered to be a result, at least in part, of careful sorting of the rags.[22]

Regarding the use of hemp, flax, and cotton fiber in papers from this period, microscopic analyses by Thomas Collings and Derek Milner of paper specimens made in Europe between 1400 and 1800 generally showed mixtures of hemp and flax fiber with higher concentrations of hemp, e.g., 75 percent, during the earlier dates.[23] While cotton, or cotton-containing fabrics, were available in Europe during this period, their use was not common enough to generate substantial cotton-rag material for papermaking until the nineteenth century. Cotton fiber in significant quantity is therefore rare in papers before 1800, according to these researchers.[24]

The question naturally arises as to the use of new fiber, in the form of waste generated during processing of plant to fiber to thread or new textile cuttings. Raw unspun fiber, thread, and unbleached cloth waste were certainly available, but their strength in combination with their often dark color would have relegated them to use only in thicker, poorer, rougher-quality papers. Whitened new material in the form of cuttings from garment making or other sources must also have been at hand, but its strength was still a disadvantage. Fermentation and stamping techniques could have been employed to reduce any type of fiber to the proper length for papermaking, but only with great expenditure of time, space, and labor. "New material," writes Lalande, "is not altogether suitable: it takes too long to fine down."[25]

While apparently new, long fibers do seem prevalent in some thick papers used as cover stock in Italian limp-paper binding, such fibers were rare in the 130 historical book-paper specimens

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21. Lalande, *Art of Papermaking*, 9.

22. Voorn, Henk. "The Story of Early Dutch Papermakers in Sweden." *The Paper Maker* 29, no. 1 (1960): 20.

23. Letter from Thomas Collings to author, 7 February 1987.

24. Collings, Thomas and Derek Milner. "The Nature and Identification of Cotton Paper-Making Fibres in Paper." *The Paper Conservator* 8 (1984): 59–71.

25. Lalande, *Art of Papermaking*, 5.

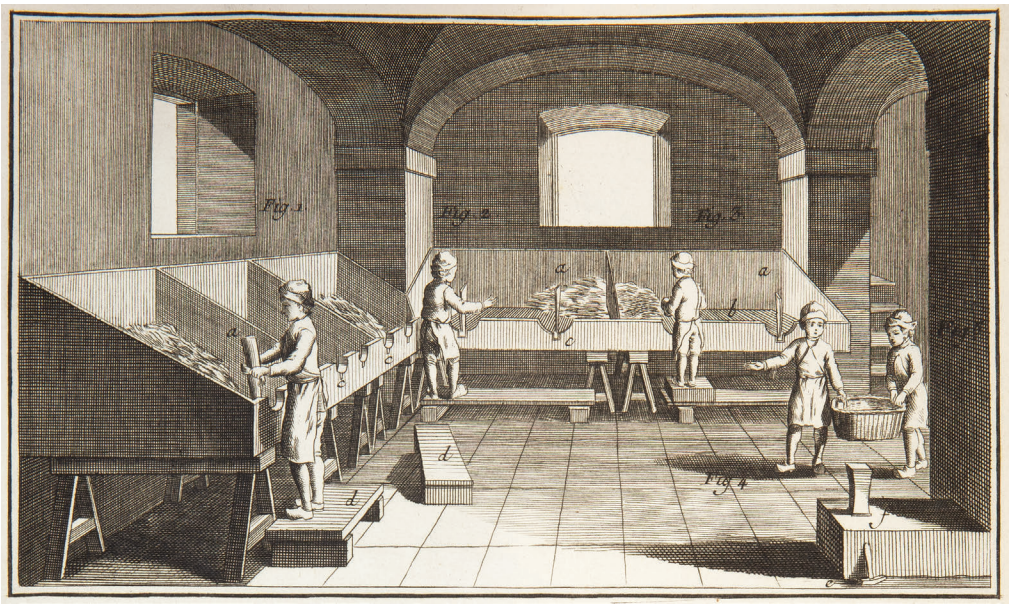

Fig. 2. Cutting rags into smaller pieces and removing buttons, pins, and other foreign matter; Diderot, *Encyclopédie*.

selected for the 1989 research.[26] There were only four examples (specimens P160, P153, P79, and P43). All were thin, gray, knotty, and made of pulp that seemed to consist, at least partly, of a long fiber, perhaps new flax or hemp waste, combined with recycled printed paper. One other quite long-fibered paper (G17) was noted, dating from around 1400 based on the watermark. It may have been made from raw fiber, but is more likely to have been made from select, carefully prepared rag. Generally, a wide variety of old, well-worn, and tender materials formed the bulk of the rag stock in mills where high-quality book papers were being made. Fig. 2.

