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THE MICROSCOPE IN DOCUMENT EXAMINATION

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The microscope is no doubt the most widely used optical research instrument. The fruits of its use have come from fields undreamed of by the average person and have benefited man in innumerable aspects of his life. In recent decades the microscope has added its important contribution to the administration of justice, specifically through its application to the examination and interpretation of physical evidence and the presentation of the findings in court.

In this sphere one of the most effective uses of the microscope has been in the particular field of the examiner of questioned documents, who specializes in the identification of handwriting and typewriting, and the analysis of paper and inks and other elements of documents.

The work of the questioned document examiner is divided into two main problems: (1) *Discovery* of the facts, and (2) *demonstration* of the facts. The microscope is sometimes very helpful in the latter sphere. In the former it is often indispensable.

The microscope is the instrument which makes it possible to see physical evidence on documents which would otherwise remain invisible and useless. The average unaided human eye can distinguish only 250 separate lines to the inch. This means that any small details which involve dimensions or separations of less than 1/250th of an inch are lost to the eye, which sees them as a connected, solid mass. As an illustration, the myriad separate graphite granules which make up an ordinary pencil line appear to the naked eye as a solid line.

These small details are often of utmost importance in the determination of questions respecting the authenticity or spuriousness of documents. In many instances the evidence of the microscope is conclusive and irrefutable. The microscope has therefore become indispensable to the examiner of questioned documents.

THE STEREOSCOPIC MICROSCOPE

The low power, wide field, binocular stereoscopic microscope, and the low power comparison microscope with matched objectives bringing two separate images into a single eyepiece, are the two most useful microscopes in document examination. Occasionally the standard laboratory miscroscope is of value in certain types of examination, when higher magnifications are desirable. But the stereoscopic microscope has supplanted the standard monobjective laboratory microscope for nearly all kinds of disputed document examinations. Its advantages are many. (1) Stereoscopic vision is preferable in many problems involving depth, such as where an ink line crosses a fold in the paper. This instrument shows ridges and furrows and minute indentations that cannot satisfactorily be seen with the ordinary microscope. (2) It is easier to use, having a tube to occupy each eye. This is especially important in demonstrating evidence to others not trained in the use of the microscope. (3) The wide area of view is often a distinct advantage, wherein a comparatively substantial section of a document can be shown. A high degree of magnification is usually not required and is often undesirable. (4) This instrument shows the image erect or upright, in its true position with respect to the viewer, and not reversed or inverted as in the ordinary microscope. (5) Its construction provides a long working distance between the objectives and the object under observation, which is a distinct advantage in document examination. This lens-to-object distance also permits a wide latitude in the choice of an illuminator and in the angle of incidence of the light thrown on the object. (6) Its optical construction permits a high eyepoint above the eyepieces, and eyeglasses usually need not be removed. (7) Because of the low magnifications used, with reflected light, no preparation of objects, such as slicing or staining, is required; the object may be viewed as is. (8) Its design permits the microscope to be moved over the object rather than the object moved under the microscope, and this feature greatly facilitates the examination of the entire face of a document, as well as eliminating the danger of folding or rolling the document to accommodate it on the stage.

The stereoscopic microscope is in effect two compound microscopes mounted side by side in the same body converging toward the object, having a separate optical system for each eye. The two eyes view the same field from different angles and stereoscopic vision thus results. The convergence of the two optical systems is approximately the same as the normal convergence of the eyes when reading or writing. Objective lenses are provided in matched pairs, and usually there are three pairs mounted together in either a rotating nosepiece or drum or in a horizontal slide, which pairs may be positioned rapidly and easily to provide varying objective magnifications with the same eyepieces. It is usually possible also to replace any of the three paired objectives with others of different powers. Matched pairs of easily replaceable eyepieces magnify the image produced by the objectives. Various powers of eyepieces are also available which, when combined with the various objectives, furnish a range of increasing magnifications in steps from about six diameters (6X) up to about one hundred fifty diameters (150X).

