# Edge Characteristics of Commercially Produced Paper Stock

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**The commercial production of paper items still involves the use of large guillotine blades to cut through thick stacks of paper stock, tablets, notebook filler paper, steno pads, and similar paper products. During the sharpening process and subsequent use, the blades acquire grind marks and nicks, and as a result, take on their own uniqueness. Depending on the thickness, type of paper stock, and frequency of use, these blades must be sharpened relatively frequently. When the blades are removed and sharpened, their unique features are removed. New grinding marks from sharpening and, upon use, a new set of unique random nicks now distinguish that blade from its prior characteristics as well as from other blades. A study of two paper cutting machines and processes at a large paper company was made to determine if more than one pad can result in identical edge features on each of the four sides. The process each machine uses to cut paper stock, the edge characteristics which result from the guillotine blade, and the likelihood of duplicate features are discussed. In addition, a method of photographing the microscopic features which remain on the edges of cut paper stock is discussed and illustrated. This information should assist the document examiner during comparisons of individual pieces of paper for the purpose of confirming common origin.**

On many occasions document examiners are requested to compare two or more pieces of paper for the purpose of determining common origin. One type of characteristic that is often present are the edge cut characteristics which are transferred by the guillotine cutting blade as the paper stock is cut to final size. Previously published information (Davis, 1958, Gencavage, 1987, and Purtell, 1953) recognized the highly unique features of the guillotine paper cuts as well as their association with a particular blade (Cain, et al, 1983).

Most document cases involve comparing a piece of paper with another piece of paper or paper source, such as a pad or tablet, for use in associating those documents. In those cases, the question facing the document examiner is *"could the paper edge cuts on a document have come from multiple pads or tablets of paper, or only from a single pad or tablet of paper?"*

## Methods and Materials

To study these possibilities, a field trip was made to the Mead Paper Company, School and Office Products Division, Alexandria, Pennsylvania. This plant produces a variety of cut paper products such as paper pads, steno pads, memo books, wire-bound notebooks, legal pads, and notebook filler paper.

## Results and Discussion

### *Guillotine cutting and machinery*

The guillotine cutting method, in place for decades, is still a system used by the industry. In a previous class conducted by other representatives of the paper industry, it was implied that the rotary cut methods had replaced the guillotine methods. This is not the case at all. Officials at Mead advised that paper edge cutting with the guillotine cutting machinery is still the industry standard (Personal communication with Wayne Talasky, Mead School and Office Products).

The plant visited used two brands of equipment that utilized a guillotine blade. They were the standard guillotine cutting press, in this case made by POLAR (Figure 1), and a German machine named WAMACKO. Other machinery utilizing guillotine blades is used throughout the industry.

### *Preparing the cutting load*

The *cutting load* is the stack or stacks of paper which are placed on the respective machines at any one time. Cutting loads are prepared on a *Ruler* machine. This machine unrolls a large cylindrical roll of paper and cuts it into large sheets. Certain types of *Ruler* machines also place lines and perforations on the paper stock at this time. The machine then stacks those sheets into individual cutting loads. These large cutting loads have rough cut edges and are the paper stock from which the smaller tablets, steno pads, or notebook filler paper will be cut.

### *Guillotine blades*

The guillotine cutting blade used in this type of machinery is a very heavy blade which has been sharpened to a

 