It is worth exploring the role washing soaps, diet, and personal hygiene may have played in affecting the nature of these old hempen and linen rags before they came to the papermills.[27] For instance, Fernand Braudel tells us that Europeans appear to have bathed less and less from the fifteenth into the seventeenth century, and that public baths became less prevalent after the sixteenth century.[28] He also tells us that the rather high consumption of meat in Europe declined after 1550, suggesting a greater likelihood of residual animal fats in rags before that date.[29] It is very likely that residual components in the rags during different eras and in different locations would have had a bearing on the chemistry of subsequent

26. Barrett, "Early European Papers," 1–108.

27. Personal communication between Bernie Vinzani and the author, 2018. Vinzani notes that Soapwart (*Saponaria officinalis*) was used in Europe early on to clean cloth and could have been a prevalent ingredient as a residue in rags.

28. Braudel, Fernand. *The Structures of Everyday Life*. Vol. 1. New York: Harper and Row, 1981, 329.

29. Braudel, *Structures of Everyday Life*, 194.

steps in papermaking, the nature of the finished paper, and the changes in paper quality and character through the centuries. Unfortunately, it has not been possible to investigate this question during this research. For the moment it remains a potential variable worthy of further attention. Whatever their specific provenance, these rags, with their unique history before arrival at the papermill, are the main reason that the better papers of the period can never be duplicated.

Retting

Retting is perhaps the least appreciated step in the early craft of papermaking. Its widespread disappearance between the mid-eighteenth and early nineteenth centuries may account for the general lack of attention to the process, and those responsible for it in contemporary discussions of hand papermaking. But its importance to the craft at earlier dates was evident to Lalande:

> The rettery constitutes a fundamental part of a papermill; in Auvergne the standard of the mill is judged by this. The room must be vaulted for the sake of cleanliness; moreover, the more it is protected from variations in temperature the less the manufacturer is liable to error in the time necessary for correct fermentation; and because of this the process is neither interrupted nor hurried.
>
> The fermentation or retting renders the paper uniform, binding, soft and gives it weight; if it is stopped too soon, the paper becomes coarse, hard, light and stiff, but [the pulp] needs much more time to be worked; the starch [pulp] flies about and settles far less readily; it is a "wild" material in paper-makers' terms [it forms a less even, less uniform sheet].... If, on the other hand, the rags are left to work too long, there would be, as far as the papermaker is concerned, a considerable wastage.[30]

Considerable skill and experience were required to evaluate the strength of the rag and the degree of retting required to produce fibers that would respond readily to stamping yet yield an optimum-quality sheet with minimal loss of fiber. In the more substantial and well-established mills, fermenting was the job of a specialist, who passed his craft on to his sons or other young artisans. Knowing how to ret rags was not unlike knowing how to ferment grape juice to make good wine. Our knowledge of wine making, and our respect for it, is still considerable because we have seen fit to preserve the art. If we were able to travel back in time to the age of rag fermentation for papermaking, the man in charge in a good mill would have skills that were at least as highly respected as those of the man in the same town who made good wine. Over the ages, the art of making wine in the old way has sadly, but perhaps naturally, proved to be closer to people's hearts than the making of good paper the old way.

The fermentation methods used by various mills are very likely to have differed as much as the construction and location of the mills themselves. Citing the fermentation routine at a

