Scientific Equipment for the Examination of Rare Books, Manuscripts, and Documents

PAUL S. KODA

Rare book librarianship has changed and improved a great deal since the publication of the 1957 issue of Library Trends on "Rare Book Libraries and Collections." The theme reflected a preoccupation with the concept of rare books and with the development of collections. During the ensuing years no one has provided an entirely satisfactory definition of rare books, but then it is not the issue it seems to have been in the middle of the 1950s. Collection development, on the other hand, has been refined and systematized during the past thirty years. Changes and improvements include: better education for rare book librarians; a clearer understanding of how rare book collections can serve a multiplicity of humanistic disciplines, an understanding that continues to undergo rapid development; the establishment of rare book standards in ethics, cataloging, and security; contributions by rare book librarians to computer automation that have provided comprehensive bibliographic control of collections; and the development of ancillary skills such as the conservation of library materials and fund raising.

During this thirty-year period the importance of rare books for scholarly research has increased. Most recently, for example, rare books have been the focus and foundation for the burgeoning area of research called the history of the book. Books have become both the substance and subject of research for scholars taking an historical approach in traditional disciplines like art, sociology, and anthropology as well as in numerous areas of history itself. At the same time, rare book librarians have continued to assist their traditional readers in textual studies.

Paul S. Koda is Preservation Officer, University of Maryland, College Park Libraries, College Park, Maryland.
PAUL KODA

and bibliography, whose emphasis has always been on the interrelationship between the physical work and the verbal text it carries. If, indeed, there has been a lesson to be drawn from their work with the physical book, it is the recognition of the primacy of the physical text. Original documents can be returned to again and again—as the scientist repeatedly returns to the natural world—to obtain significant new information as new historical methodologies are developed and as more refined analytical techniques are applied.

These new methods and techniques in no way reduce the importance of traditional approaches to the study of original documents. A case in point is the scientific analysis that was made of the Plate of Brass that was purportedly fashioned and deposited in California by Sir Francis Drake in 1579. Early scientific tests on the plate were inconclusive, yet nearly every scholar trained in Elizabethan philology would immediately question the plate’s authenticity. The point is that traditional disciplines like philology, textual studies, and history continue to offer time-tested approaches to the study of rare documents and should always be used in conjunction with new methods of scientific investigation.

There are, on the other hand, several advantages in using the new analytical approaches for studying rare documents. Perhaps the main benefit is the concentrated focus on the documents themselves—complete examinations or reexaminations with scientific impartiality can reveal new information about their contents and can stimulate fresh dialogue about their manufacture and place in history. Another benefit is the development and application of new techniques for determining the authenticity of documents. They also help conservators provide better care for documents. Finally, the new techniques refine ways of answering traditional questions about variants regarding editions, printing impressions, bindings, and paper manufacturing.

Many of the new techniques and instruments for examining rare documents are not well known outside the immediate environs of rare book libraries. It is the aim of this paper to provide an introduction to some of these instruments and to describe how they provide a better understanding of rare documents.

EQUIPMENT

The First Group

The equipment required for the physical examination of books and documents falls into four groups. The first group includes large and
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expensive pieces of equipment. The largest and most expensive is the atomic particle accelerator (see R.N. Schwab's article in this issue for an extended discussion of its operation and usefulness for research). Accelerators operate with a combination of funds and staffing from major universities and the government, and they are only available for research in a few areas of the United States. Using an accelerator requires teams of researchers, including librarians, physicists, bibliographers, and technicians. The financial cost for performing such analyses is very high, as one can imagine, so it is understandable that the documents which have been studied are of paramount importance to Western history and culture: they include works like the Gutenberg Bible and the Bay Psalm Book.