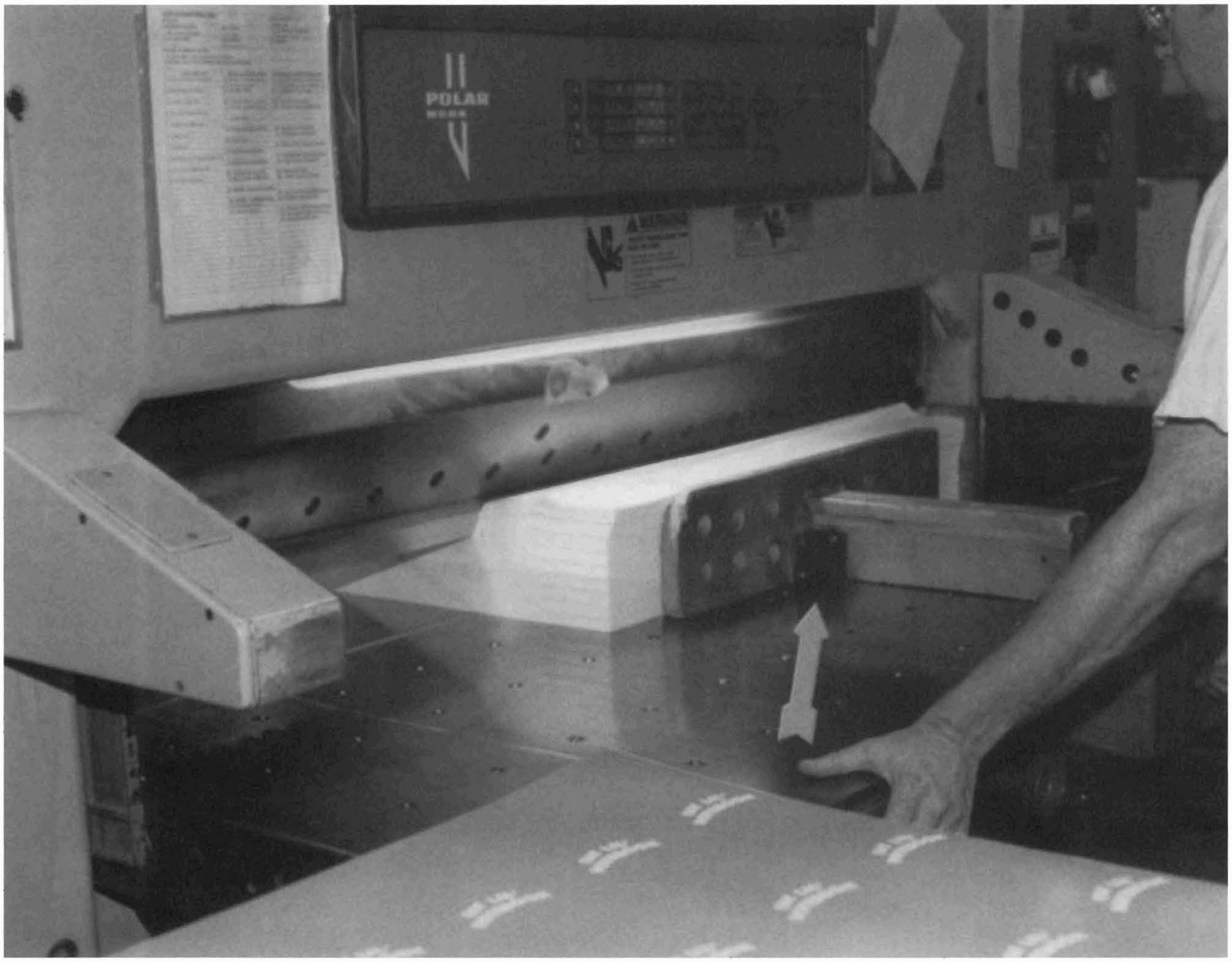

**Figure 1.** An operator uses a wooden fence to move and position paper on a POLAR guillotine cutting press.

razor like edge. The blade contains grind marks from the sharpening process and further accumulates nicks during its usage. The blade eventually becomes dull, depending on the paper stock being cut. Heavier papers, cardboard backed pads, vinyl coated papers, file folder stock, etc. typically dull a blade faster than basic paper stock. Also, the heavier the stock, the larger are the nicks that will occur in the blade. This is easily observed when viewing the stacks of cut stock of the various products. The edge striations on the heavier stock are much more apparent than that on the thinner paper stock.

To sharpen the guillotine blade, it is placed in a special machine, and a rotating grinding wheel (see arrow, Figure 2) passes over it, removing any prior marks and leaving a new set of curved grinding marks. Then, as the blade is used and forced through the paper under pressure, tiny bits of the edge break away, leaving a series of random edge characteristics (Figure 3). Both the grind marks and edge characteristics are random and combine to give the guillotine cutting blade its own uniqueness. When the guillotine cutting blade is pressed at an angle through a stack of paper, it impresses those unique knife blade edge characteristics into the edges of the cut paper. Those striae, transferred from the guillotine blade, as seen in Figure 4, can be microscopically observed and compared.

As the blade is forced through the paper, these marks and nicks will appear on one side of the cut paper stack in a positive image but on the opposing side of the stack in a negative image (see inset of Figure 11). This means that even though the same blade has cut paper in half at the same time, the characteristics on one side will be microscopically distinguishable from the other side. For instance, a concave chip on the blade will reproduce on one side of the cut paper as concave and on the opposite side as convex. Hereafter, the following discussion will refer to one side as the positive side (+), where the striations are raised, and the opposite side as the negative (–) side, where the striations are indented.

### *Cutting paper on a POLAR machine*

POLAR machines come in different sizes, equipped with both short and long guillotine blades. They are, there-

**Figure 2.** A rotating sharpening wheel (arrow) will travel across and sharpen the edge of the long guillotine blade when mounted in this machine.

fore, capable of handling a variety of cutting loads. Although the POLAR machines have computer driven blades, the initial placement of the paper stock and most movements of the paper before and during the cutting operation are performed by the operator.

To illustrate the process of cutting paper on the POLAR machine in a way that will enable the discussion of cut edge characteristics, a series of diagrams was prepared. The diagrams represent a cutting load of seven layers which will be cut into 49 tablets of paper per layer, consisting of seven rows and seven columns. The diagrams will help keep track of the various cuts made and will assist in determining the number of tablets, if any, would have identical guillotine edge cut characteristics.

The bed of the POLAR machine has a rear fence and a side fence on the right side. To begin this process, the cutting load is lifted by the operator and positioned on the cutting bed. For discussion purposes, the sides of the cutting load have been labeled N, E, W, S and will remain the same as the cutting load is moved.