30. Lalande, *Art of Papermaking*, 8.

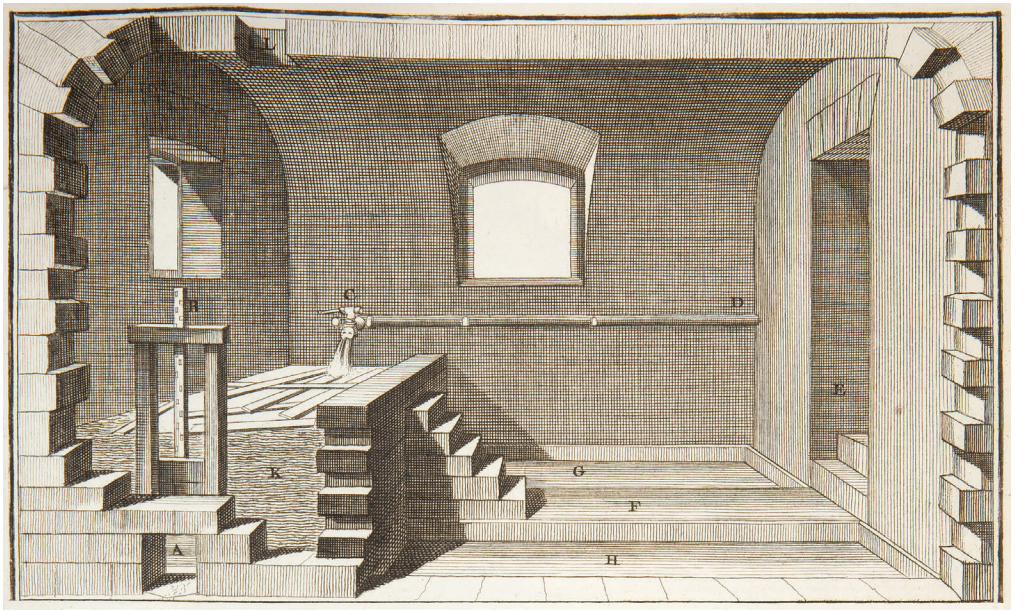

Fig. 3. Rettery for fermentation of rags, which were pushed down from the sorting and cutting rooms above through a hole in the ceiling; Diderot, *Encyclopédie*.

particular mill is therefore a bit risky but probably worthwhile in light of our general lack of exposure to the technique. Fig. 3. Lalande offers descriptions of several approaches:

> In certain parts of Auvergne the rettery...is no more than a large basin of dressed stone for the fermentation and, so to speak, the rotting of the rags; it can be up to sixteen feet long by ten feet wide and three feet deep; the sides are cemented, but not the bottom, and the water thrown on the rags that this basin...contains can drain away by itself.... When the retting tank...is full of rags, water is thrown over them until the tank is full [and is then allowed to drain] over a period of ten days, eight or ten times a day, without stirring. They are then left alone for another ten days approximately, without being watered; they are turned and the centre is brought to the surface to help the fermentation; when they have been turned, they are again left to ferment for fifteen to twenty days with the result that the rotting-down process can last up to five or six weeks; there is no fixed time limit, but when the heat has increased to the point where the hand can be left inside for a few seconds only, it is considered time to stop the process.
>
> In the mills where there are but a few rags to be used, they are allowed to rot for a longer period, since the piles, being smaller, heat up less and with greater difficulty; so it is impossible to fix a precise duration for the retting process. It depends also on the quality of the cloth; the finer linen rots down less quickly than the coarser material, and old cloth with more difficulty than new because the moisture content

> which predisposes the fibres to fermentation is greater in new or coarse cloth than it is in fine or old.[31]

Lalande's latter comment about the speed of the retting action (which he attributes to variations in moisture content of the rags) is of considerable interest. Pure cellulose is quite resistant to most bacterial and fungal attack, partly because of its inaccessible crystalline structure, but also because it lacks the nutrients sought after by most organisms, including those secreting cellulolytic enzymes.[32] Newer or less fine linens and cloths may have fermented more quickly, as Lalande reports, simply because they contained components that acted as food for a larger organism population. No mention is made in the older references surveyed for this study of the addition of materials that may have acted as a "nutrient broth," but, as suggested earlier, residual components in the old rags themselves may have played a key role in the ability of a pile of rags to support enzyme-secreting organism growth in a relatively short time.

Proteaux quotes an enlightening 1813 French description by D'Arcet and Merimée, of the effects of retting:

> The first change observed in the rags, after they have been for some time in the fermenting vat, is the disengagement of a material resembling mucus, so sparingly soluble in water that it is not removed in triturating [separating/macerating] the rags, and is even found in the vat at the time of manufacturing the paper. Pulp, produced by rags thus prepared [insufficiently fermented?], retains water, so that the paper made of this material shrinks very much in drying and in consequence has neither the weight nor the [dimensions] which it should have.
>
> This mucosity is more abundant in proportion as the rags are coarser, as they have been less thoroughly washed before rotting and as the air of the fermenting vessel is more stagnant. This substance decomposes, as the putrefaction advances, and gives rise to a kind of white mildew, similar to that which is seen on manure; and by that time a considerable portion of the rag fibres have been reduced to mould.
>
> In regard to the quantity of water which this mucous substance in the pulp will retain, the paper resembles that made from tow, containing a great deal of gluten.... Fermentation facilitates trituration by destroying the glutinous materials which unite [or are present in] the rag-fibres.[33]

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31. Lalande, *Art of Papermaking*, 7.

32. Cellulose is made up of sugar rings packed quite closely together into a crystalline-like structure. Cows and other ruminants have certain microbes in their second stomachs that secrete enzymes that break cellulose apart into component sugars or starches that the animal can consume as food. Ordinarily, however, cellulose is quite resistant to enzymatic, chemical, and other forms of degradation.