The Second Group

The equipment in the second group is much less expensive and much more likely to be found on every university campus and in many industrial research centers. The single most important instrument in this category is the electron microscope (EM). The technical ideas for electron microscopy were first promulgated in the 1870s, but it was not until the 1930s that they were practically put to use. The success of electron microscopy is based on the fact that the wavelength of conventional light is approximately 500 nanometers (nm) and that the standard optical microscope is incapable of separating details finer than 250 nm. Instead of using a beam of conventional light, therefore, an EM uses the extremely short wavelengths of an accelerated electronic beam to form images in which fine detail is resolved, resolutions as fine as .2 nm.

Electron microscopes are traditionally classified as either transmission or scanning instruments. In transmission electron microscopes (TEM) a beam of electrons passes through the specimen being examined. In a scanning electron microscope (SEM), which is the preferred instrument for examining documents, the beam of electrons passes uniformly and systematically over the surface of the specimen. The illuminated points are "collected" electronically and formed into images that are projected on high-resolution television or computer monitors. Because the angular aperture of the SEM's probe-forming lenses can be very small, a large depth of field similar to conventional photographic cameras is possible. The resulting images are clear and astonishingly three-dimensional and of considerable diagnostic use.

In order to perform an analysis, a small specimen has to be extracted from the document. During specimen preparation (either
micro-paring for a TEM or metallic coating for a SEM), the specimen is effectively destroyed. This, of course, is a major drawback regarding precious or unique documents. Though a typical sample specimen has a diameter of only 3 mm, its loss to a document may well be unacceptable. In these cases electron microscopy is not a viable tool for the physical examination of documents.\textsuperscript{12}

On the other hand, there are some instances when taking a specimen from an important book or manuscript is justified.\textsuperscript{13} They include the one-time authentication of a suspect document (the recent discovery of what purports to be an original copy of A Freeman's Oath is an example); the understanding of previous conservation measures taken with a document (the holograph copy of the Declaration of Independence comes to mind); and the anticipation of future conservation work on an important manuscript (the Book of Kells is a possible candidate).\textsuperscript{14}

The fact that a document is altered when analyzed by electron microscopy makes it imperative that careful planning is done so the chosen specimen will yield the greatest amount of useful information, while at the same time being a fragment whose removal has the least impact on the document.\textsuperscript{15} Such planning requires the assistance of librarians, conservators, researchers, and technicians.\textsuperscript{16}

The ethical quandary of whether or not to extract a specimen diminishes when several copies of a printed book are available for analysis and when the questions being asked are common to every extant copy of a book.\textsuperscript{17} The risk diminishes even more when breakers (or, perhaps, leaf books) are available for analysis. In this regard, librarians may want to hesitate before disposing of duplicate fragments or minute pieces that come free in the day-to-day handling of books and manuscripts. They can be used to build badly needed collections of standard specimens.\textsuperscript{18}

The greatest potential for electron microscopy is probably with nineteenth-century documents because the uniformity of their materials and manufacturing makes it impossible to discern the differences readily visible in handmade documents. In the analysis of paper, for example, a SEM can be extremely useful in measuring the minute pattern made by the weave of the wire used in producing machine-made paper, a task that is notoriously difficult even with optical microscopes. Even more important, the SEM provides a clear picture of the length, fibrillation and shearing of paper fibers that take place during the beating phase of manufacturing, thereby providing information about the specific batch of pulp from which the paper was formed. This information can be used in determining whether particular sheets of paper were
produced at the same time by one manufacturer. In addition, SEMs provide vivid pictures of fiber interlocking (or lack of it), calendering, kinds of fibers, interstitial loading, and surface coating—important for identifying and classifying paper and invaluable for proposing conservation treatments and predicting longevity. The SEM can easily isolate the different graphic processes used to illustrate books in the nineteenth century. Very little detailed microscopic investigation has been undertaken to identify and classify the myriad photographic processes that were developed in the nineteenth century; a systematic examination of these photographs to document the processes can be materially aided by using scanning electron microscopy. 19

The Third Group

The instruments in the third category are often found in rare book libraries or in special collection departments within larger libraries. By and large, these instruments are divided into five groups: first, optical microscopes; second, photographic equipment; third, mechanical/optical collators; fourth, equipment to record watermarks; and fifth, ultraviolet lamps.