Since the cutting load has rough edges, the first step is to trim approximately 1/4 inch from each of its four sides. To do this, the operator first pushes the cutting load against the rear fence, using a large portable wood fence to help move and align the edges (see arrow, Figure 1). Beginning with the cutting load positioned as in Figure 5, the S side is against the rear fence as the blade trims the N side. The cutting load is then rotated by hand 1/4 turn clockwise with the E side to the rear as the W side is trimmed (Figure 6). Then N is rotated to the rear as the S side is trimmed (Figure 7). Finally, the W side is rotated to the rear as the E side is trimmed (Figure 8). The fence on the right side is not used during this portion of the operation. With the cutting load in the

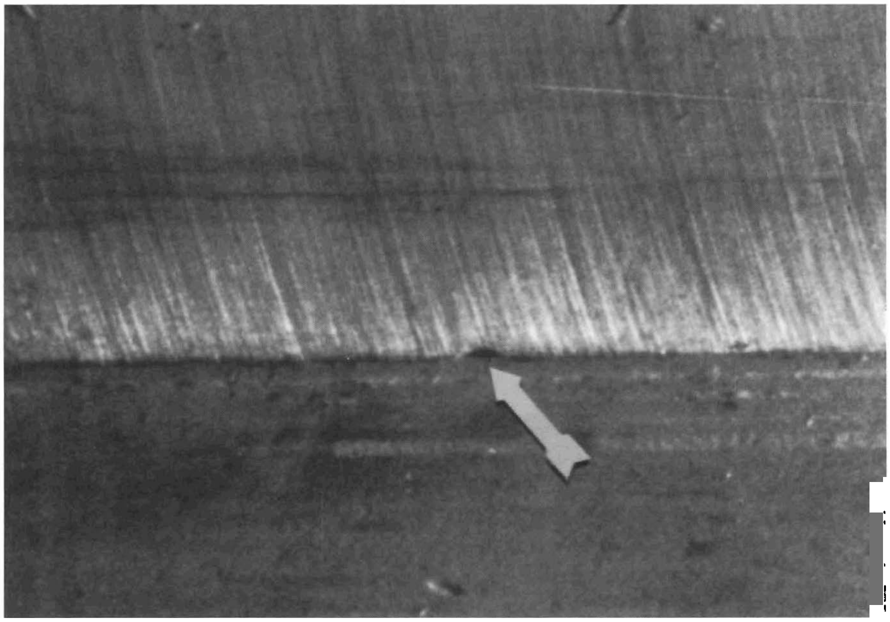

**Figure 3.** Identifying marks remain from the grinding wheel and random individual characteristics, in the form of nicks on the blade (arrow), are also acquired as the blade is used.