Between the objective and eyepiece in each tube there is placed an erecting prism which causes the image to be seen upright rather than inverted as in the monobjective microscope. Thus movements of either the microscope or the object are normal and easy. Some models are supplied with eyepiece-and-prism bodies which incline toward the viewer, a feature which makes the instrument easier to use from the standpoint of posture.

The body is clamped to a focusing rack, which in turn is attached to a stand having two arms extending out away from the main column in a U-shape. These arms have a wide working space between them, with a recess into which a glass or metal stage fits. In document examination this stage is usually removed. A base having a substage mirror may be provided for transmitted light use. An inclination joint in this base allows tilting of the instrument toward the viewer.

In contrast to the standard microscope, the objective lenses alone in stereoscopic microscope, separate from the eyepieces, are designed to give only relatively low magnification, or even reduction from actual size. The range is roughly from 0.6X to 8X. The image from the objectives is then magnified by the ocular lenses, where the greater magnification occurs. The range in power of oculars is roughly from 9X to 20X. Thus a 10X ocular and a 0.6X objective will give a 6X final magnification, and a 15X ocular with a 6X objective will give a total magnification of 90X.

This emphasis on magnification in the oculars rather than in the objectives as in the standard microscope is not strange when it is considered that the lower the magnification of the objectives is, the larger will be the field of view, and vice versa. Since the stereoscopic microscope is designed to provide a wide field, a low power initial image increases the field area subsequently magnified by the oculars. However in paired objective lenses of this type the resolving power (or numerical aperture) is comparatively low, and the resultant image cannot be satisfactorily magnified to a great degree. Hence the total magnification limit of about 150X. This limit is of little consequence however, since magnifications between ten and seventy-five diameters suffice to cover nearly all document examination problems.

As would be expected, an increase in magnification is accompanied by a decrease in depth of focus, but this is not a serious disadvantage in document examination, where the object is usually flat and the range in highs and lows small. This indicates however, along with the desirability of the widest possible field and optimum resolution, that it is preferable to use the lowest magnification adequate for the problem at hand.

A given magnification may often be obtained or approximated by more than one combination of objective and ocular lenses. To illustrate, a magnification of 60X may be obtained either with 6X objectives and 10X oculars or with 3X objectives and 20X oculars. Each combination however has its own resultant optical characteristics as to definition of the image and width of field. The examiner should use the combination of lenses which is most suitable to the problem at hand. The guiding principle is this: At a given magnification, if optimum definition is desired use a higher power objective and a lower power ocular; if width of field is more desirable, use a lower power objective and a higher power ocular.

Two adjustments are necessary with binocular microscopes which are not characteristic of other microscopes. The first is the distance between the two eyepieces, which may be moved together or apart to suit the distance between each individual observer's eyes (interpupillary adjustment). The adjustment is correct when the observer perceives the stereoscopic effect of depth and the two images exactly coincide. The proper distance of the eyes from the oculars is also necessary to see the entire field including its sharply defined edges. The other adjustment is the suiting of the focus of the oculars to each eye of the observer, by first focussing the instrument to bring the non-adjustable ocular into proper focus for its eye, and then bringing the image in the adjustable ocular into optimum focus for its eye by turning its knurled ring.

The stereoscopic microscope has countless uses in the document examiner's work. Illustrative examples are given here.

The greatest usefulness of this instrument is its application to the most frequent problem submitted to the document examiner: the authenticity or spuriousness of signatures. The delicate tremor of forgery due to slowly drawing rather than freely writing a signature—the most prevalent evidence of forgery—is shown with clarity under magnification. The minute retracings, over-writings, or overlappings;

the unnatural retouching or patching; the stops or lifts of the writing instrument at unlikely locations; the uneven, irregular ink distribution —characteristics of forged signatures which to the eye may appear to have natural, freely written, continuous lines—are revealed by the microscope to brand the signatures as bungling, sloppy failures.

An examination with the light coming through the paper (transmitted light) will often show some of these features even more glaringly. For this purpose it is handier to place the document on a box or table with a glass top having a light beneath it, or on a photographic contact printer. The base with substage mirror may of course be attached to the microscope for a transmitted light examination.