Optical Microscopes

The variety of optical microscopes that have been introduced since they were first employed in the seventeenth century are legion, and many of them help librarians examine the books and manuscripts in their collections. Yet no library has the resources to acquire more than one or perhaps two of these instruments. However, it is possible to acquire one instrument that meets most of the research needs of scholars. The characteristics of the ideal microscope include the following six features. The first is stereoptical viewing so both eyes can be used for looking at specimens. The eyepieces should be protected by rubber or Teflon cups which protect and allow researchers to wear eyeglasses; the eyepieces should also adjust to account for extremes in sight variation. Second, the microscope should be attached to an adjustable, extendible arm so large documents such as atlases and prints can be examined easily. Viewing oversized specimens can be improved with large, maneuverable staging platforms. Third, microscopes should have zoom lenses so a wide range of magnification is possible. They should also have a mechanical or electronic gage that accurately records every level of magnification for permanent records or photographs. Magnification from 2X to 580X is appropriate. Fourth, specimen illumination should
include reflected and transmitted light, though the former is used more frequently with documents. Light should be even, high intensity, and continuously variable. For day-to-day use, internal illumination is adequate (which can be modified with selective filters), but a source of light on an adjustable mount that is not connected with the microscope is very useful in providing different kinds of raking light. Ring illumination is also helpful when a large specimen is under view. Fifth, an attachment for microphotography is necessary if photographic records are required. Sixth, eyepiece micrometer discs or reticles (in either English or metric calibrations) facilitate the micromeasuring of fibers, web and wire marks, and type strokes.

Photographic Cameras

Many different kinds of cameras have been invented since they first appeared in the nineteenth century and many of them can be used to investigate documents. The photographic requirements for such investigations usually fall into the following categories: first, the ability to provide close-up photographs; second, the possibility of attaching the camera to a microscope; and third, immediate results so photographs can be retaken if the originals do not capture the required evidence or if the specimen has to be repositioned.

One class of camera that meets most of these criteria is manufactured by Polaroid. Everyone is familiar with the ability of Polaroid cameras to take photographs that develop in a matter of seconds, but it is not generally known that Polaroid has developed cameras that are used for medical close-up photography and forensic analysis. They are easily adapted to the needs of the librarian or bibliographer. The best and most versatile Polaroid system is the CU-5 Close Up Camera. It is a light, portable model that can be taken into the field by researchers who travel from collection to collection. More important, however, is that the camera is easy to manipulate so hard-to-take pictures of details like binding structures are captured quickly and efficiently even by those not well-versed in photography. The photographic records can be the same (1:1), magnified (2:1, 3:1, 4.5:1, and 10:1), or reduced (1/2:1, 1/3:1, and 1/4:1). Both black and white (with a reusable negative) and color film can be used. By attaching a hood the CU-5 can also make hard copy records of SEM displays.

Watermark Reproduction

Almost from the very beginning of paper manufacturing, papermakers have formed sheets of paper that contain watermarks and countermarks, which are designs, patterns, dates, and names that are visible
when a sheet of manuscript or book paper is held up to the light. These marks are useful for dating books that do not have manuscript or printed dates, in determining the sequence in which the sheets of a book have been printed (vital to librarians helping textual scholars establish a text), in identifying first impressions or first editions of a book, and in verifying a document's authenticity.

Until the middle of the 1960s, the customary ways of recording watermarks were either by tracing or by translating measurements into line drawings. Both methods are cumbersome, hard on the eyes, and frequently imprecise. For several years more reliable methods of recording watermarks have been available. The first is called beta-radiography; it is a process that uses beta rays. A radiographic plate is placed behind or beneath the sheet of paper to be examined. The paper is exposed to the plate for several minutes. Because the paper is thinner in the place where the watermark has been formed in the sheet and because various thicknesses of paper block different levels of beta radiation, images of the watermarks can be recorded.