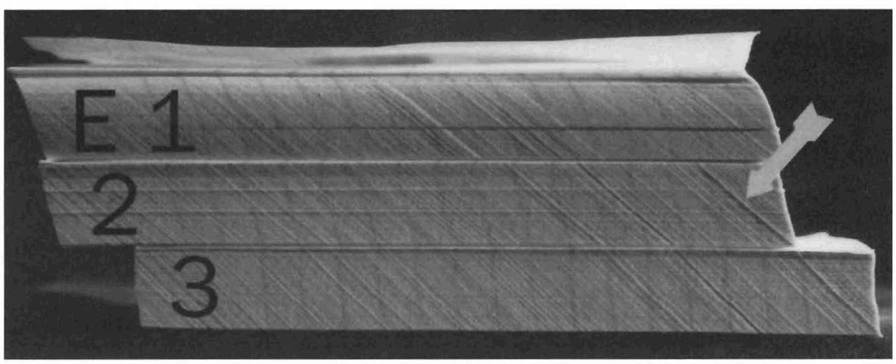


**Figure 4.** The characteristics of the guillotine blade are transferred to the edge of the paper as it is cut.

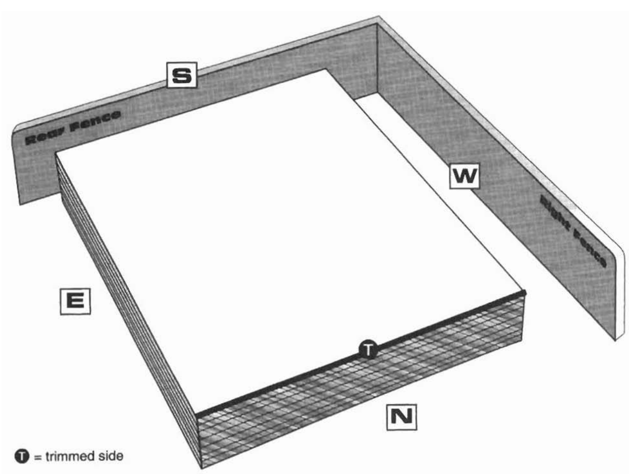


**Figure 5.** The cutting load is placed against the rear fence of the POLAR machine as the opposite side is trimmed.

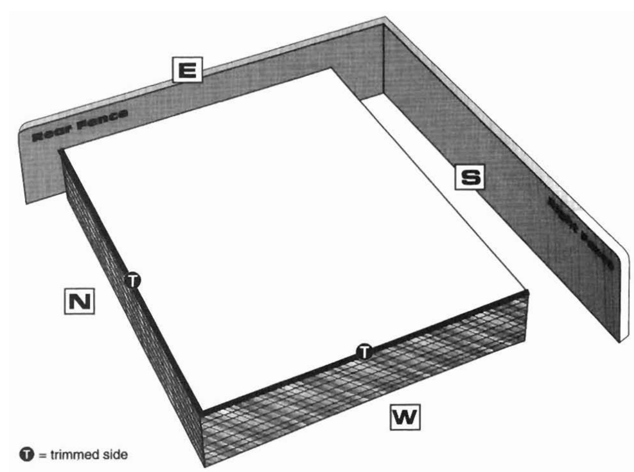


**Figure 6.** The cutting load is rotated one-quarter turn clockwise, and a second side is trimmed.

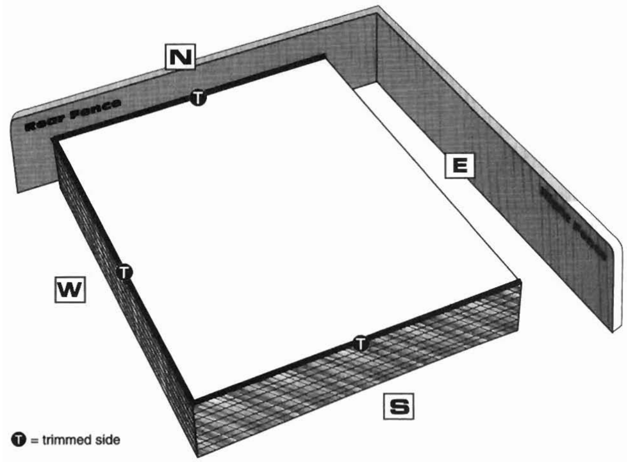


**Figure 7.** The cutting load is again rotated one-quarter turn and the third side is trimmed.

same position (E in front, W in rear) the operator will now make cuts 1, 2, 3, 4, 5, and 6 (Figure 9). To make these cuts, the POLAR machine moves the rear fence forward, advancing the paper the proper distance for each cut. These cuts divide the cutting load into seven long rows. Since the blade separates the cut stock during each cut as the blade passes through it, the operator must push the cut stacks of paper back together with the hand held wooden fence. The right hand fence is still not used during this portion of the operation.

Then the stack is rotated 1/4 turn to the right (S in rear, N in front). At this point the stack is moved against both the rear and right fence. Next, cuts 7, 8, 9, 10, 11, and 12 are made (Figure 10). The machine, after cut 7, moves the rear fence forward, advancing the paper to the position for cut 8 and so forth for each cut. In between each cut, the operator pushes the paper back together and against the rear and right fences using the wooden fence.

At this point, the stack is positioned as in Figure 11.

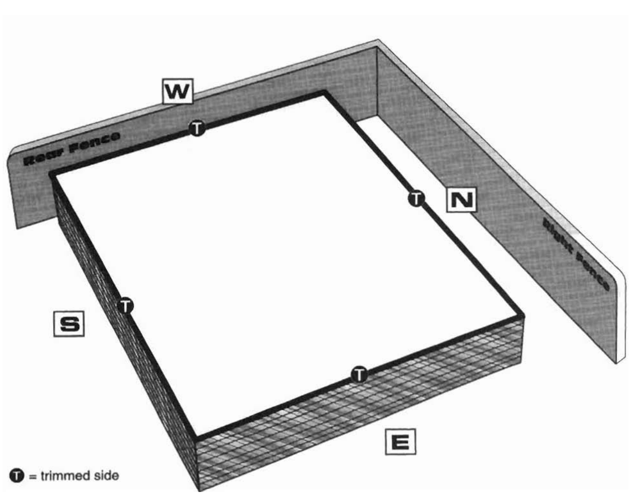


**Figure 8.** The cutting load is rotated a third time, and the final side is trimmed.

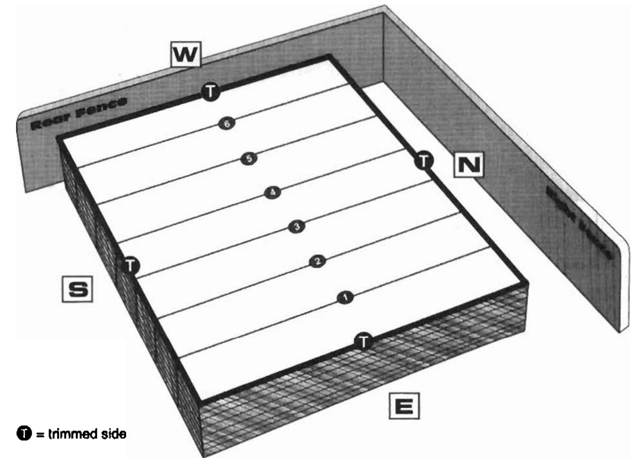


**Figure 9.** With the cutting load against the rear fence, the machine advances the rear fence forward the proper distance, and makes cuts 1, 2, 3, 4, 5 and 6.

The edges of the cutting load are marked with a T and the cuts have been sequentially numbered. The outer edges were the initial trim cuts without the load against the right fence, but with the blade in approximately the same location. Since they are all on the same side of the blade when cut, they will all be either positive or negative, respectively. However, the direction of the striations created by the blade will be in different directions on different sides. Since the stock is rotated with each trim cut, as you face the stack of paper as pictured in Figure 11, the direction of the cut on the S side runs top to bottom and right to left, but for the N side, facing the stack the same way, it runs top to bottom left to right. Sides N, E, W, and S will all be positive since they all faced the blade in the same direction before being rotated.

Cuts 1, 2, 3, 4, 5, and 6 will all run in the same direction and will be cut with the blade in the same respective

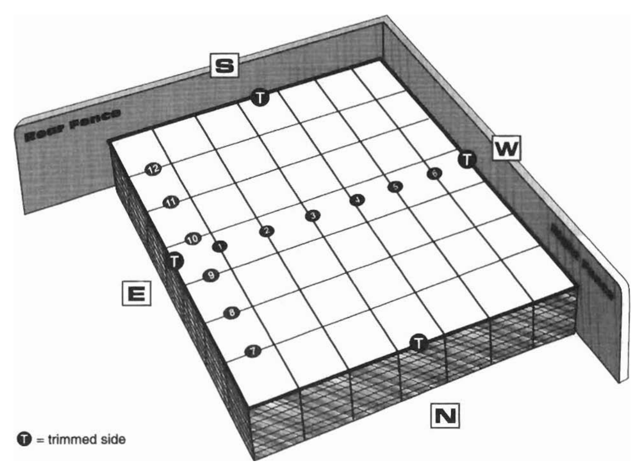


**Figure 10.** After the operator rotates the cutting load one-quarter turn to the right, the machine advances the rear fence forward the proper distance to make cuts 7, 8, 9, 10, 11 and 12.