33. Proteaux, *Practical Guide*, 162–163. D'Arcet and Merimée, Proteaux tells us, were commissioned by the Societé d'Encouragement of Paris in 1813 to investigate the means of improving the sizing of paper. Their report, according to Proteaux, is incorporated in volume 26 (1813) of the transactions of

The "mucosity" referred to here may suggest the presence of a by-product of fermentation that acted as an antiflocculant or a formation aid. Such a component in fermented pulps would help explain the excellent knot-free formation seen in some higher-quality sheets. While each mill certainly had its own resident population of organisms adhering to rettery walls from countless previous rets, the only artificially introduced starter or catalyst commonly mentioned in historical references as an aid to fermentation is lime. As an alkali, lime served to swell the cellulose, opening it up and making it more susceptible to chemical action by the enzymes secreted by the organisms present during the fermentation. Lime may have also encouraged the growth of microbes that favored the higher pH range. Whatever the chemistry, lime so effectively contributed to the speed of the ret that it was outlawed by regulation in some areas. Curiously, in complete contradiction to Lalande's warnings about lime, D'Arcet and Merimée, writing in 1813, described the use of lime to stop, rather than to accelerate, fermentation:

> Lime, it is well known, has been employed at all times in our [French] paper-mills, and in some of them is so at the present day, not, however, to macerate the rags, but on the contrary to arrest the effects of maceration. When some circumstance has given rise to long delay the rags are taken out of the fermenting vessel, where they would not remain long, without turning into mould, and dipped into a milk of lime. The material, when thus prepared, can be kept indefinitely. The same means are also employed to preserve the pulp, while in the condition of half-stuff.[34]

This approach and view more closely match my use of a slaked lime, $Ca(OH)_2$, (calcium hydroxide) cook to stop a fermentation of new raw-flax fiber, kill microbes and most spores, counter the acidic pH of the ferment, and leave a residual compound that eventually will act as an alkaline reserve in the form of calcium carbonate.[35] The contradictory views on lime mentioned above may be related to a historical reporter's or translator's confusion over the form of lime employed. The more aggressive quicklime, CaO (calcium oxide), would have given much more action on the fiber than a slaked lime, $Ca(OH)_2$, or old slaked lime that may have long since changed to the benign $CaCO_3$ (calcium carbonate, limestone, or chalk). With the possible exception of some form of lime, in most mills the only catalyst was apparently the leftover resident "starter" from the previous fermentation. It is very likely that this was a distinctive population that evolved at each mill over many decades of repeated ferments. While early voices are generally silent on the matter, papermakers at later dates wished for an alternative to retting. Lalande lists several advantages to doing without the step:

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the Societé d'Encouragement, 439. This quotation is related to the proper preparation of pulp prior to forming sheets intended for eventual gelatin sizing.

34. Proteaux, *Practical Guide*, 163.

35. Barrett, "Early European Papers," 73–75.

Fermented rag	Starting weight	Loss by cutting and dusting	Remaining weight	Duration of fermentation in days	Yield after washing and drying
Whites, fine	1,000	60	940	6	720
Whites, half fine	1,000	80	920	12	660
Grays, coarse	1,000	100	900	24	400
Colored, fine	1,000	60	940	8	580
Colored, coarse	1,000	80	920	15	500
Boiled rag (pressure at one atmosphere)	**Starting weight**	**Loss by cutting and dusting**	**Remaining weight**	**Hours of boiling**	**Yield after bleaching and drying**
Whites, fine	1,000	60	940	5	780
Whites, half fine	1,000	80	920	6	730
Grays, coarse	1,000	100	900	12	580
Colored, fine	1,000	60	940	6	700
Colored, coarse	1,000	80	920	8	630

Fig. 4. Piette's comparison of yields from fermentation versus cooking. All weights in kilograms.

> If it were possible to destroy the strength and weave of the material and to degrease it without corrupting the substance by rotting, if one undertook the task of reducing the rags to pulp without fermentation, the paper would be stronger, less brittle and whiter. Some manufacturers say that retting gives, at least to the surface of each rag, a yellowish tinge that the mill eradicates only with difficulty and cannot eradicate completely if the material is too far gone.[36]

Cooking and bleaching, the modern substitutes for fermentation and washing during beating, apparently came into use in Europe in the early nineteenth century. In the only such reference known to me, Proteaux cites work by Louis Piette and reprints his actual comparisons of the yields of different grades of fermented versus cooked rags.[37] Fig. 4.

The data here show a clear yield and time advantage to the cooking approach (chemical and concentration not given), but no mention is made of the effects of the two techniques on paper quality (paper permanence, durability, performance in use, and character).

Whatever the losses, the fermentation step was crucial to the early craft. It weakened the fiber and left it more readily shortened and fibrillated at beating, it helped cleanse the rags by ridding the fiber of noncellulosic impurities, and it played a key role in determining the quality

36. Lalande, *Art of Papermaking*, 8–9.

37. Proteaux, *Practical Guide*, 41–42. Proteaux has taken this chart from Piette, Louis. *Manuel du contremaître et du chef d'atelier de papeterie.* Paris: Bureau des fabricants de papier, 1861.