Beta-radiography does have a few disadvantages. The beta plate and film are expensive; approval to acquire and use a plate is time consuming because clearance has to be obtained from the Nuclear Regulatory Commission; special security and operational procedures have to be set up to ensure safety, though its danger to people is virtually nonexistent; and the time required to record a watermark can be lengthy, which reduces research productivity, a not inconsiderable problem for visiting scholars under severe time constraints.

The great advantage in using beta-radiography to record watermarks is that the writing or printing on the surface of the paper is too thin to affect materially the recording of the watermark. The resulting images are unobstructed and sharp. Another advantage is that the recorded image is a precise duplication of the watermark, making it possible to measure the watermark accurately and to publish it so that scholars can take advantage of the research. (See Woodward's article in this Library Trends issue for another discussion of beta-radiography.)

A more recent method of recording watermarks is the DYLUX process. It works by passing visible and ultraviolet light through a sheet of paper to DYLUX photosensitive paper. Primarily designed for obtaining virtually instant image proofs of line, text, and halftone negatives, the process effectively records watermarks, countermarks, wire lines, chainlines, and the weave in machine-made paper. Because paper is thinner at the location of a watermark, a sheet of paper acts as a quasi-negative by allowing differing amounts of light to shine through it. The process is simple and is done rapidly in two steps. The water-
marked paper is placed in a lightbox and covered with a sheet of DYLUX paper. Both are then exposed to visible light which records an image of the watermark on the DYLUX paper. The watermarked paper is removed and the DYLUX paper exposed again, this time to ultraviolet light to raise and fix the image, making it a permanent record visible to the naked eye.

Unlike beta-radiography, the rays of visible light used in the DYLUX process can be blocked at times by the manuscript or printing ink; the result is an image that is blurred or partially obscured. This drawback is often overcome by several advantages in using DYLUX. Both the machine and the DYLUX paper are relatively inexpensive, mainly because a beta plate has to be replaced every two or three years. It is a dry process that does not require water or chemicals, and the equipment can be set up and operated in a space no larger than an ordinary office desk. Perhaps its greatest advantage is speed, for it usually takes only a couple of minutes to reproduce a watermark and is a procedure that can be mastered by an amateur in a brief amount of time.25

**Mechanical/Optical Collators**

Collating instruments are used to compare copies of printed books against a known text to find out whether they have been typographically reset, thereby revealing undiscovered editions or states of the text. During the past thirty years three mechanical/optical collators have been invented and used for examining texts. The first, and by far the best known and still employed, is called the Hinman Collator.26 It was invented and used by Charlton Hinman to collate numerous copies of William Shakespeare’s First Folio to discover where the text may have been changed during typesetting and printing. The results were much better than expected. Not only was Hinman able to make major advances in restoring the text of many of Shakespeare’s plays, he was also able to discover new and important information about the way English Renaissance compositors and printers worked. The result was his monumental work on the printing of Shakespeare’s First Folio which is a model of investigation and identification for librarians examining documents or assisting researchers in using library collections.27

The Hinman Collator works on a principle of oscillating light. Two copies of a document—which can be a printed book, engraved plate, score, or map—are placed on adjustable cradles and aligned so they overlap exactly when viewed through a binocular eyepiece. The oscillating light is turned on; each page is illuminated in turn and is
visible through the eyepiece. Because the human eye retains a lighted image for an instant after it disappears, any variations of the overlapping text/graphic image will appear as a rapidly moving word, phrase, or detail that can be tagged and examined more carefully when time allows. The collator is used to examine lengthy texts or a single broadside; it is used to uncover changes in graphic images or to discover reset pages or substitute leaves.