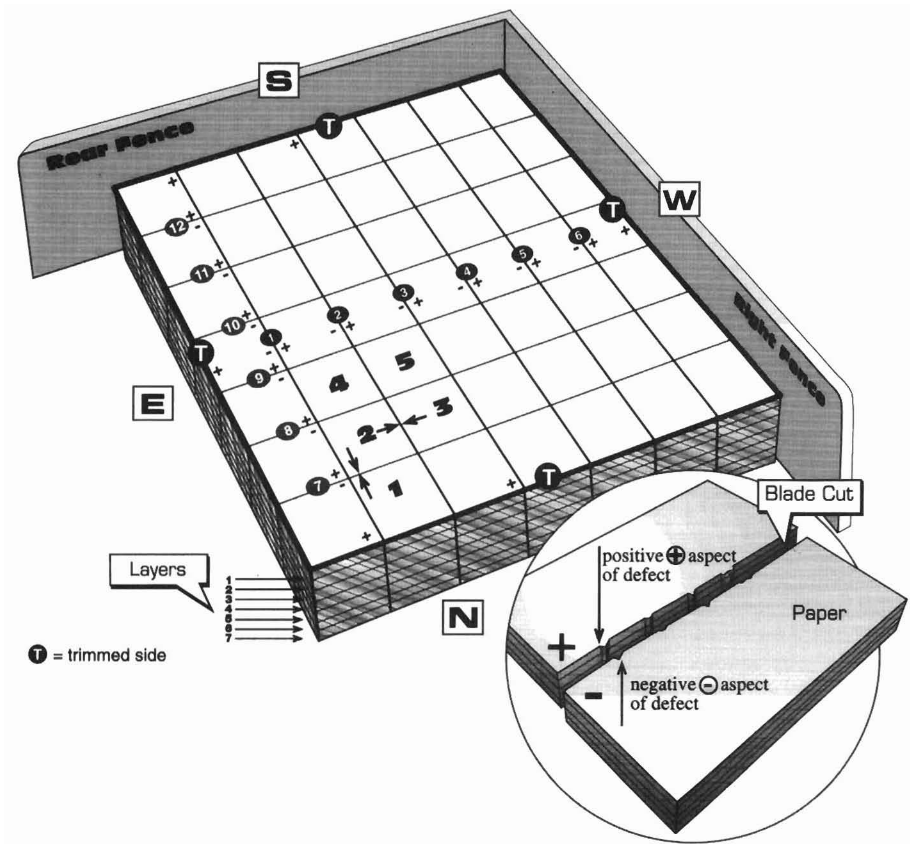


**Figure 11.** None of the resulting stacks of paper have similar cuts on all sides.

position for each cut. As the blade makes each cut, one side of each cut will be leave a positive (+) reflection of the blade defects, whereas the other side of the cut will leave a negative (–) reflection of the blade defect. These characteristics are microscopically distinguishable. Cuts 7, 8, 9, 10, 11, and 12 will also run in like directions, with the blade in the same respective position for each cut, and with one side positive(+) and the opposite side negative(–).

Sample pads were taken from the positions marked with the bold numbers 1, 2, and 3 in the diagram. Arrows were drawn on them before thev were removed to record their relative positions. In addition, two other pads in Figure 11 have been labeled as 4 and 5 for discussion purposes. As Figure 11 shows, there is a large variation in the positions in which the cut characteristics occur. No pad from the same layer of 49 pads will have the same cuts on all edges.

Comparing pads 1 and 2, the position of the N cut (outer edge trim cut) on pad 1 was made when the cutting load was not positioned against the right fence. Subsequent cut 7, between pad 1 and pad 2, was made after the cutting load had been moved against the right fence and will therefore be from a different part of the blade than the T cut on pad 1. The S side cut of pad 1 will be negative (–) and the N side cut of pad 2 will be positive (+). The respective S side cuts of pads 1 and 2 will be identical since they are cut with the same portion of the blade. The S and N sides of 2 and 3 will be from different parts of the blade and will be different. The respective E and W sides of pad 1 and 2 are also different since they are also cut simultaneously with different parts of the blade. The E sides of 2 and 3 will be identical since they were cut by the same portion of the blade. The E side of pads 1–3 are depicted in Figure 4. The W sides of 2 and 3 will be identical.

It should also be noted that in this example, there are seven layers of pads cut simultaneously. As the blade travels downward at an angle, the position of the identifying features shifts from the top pad layer down to the seventh pad layer. Even if the stack of the cutting load is deep enough in relation to the individual tablet width for the blade to coincidently return to the same position at a lower pad, the adjacent side cuts of the two levels would be different. It is noted that when comparing single pieces of paper to one another, it may not be possible to determine if they came from the same pad or if one came from the last pages of a pad with the other coming from the first pages of the pad the next layer below.