A carbon paper or pencil outline, or a bare indentation in the paper, which serves as the guide line for a forgery by the tracing process—the "sister" line characteristic of some traced signatures—can be seen unmistakably with the microscope even when an attempt has been made to erase it, where it might be impossible to detect with the unaided eye.

Where there is a question of whether a signature was affixed before or after the writing above it on a document, the signature and the other writing will sometimes intersect or overlap. In these cases it is often possible to determine which was written last through a microscopic analysis of the sequence or order-of-writing of the intersecting strokes.

In this connection it is well to note that a sort of "optical illusion" often misleads the casual observer, with or without the microscope. This is the effect that the darker line usually *appears* to be "on top" (written last), even though that may not actually be the case. The reason is that the darker line appears to have continuous, uninterrupted margins because they are not obscured by the lighter line, even if the latter was written last. On the other hand, the lighter line's margins seem to be discontinuous or interrupted because their visibility is obscured by the darker line, even when the lighter line was written last. Since the ordinary observer will judge the order or sequence of the strokes by the apparent (but possibly illusory) continuousness of their margins, he may be deceived where the lighter line was written last.

In addition to intersecting ink strokes, the same type of question involving pencil writing, typewriting, carbon copies, rubber stamps, and other impressions can often be solved with the use of this microscope. As an added example, where ink crosses freshly written typewriting, the oil in the typewriting will often repel the water of the ink. When examined later, there will be a definite gap or thinning in the ink stroke where it crosses the typewriting. This is an unmistakable evidence of the ink having been written last.

The danger of the same type of "optical illusion" described above is present wherever a light impression and a dark one are concerned in any of the various combinations possible of intersecting material.

The stereoscopic vision of the binocular microscope is a real advantage for certain types of problems involving depth. Where an ink line crosses a fold in the paper, suitable magnification will disclose the conditions which indicate whether the ink was on the document before the fold was made or vice versa. There are usually minute ridges and depressions within the main depression of a fold, and stereoscopic vision greatly facilitates the interpretation of the ink conditions therein. In general, indications of the ink running out along the fold beyond its normal margins mean that the ink was placed on the paper after the fold was made.

Where perforations, tears, holes, or cuts in the paper, or the raised embossings of notarial seals and the like are concerned, the stereoscopic microscope is again of inestimable value.

Disturbances of the surface of the paper, such as caused by mechanical erasure, are seen in bristling relief when viewed through the stereoscopic microscope with the light directed slantingly from the side. The appearance is often that of a veritable forest of raised individual fibers standing out of the paper.

Ink, pencil, typewriting, or other written characters or words are sometimes altered with a writing medium of a different shade or nature. Though this alteration may escape a casual inspection with the naked eye, it will not often escape a microscopic search.

The use of a low magnification—between five and ten diameters—facilitates the discovery of the features in typewritten characters that establish the identifying characteristics of the individual machine which was used to type a document. Use and misuse cause minute imperfections and damage to the type, all of which in combination may distinguish the product of a single machine from that of all other typewriters. But these are not always discernible to the eye alone. In cases involving the identity of a typewriter where the machine in question is available for inspection, an examination of the type on the machine itself with the stereoscopic microscope will establish these identifying features beyond question.

Because of the long working distance between objective lens and object observed, the great latitude of the focussing mechanism, and the ease of handling and moving of the stereoscopic microscope, it is ideal for examining "unusual documents" or objects related to document problems, such as writing instruments; books or pads; labels, papers, or writing attached to other objects such as boxes, cans, or bottles. Believe it or not, wills have been filed written on such unusual objects as a match box, stepladder, and a petticoat.

THE COMPARISON MICROSCOPE

A comparison microscope manufactured by the Bausch & Lomb Optical Co. and designed following the suggestions of the late Dr. Albert S. Osborn, dean of document examiners, permits the microscopic comparison of any two objects that can be brought within its field. It consists of two tubes bearing objective lenses at the lower ends and joined at the top by an optical bridge. The two resultant images are brought together by this bridge and are seen side by side in a circular field through a single eyepiece, each separate image occupying one-half of the field, with no intervening space between them. Matched objectives are used so that an accurate comparison of the two fields of view can be made. Each objective lens may be focussed independently by means of a milled collar. The main focussing mechanism and stand are very similar to, though smaller than, those of the stereoscopic microscope.