A more recent invention for collating documents is the Lindstrand Comparator, created by Gordon Lindstrand. It has the same function as a Hinman Collator but works on principles of stereoptics. A slight variation in spelling, punctuation, or design is immediately visible through a three-dimensional distortion or disorientation to the eye. Its advantages over the Hinman Collator are that it is easier to use, does not require an electrical source of power, is much smaller, and has better success when collating a photocopy of a book with an original printed version. The major disadvantage is that the operator requires good eyesight or eyesight that has been corrected. This may bother some senior scholars who use rare book collections.

The most recent addition to the field of mechanicaVoptica1 collators is the McLeod Collator. It was invented by Randall McLeod and works on optical principles similar to the Lindstrand Comparator. The major differences between the two instruments are that the McLeod Collator can be broken down for easy portability (it weighs less than thirty pounds); the positioning of the mirrors is more flexible, enabling the researcher to place the documents in several convenient positions; and the person using the collator can sit in a much more comfortable position.

_Ultraviolet Lamps_

The use of ultraviolet light to reveal alterations or additions to documents has been available to librarians for many years. It works on the principle that all materials absorb electromagnetic light waves and reemit them uniformly according to the construction or formation of the object. When a document has been disturbed in some way (by erasing, washing, or restoration, for example) the affected area will fluoresce differently than will the original material. Ultraviolet lamps come in many sizes and intensities. Portable models are available (some with battery packs), and standing models can be equipped with mounts for cameras to record evidence brought to light when exposed to ultraviolet rays.
The Fourth Group

The fourth group consists of common instruments found in every library and private study. They include items like magnifying glasses and rulers. Most of the time they are perfectly adequate to do the jobs for which they are intended, but the fact that they are taken for granted ought to make the librarian pay attention to them on occasion.  

Micrometer Calipers

Micrometer calipers are finely calibrated tools that measure thickness. They are especially useful for measuring the thickness of paper because they are graduated in thousandths of an inch or centimeter. Some are made specially for measuring paper because the micrometer's anvil and spindle faces are lapped and extra-large in order to prevent compressing the paper being measured and to ensure accurate readings. A floating anvil disc which adjusts itself to different surface conditions is especially helpful in measuring the uneven surfaces of handmade paper and cloth case bindings.

Viewfinders

Viewfinders, which are small magnifying instruments that usually rest on the document they are magnifying, come in many forms and styles. They include linen testers, calibrated reticles, eye loupe magnifiers, and type size finders. They are valuable for examining cloth and leather bindings, type, details of illustrations, and paper. Because viewfinders are used by resting them on documents, the bottoms of their bases should be smooth. And whether the sides of their bases are open or transparent plastic, their overall design and construction should allow in the maximum amount of light. Magnification usually ranges from 2X to 8X, with 3X to 6X being the most popular (sometimes lower magnifications are better for examining details on a document, as, for example, an autograph).

Dividers

Dividers are especially useful for measuring binding patterns and multiple lines of type. The most versatile dividers are expandable to 250mm. Often the ends are pointed which may pose a danger to documents. But some are manufactured with blunt ends with fine center points for precise measuring.

Ruler

Rulers seem to be just rulers, but some are better for measuring documents than others. Precision engineering rulers that are machine
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divided provide the most accurate measurements. Rulers should be transparent, flexible, have English and metric calibrations, repeat on both sides, and be calibrated from flush left on one end so they can fit into gutter margins.

There are many more instruments and techniques that are beginning to be employed in the investigation of rare documents. Future research promises to bring to light much new and important information about the composition, history, and possible conservation of books in rare book libraries. Through cooperative projects and the use of equipment now available, librarians can take an active part in promoting and aiding these new methods of research.