Of course, paper with different class characteristics, such as color, lines, size, etc., because of the obvious differences, would not enter into a document problem of this type. For paper having similar class characteristics, based on the operation of the POLAR machinery observed at the Mead facility, the possibilities of getting cut paper with identical edges can be summarized as follows.

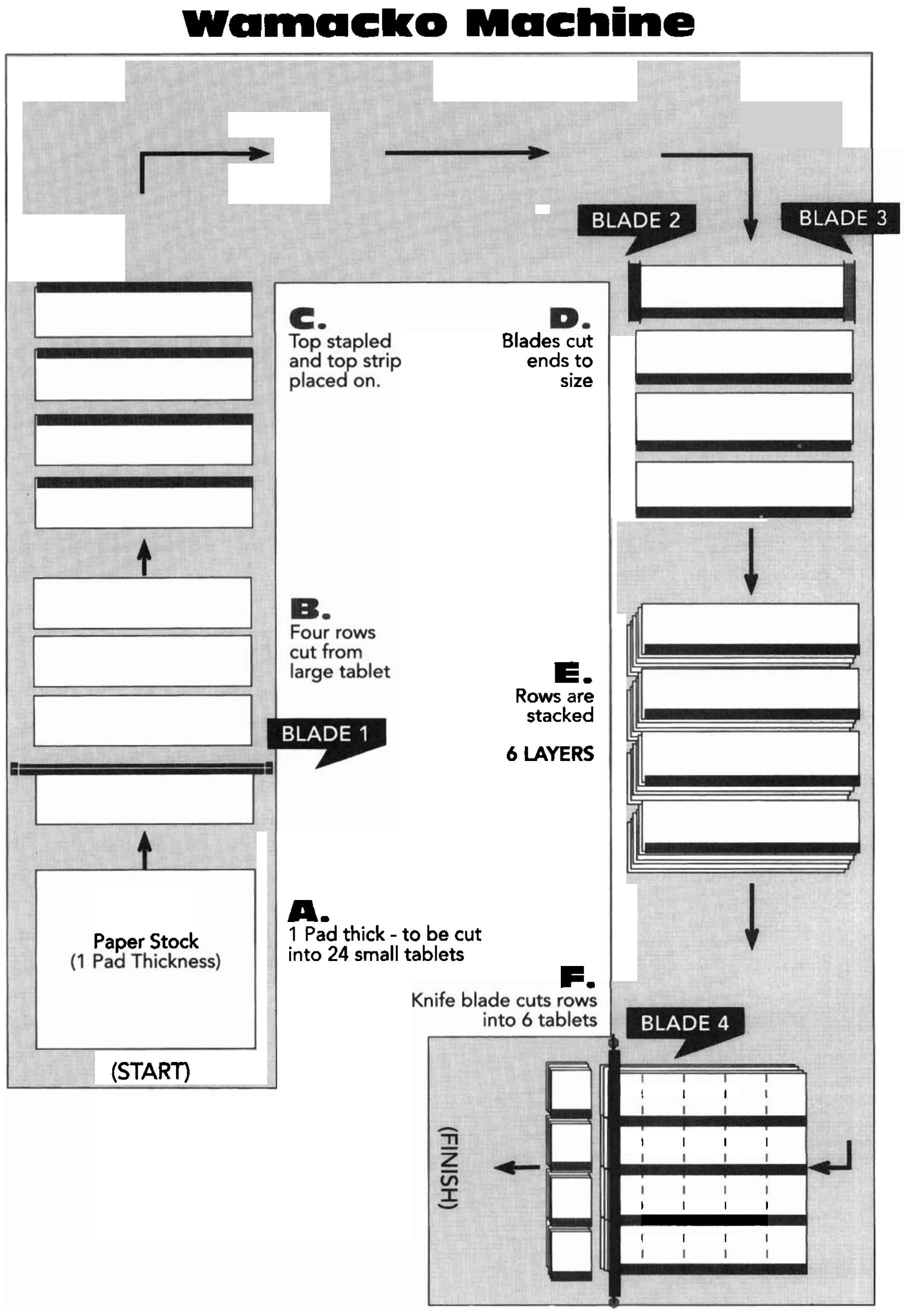


**Figure 12.** The Wamacko Machine contains several stations, which cut, staple and stack the pads of paper.

1. Only paper cut during the time frame when the same blade was being used could potentially have the same edge cut characteristics since the edge cut characteristics change when the blade is sharpened.
2. When considering items sharing the edge characteristics of *one edge* only, many pads could potentially share identical edge cut characteristics along a single edge, particularly considering the movement of the blade.
3. When considering items sharing edge characteristics of two or more edges, when the edges are *opposing* ones, such as the N side and S sides, there would also be many possibilities that paper or pads cut from the *same layer* could have identical edge cut characteristics.
4. When considering items sharing edge characteristics of two adjacent edges, such as the N side and E side, or sharing edge characteristics of three or more sides, different pads or paper from different pads would not have combined identical edge cut characteristics.
5. The only possibility of getting a cut item with identical cuts on all four sides would be on subsequent cutting loads where the pertinent cuts had been in the same positions. This could occur if the initial cutting load were placed in the same approximate position and would also have to take place during the period of

time that the same blade, having the same unique edge characteristics, was being used and while the same size and style of stock was being cut. It is noted that the blade acquires additional nicks as it is being used during its cutting edge life in between sharpening. In a factory such as the Mead Corporation facility, the machines are used almost continuously and the blades are changed anywhere from 1 to 3 times per 8-hour shift on the machine, depending on the type of paper stock being cut. Although it would be potentially possible to get pads on sequential runs to share identical characteristics on all sides, the overwhelming majority of pads would be different within the time frame a particular blade was being used. After blade changes, the characteristics would never match.