This microscope is particularly valuable for comparing the characteristics of ink strokes. Through the use of a double set of prisms the two images are in immediate juxtaposition, and two ink strokes may thus be abutted one against the other as though end-to-end, so that they appear as one continuous stroke. A highly critical comparison may be made in this manner in which delicate distinctions in tint, width, amount of deposit, character of margins, purity or contamination, and so forth, may be detected which would be impossible with the naked eye and difficult or impossible to determine with certainty with any other type of microscope.

The same use applies of course to other types of evidence on documents where comparison is necessary. The same fine differentiation can be made with respect to pencil strokes, typewriting, and carbon copy impressions. It is often possible from ink writing to distinguish between different pens by the flexibility, width, or some peculiar nib characteristic shown in the writing. Personal writing habits in the manner of holding the writing instrument may show in the writing and serve as an identifying feature, e.g., where one pen nib makes a distinctly deeper indentation in the paper than the other.

This microscope is also useful in the comparison of paper specimens. The color, texture, surface appearance, presence of blemishes, etc., may be noted.

Certain precautions are necessary when making examinations with the comparison microscope. Pains should be taken to eliminate all possible misleading causes of variation not relevant to the point under consideration in the comparison of two specimens. This is especially necessary in the comparison of ink strokes, where for example if the question is whether the same ink was used in the two specimens under investigation, the heaviness of deposit and the width of strokes should be as nearly comparable as possible. It is easy to understand that the same pen with the same ink could easily produce two strokes differing vastly in appearance if one were blotted immediately and the other not. Variations in the color and surface of the paper on which the material is written must be taken into consideration also, and even where the paper is the same the precaution must be taken to have the background color beneath the paper uniform. One might be misled if one specimen rested on the dark wood of a table while the other rested on white paper.

A third essential is that the light that illuminates each specimen is of the same composition and intensity and comes from the same relative direction. It would not do to have one specimen illuminated from one side by daylight coming in the window and the other by light from the opposite side from an incandescent lamp.

ILLUMINATION

There are numerous and varied microscope illuminators on the market, providing a wide choice for both general and specialized lighting problems. In document examination the preferred illuminator is one which gives a uniform light over a comparatively large area. If it can also provide a concentrated light on a smaller area by means of some type of focussing or condensing, so much the better.

A general purpose reflector illuminator is marketed having a low-wattage incandescent bulb in an elliptical mirror and a transformer with rheostat to vary the intensity of the light. The bulb may be moved in or out to spread the light over a wide area or concentrate it. It is a most useful and versatile light.

A universal microscope lamp designed to give variable illumination has a low-wattage incandescent bulb with a rheostat-transformer to vary its intensity. The cylindrical housing bears a condenser which permits focussing from a sharp image of the filament to an evenly illuminated spot of light of variable size.

A fluorescent light illuminator is available having a long glowing tube which throws an even light over an especially wide area. The relatively small amount of heat developed by this lamp is an advantage.

The composition of the light is closer to daylight, containing more blue than incandescent light; the tube is marked "Daylight." There is a slight flicker effect not found in incandescent lights. Notwithstanding this disadvantage, this light is exceedingly useful. Its intensity is somewhat lower than the two previous illuminators, but its shielded tube with reflector can be moved exceedingly close to the field of view without danger and furnishes ample light for most document examinations. It is particularly useful for the examination of ink strokes with the comparison microscope. It has a very white light, and the tube is longer than the distance between the two objectives of the comparison microscope and thus furnishes a uniform illumination to both areas under observation.

Other more specialized illuminators are available providing for the use of iris diaphragms to control the amount of light and filter attachments to control the color, composition, or heat of the light. Most of these illuminators are provided with adjustments for varying the position of the lamps with respect to the microscope.