References

1. Because there is no collective term for books, manuscripts, and documents that are rare, the word document is used to refer to any and all of them.
5. Before acquiring equipment the librarian should try it out (if possible, in the location in the library where it will be used) and find out about guarantees, warranties, maintenance agreements and costs, and ancillary equipment and supplies that may be required.
6. For some analyses it is necessary to transport the document to the equipment used to examine it. Planning for safety and security is necessary and will likely take up greater amounts of librarians' time as more analyses are proposed and performed.
7. Medical X-ray equipment has also been used to find out how hardened papyrus rolls may be safely unrolled. As time goes on, rare book librarians will undoubtedly find many more uses of available technology for document analysis.
8. A nanometer measures 10 angstrom units or 4 x 10⁻⁹ inch.
9. Scanning electron microscopy usually achieves its best resolution at 20 to 50 nm.
10. Linking computers to SEMs can provide image content analysis with "interpretations" provided in tabular or graphic forms.
11. Librarians can learn to use electron microscopes in workshops and seminars offered from time to time in several locations in the United States. Previous experience with scientific instruments is helpful.
12. There is a certain irony here because it is only through analysis that one can know whether a selected specimen has useful and/or representative information. Preliminary investigation with an optical microscope (see later discussion) may assist the researcher in choosing satisfactory specimens.

13. It is always possible to rationalize the extraction of ‘just one small sample’ for scholarship purposes. If a study proves inconclusive, there may be pressure in the future to extract another specimen for study. Good planning, which may include delay, prevents repeated damage to a document.


15. There are precedents in art scholarship where analysis or testing of surface pigments “destroys” a small portion of the object in order to gain sufficient information for restoration or conservation. Whether or not documents should be restored has been debated by librarians for years. The problem may be solved in part through optical or digital disc technology, which can provide an electronic enhancement of a graphic image. Most research may be satisfied with enhanced images. They do not, of course, provide information about details like watermarks which are not normally “seen” in image processing.

16. Many analyses of documents require cooperation among researchers, often to the point where permanent or semipermanent research teams are formed for long-term projects.

17. This situation does not apply to unique documents. And it may not apply to details that are copy specific to a printed book (an example is an autograph presentation inscription). It may be argued that on the microscopic level every analysis of a printed book results in unique information, but statistical analysis usually resolves anomalies.

18. The true potential for the scientific analysis of documents will be realized only when standard samples of specimens are collected. Librarians, bibliographers, and conservators will then be able to compare documents with established standards. Building specimen collections would be a useful project sponsored by the Preservation of Library Materials Section of the American Library Association or by the Bibliographical Society of America. Also, much better bibliographical control is needed for nineteenth-century specimen and sample books that were issued by the various book manufacturing trades.

19. All of the analytical techniques described in this paper are used on finished documents. A thorough knowledge—preferably gained through study and hands-on experience—of the manufacturing processes that produce books and manuscripts is necessary to interpret data obtained through scientific examination.

20. A Polaroid SX-70 camera and adapter is good for microscopic photography.

21. Comparison microscopes are very useful for comparing two specimens simultaneously. With calibrated eyepieces they are good for examining type faces, paper formation, and the weave and patterns in cloth casings.

22. Librarians who want to learn more about document investigation should also read some of the excellent journals, technical reports, and monographs in the area of forensic science. A good place to begin is with Ordway Hilton’s Scientific Examination of Questioned Documents. New York: Elsevier, 1982.

23. The CU-5 system is already used in many libraries to copy printed catalog cards.

25. At the present time only the watermarks in flat paper specimens, such as broadsides, letters, and maps, can be recorded by the DYLUX method. Additional technical development is needed before watermarks in codex papers can be recorded. Betaradiography, on the other hand, can be used with codex papers.


29. Personal correspondence with McLeod.

30. Several computer programs are now available to collate printed texts. Mechanical collators for examining graphic images will continue to be used as before. In this regard see: Sternberg, Paul R., and Brayer, John M. “Composite Imaging: A New Technique in Bibliographic Research.” *Papers of the Bibliographical Society of America* 77(no. 4, 1983): 431-45.


33. Although this paper does not have space for a discussion of the use of computers for the examination of physical materials, a great deal of interesting work has been done with them. An example is the digital image enhancement of palimpsests. In the future, computers should be used to classify type fonts and faces, which would aid in the identification of anonymous printers of early books. They would also help type designers and manufacturers copyright their creations.