### *The Wamacko pad machine*

This machine is considerably larger than the POLAR machine and transports the paper stock via conveyor belts through several stations in a multi-step process. It is used to cut and prepare pads that have been stapled and have a glue and tape strip. The machine's cutting load can be varied in size.

Referring to Figure 12, the rough paper stock, in the form of a multi-page layer, approximately 30 × 32-inches in size, is loaded at one end of the machine (12A). In this example, each multi-page layer of paper stock will eventually be cut into 24 smaller 5 × 8-inch pads. Cuts are first made to divide the stock into four rows (12B). The machine then advances the rows one at a time. Each row is then stapled and then a colored strip is glued at the top (12C). The rows are then moved via conveyor to the other side of the machine. Next, two guillotine blades, one on each side, will separately cut the outer edges of each row (12D). Then the trimmed rows are advanced and stacked on top of one another (12E). The stacked rows are then finally cut with a long guillotine blade into six pads per row, with a final dimension of 5 × 8-inches for all pads (12F).

Looking at the labeled diagram of the pads (Figure 13), none of the pads will have four identical sides. All of the pads of the same number (1, 1a, 1b, etc.) will have a common top edge and common bottom edge made by the original cuts of blade 1. All of the pads with the same letters (2a, 3a, 4a,& 5a) have identical respective left and right edges, except for the 1st (1a, cut by blade 2) and 6th (6a, cut by blade 3). Because the position of the pads is determined by the automatic machine, pads in subsequent cutting loads which are in the same position on the same level could have identical cuts before blade changes are made. The fact that all of the knife blades, except the final one (blade 4), are only cutting through a 1-pad thickness, means that the blades will not be changed as often.

### *Photographing paper edge cut characteristics*

A method known as the *point light source* has been used for many years (Personal communication with W.H Peters, Special Photographic Unit, FBI Laboratory) and is easy to use and provides unsurpassed sharp edge detail. The method is used not only to provide sharp photographs of edge cut characteristics on paper, but also for photographing ESDA lifts and transparent shoe and tire impressions.

The set-up for this photography is depicted in Figure 13. It includes a recessed or tubed light source in a 12-inch deep tube which is fitted with a small 100 watt GE BMY projector bulb (FG 1119-G) or other similar light

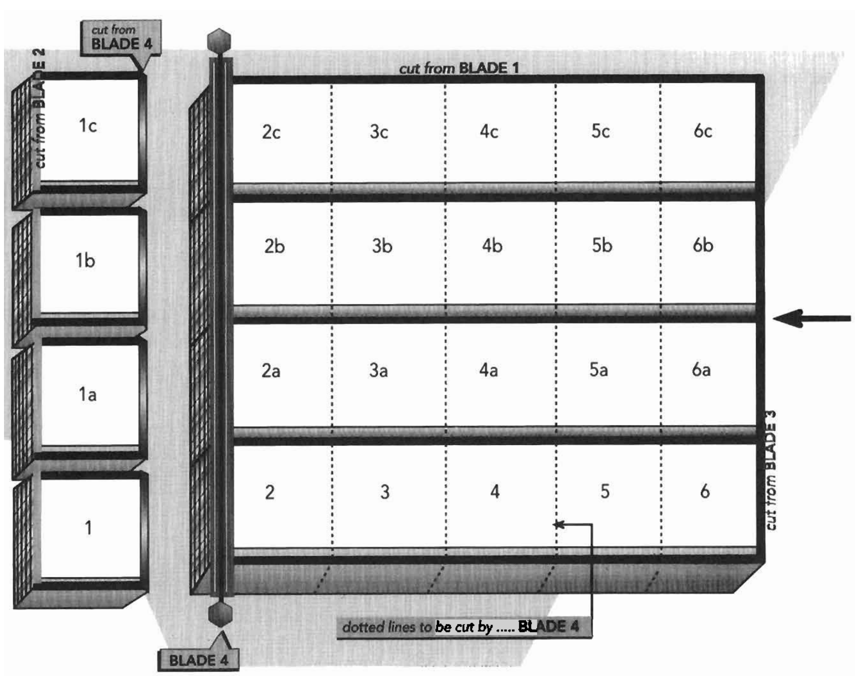


**Figure 13.** None of the pads cut on the Wamacko machine share the exact cut edge characteristics on all four sides.

bulb, connected to a rheostat. A table or counter, approximately six feet below, provides the work surface. This surface is covered with a black matte board cover. It is noted that for a height of six feet, the circle of light hitting the table is approximately 36 inches in diameter, which is sufficiently large for the applicable film sizes. If the distance between the light and the work surface is reduced, or the diameter of the light tube changed, the circle of light will be changed.

The procedure, described below, should either be conducted in total darkness or, for the films listed below, with the use of a photographic safelight filter 1A. Other films and papers may require different safelight filters.

To make an exposure, a piece of KODAK fine grain positive film (Kodak 7302) is placed on the black matte table surface with the emulsion side up. (The film comes in many sizes including 8 × 10, 11 × 14, and 20 × 24 inches.) The document or ESDA lift is laid on top of the film. A clean glass cover (architectural grade glass) is then placed on top to flatten the document against the film. If one intends to later make enlargements of any part of the negative, a transparent ruler scale should be included in the original fine grain positive exposure.