Most illuminators develop considerable heat, especially if the light is focussed to a small point. Caution must be exercised to avoid burning a document or the table or injuring the lenses or other parts of the microscope.

Proper illumination for microscopic examination is of course not simply a matter of flipping a switch. In document examination most problems call for varying the distance, the angle of incidence, the direction, and the intensity of light to obtain the precise effect desired. This is especially important in problems involving the sequence of writing of intersecting strokes, where differences in reflectivity are often an important factor in solving the problem.

Other factors also should be varied, in order to observe the problem under all possible conditions which might lead to its solution. Both reflected and transmitted light should be used; both artificial light and daylight.

Care of Documents

It is essential in the examination of documents that they be safeguarded from injury, soiling, or undue wear from handling. They should not be folded or creased unless absolutely necessary, and crucial documents not at all. Where for facility a document is rolled in placing the desired area under the objectives, care should be exercised to prevent damage to the paper. Crushing a document, no matter what the reason, is of course inexcusable.

Fortunately with the stereoscopic and comparison microscopes it is usually possible to examine a document flat on a table without the necessity of folding or rolling. For this purpose a protective covering for the document has been devised by Clark Sellers, Examiner of Questioned Documents, Los Angeles, which prevents any injury by the base of the microscope. It consists of a rectangular sheet of heavy transparent celluloid or clear plastic (.025 to .050 inch thick) marked with lines to indicate the position of the feet of the microscope and having three circular holes cut in the exact position of the fields of vision, a larger one for the stereoscopic microscope and two smaller ones for use with the comparison microscope. In a pinch a heavy sheet of paper with an appropriate hole cut in it may serve as a substitute. A sheet of glass is not recommended because of its sharp edges and the danger of breaking.

Demonstration in Court

The microscope can be used very effectively in court in demonstrating the evidence in certain types of document problems. Most courts nowadays freely admit its use as a means of bringing out the facts more clearly. There can be no doubt that showing a judge or juryman on the document itself the actual basis of a statement is much more convincing than merely making the statement alone. "Seeing is believing."

Where a problem involving differences of color or depth of vision is concerned, the microscope may often be utilized to better effect than photographic demonstrations. In a probate trial the author was able to show the judge through the use of the microscope that three different shades of blue ink were involved in the fraudulent change of the date of a holographic will, the effect of which would have been to invalidate an actually later genuine will. The document was denied probate.

Most judges and jurymen have had little or no experience in viewing through a microscope, but are nonetheless usually eager to do so in court. Close and specific guidance is necessary however to assure that they observe the relevant evidence under the proper conditions. The microscope, illuminator, and document should first be set up and properly adjusted by the witness testifying. Suitable illumination should of course be provided. (It is well to rehearse the exact arrangement before coming into court.) The judge or juryman should then be asked to look through the instrument. He should be instructed to vary the interpupillary distance adjustment himself to suit his own eyes and also to vary the focus to suit himself by turning the knob. His eye distance above the oculars should be checked, and the suggestion made to vary it if it is not satisfactory. The viewer should be asked if he can see satisfactorily. When the witness is reasonably sure the viewer sees the field of view properly, he should inform the viewer exactly what he is looking at and how much of it is being seen, and whether it is inverted or upright. Then the witness should describe slowly in detail the evidence that forms the basis of his conclusion, with appropriate pauses where necessary. If desirable, a small pointer such as a blunt knitting needle may be used to direct attention to specific locations, care being taken not to injure the document. The viewer should not be hurried during the course of his examination.

The suggestion should previously be made to the trial attorney that he request the judge (if there is no jury) to dictate what he sees, or at least whether he sees what the witness is pointing out, so that it will go into the record.

Many questions concerning the authenticity or fraudulence of documents would go unanswered were it not for the microscope. It is essential that where the microscope is used, a proper examination be made so that the evidence is interpreted correctly, and no pertinent bit of evidence is overlooked. Ample time for extended examination under the proper circumstances is essential when evidence is to be interpreted that will have a bearing on the correct decision of a legal controversy. In the hands of the qualified specialist the microscope, no less than any witness, may thus speak out to aid in the administration of justice.