The exposure is made by turning on the recessed light, which transmits a straight point of light against the document edges or through the transparent ESDA and impressions. Depending on the rheostat setting, the exposure time will vary. When initially learning this technique, some trial and error will be needed to approximate the settings and exposure time for your particular set-up and film. The fine grain positive film is developed in Dektol, a common black and white paper developer.

To make photographic prints, the developed fine grain positive film is used as the negative. The exposure onto the Kodabrome II RC F2 paper can be made in two ways. Using the point light source technique, described above, the Kodabrome paper is placed emulsion-side up on the work surface. The fine grained positive film negative is then placed on top of the Kodabrome paper which is then covered with a piece of glass. The exposure is made using

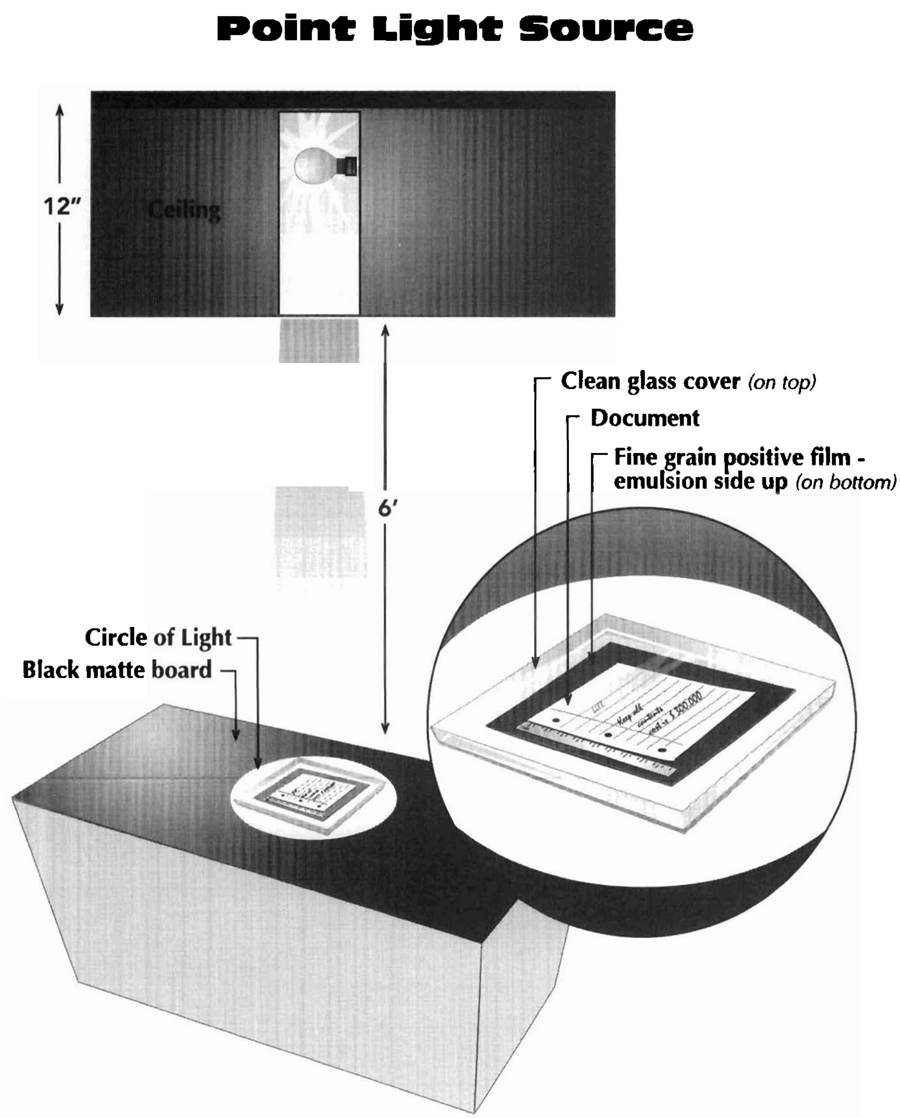


**Figure 14.** The point light source method of photography.

the point light source. This method is used for exposures of larger paper or of clear transparencies such as ESDA print, shoe prints and tire impressions, which may not fit into an 8 × 10-inch enlarger. The second choice is to use an 8 × 10-inch film or to cut the pertinent section of the larger fine grained positive film negative to an 8 × 10-inch or smaller size. The film can then be mounted into an enlarger and printed onto the emulsion side of the Kodabrome paper.

## Conclusion

A look at two processes and examples of the resultant cut possibilities demonstrates the varied edge cut characteristics which occur during the commercial production of pads, tablets and other cut paper products. First, in both processes, the position of the cut characteristics on the edges of paper cut from one level of the cutting load differ from the positioning of those cut from other levels. Paper, cut from subsequent cutting loads on the same level and in the same position with regard to all sides, and cut prior to blade changes, could potentially have identical cut edge characteristics. Second, the cut edge characteristics made by a guillotine blade are unique and only short lived in the production cycle. Consequently, these characteristics are of significance to the document examiner. When comparing documents, as more edge characteristics can be associated, the more likely those documents originated from the same cutting source. Questioned pages, alleged to be sequential pages that originated from a single pad, tablet or other source of cut paper, should share these cut features. Questioned pages from different sources *should not* share these features.

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