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Positive Identification of Torn Burned Matches with Emphasis on Crosscut and Torn Fiber Comparisons

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ABSTRACT: Torn paper match examinations are one of the important types of examinations made by the Document Section of the FBI Laboratory and are probably some of the least heard about and least publicized examinations made by this laboratory. These examinations have often been extremely important and conclusive, particularly in investigations involving arson on both federal and nonfederal properties, espionage, burglary and breaking and entering, as well as in at least one prison escape case.

This paper will delineate the basic conditions of identifying torn burned matches with a matchbook, and in particular a method whereby positive identifications can be effected entirely by what will be referred to as crosscut and torn fiber comparisons. It will describe two elements of comparison that, to the author's knowledge, have not been previously used in torn match identifications. These elements require high magnification examinations of crosscut and torn fibers and foreign bodies embedded in the paper matrix, called inclusions, which, when properly interpreted, will allow positive identifications where other elements of comparison are inconclusive. This method in theory is basically a simple side-by-side comparison procedure, as are most all other crime laboratory comparisons. However, in practice, it is a very painstaking, time-consuming, and difficult comparison method, requiring extreme caution.

KEYWORDS: questioned documents, papers, matches, crosscut and torn fibers

Torn paper examinations are not usually difficult, and positive identifications can be made and demonstrated photographically with a minimum amount of effort. This is true because most torn paper examinations involve sheets of paper that have had a piece or pieces torn away; comparisons of the torn edges are actually comparisons of an infinite number of points along a fairly lengthy tear, often running in horizontal length from a few centimetres to several inches. More difficult examinations occur when a document examiner is dealing with perforation tears, such as postage stamps torn from books or rolls of stamps and checks torn from checkbooks or from commercial type ledgers. These examinations can involve difficult and time-consuming comparisons because of the limiting factors of extremely small tear surfaces (between perforations) and the ability of the perforations to control the horizontal direction of the tear. However, by careful microscopic examination and comparison of both the front and back of perforated tears, satisfactory results are often obtainable. Comparison of torn paper matches is thus a mere extension of an expertise developed over a period of time from numerous torn paper examinations.

In the case of torn match examinations, however, a number of new elements are involved in obtaining satisfactory identifications. The major factor that is considered more over other

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types of torn paper examinations is the makeup of the match material or paper itself. Paper matches are made for the most part from fairly coarse heavy fibrous cardboard-like material that is made from recycled paper products which contain a great deal of foreign matter, such as dirt, small rocks, styrofoam, and so forth.[2] This foreign matter shows up in the matrix of the paper matchboard (cardboard) as inclusions. Inclusions and their importance will be discussed in more detail later in this paper.

According to the *Encyclopedia of Industrial Analysis,* "paper book matches, which have become the most successful type in the U.S., were invented by Joshua Pusey in 1892. Their convenient small size and ease of handling brought them public acceptance in the U.S., but their rapid growth did not start until after World War I [*1*]."

The first positive identification of torn paper matches by the FBI Laboratory was made in an espionage case by E. P. Coffey in 1942. This was very likely the first identification made anywhere in the world. The case involved an arson fire in a warehouse of the Western Pipe and Steel Co. in San Francisco. A paper match was found at the fire scene and submitted along with a book of matches recovered from a suspect. The identification was made based on the torn edge and the cut edges of the burned match compared to the adjacent match remaining in the book.

Nearly all paper matches are manufactured in the United States by only seven major match manufacturers:[3]

- Diamond Match Co., Springfield, MA.
- D. D. Bean Match Co., Jaffrey, NH.
- Superior Match Co., Chicago, IL.
- Lion Corp. of America, Chicago, IL.
- Atlas Match Co., Arlington, TX.
- Columbia Match Co., Cleveland, OH.
- Universal Match Co., St. Louis, MO.

The basic manufacturing techniques are the same. First matchboard (cardboard), a sulfate paper material, is obtained by the companies to their specifications in large rolls. The matchboard is sized to the proper dimensions for the particular style of matches being made by guillotine cutting machines. The individual components of matchbooks usually consist of two rows of matchboard cut into ten match bodies or match stems each, or a total of 20 match bodies (some contain 30 or 40), by a punch press type of machine that simultaneously cuts, offsets, and spreads the match stems. One end of the match stems, where the heads are to be applied, is dipped in a wax (paraffin); every other match stem is kept separated so that each individual match body can be coated by dipping with a potassium chlorate material to form the heads. The matches are then assembled with the proper preprinted folder, which includes the activating red phosphorus striker, then stapled and boxed, with nearly all operations being automated.

Types of Comparisons of Major Significance in Torn Match Examinations

Basically there are ten major points or components of a torn match examination. They may be listed as follows:

1. Length.
2. Width.
3. Thickness.

[2]A. E. Prack, Jr., plant manager, private communication, Universal Match Co., Hudson, NY, May 1982.

[3]David Pulford, district sales manager, private communication, Universal Match Co., Silver Spring, MD, March 1982.

4. Waxing.
5. Coloration.
   a. Front and back.
   b. Thickness of coloring material.
6. Sizing (fluorescence).
7. Cut edges.
8. Torn edges.
9. Inclusions.
10. Cross-cut and torn fiber relationships.
    a. Horizontal.
    b. Vertical.

Factors 9 and 10 are two elements of comparison believed by the author to be of major significance in the identification of torn burned matches.

1. Length—This refers to the length relationship of a torn burned match, in which the head portion is still intact, to the length of the known unburned matches left in a matchbook (see Fig. 1). Matches with the burned head intact are often found in burglaries and breaking and entering cases, and sometimes in arson cases.

2. Width—This refers to the width of a torn partially burned match, which may be compared to the width of the known unburned matches left in a matchbook at the position from which is is suspected of having been torn (see Fig. 2).

3. Thickness—This refers to the thickness of matchboard of a partially burned match, which may be compared to the thickness of the known unburned matchboard left in a known matchbook (see Fig. 3).

4. Waxing—This refers to the length of the waxing dip line on the match head end of a torn burned match with head intact, which may be compared to the waxing dip line on the known matchbook at the position from which the questioned burned match is suspected of having been removed. (see Fig. 4).

Waxing is the process of dipping the match stems or the match head side in a wax-like substance before applying the head, for the purpose of keeping the match burning once the head has been lighted. This waxing can either form a fairly continuous straight line or be alternatingly uneven depending on the angles formed by the machine holding the match stems at the time of dipping. These angles may vary because of improper machine setup or because of the spread of the match stems, which may cause one row of matches to go deeper in the wax than the other.

5. Coloration—This refers to the overall color of the match bodies, both front and back. The color should be viewed both with the unaided eye and under a microscopic magnification of up to ×25. Only one side of the matches is usually painted, stained, or dyed. The

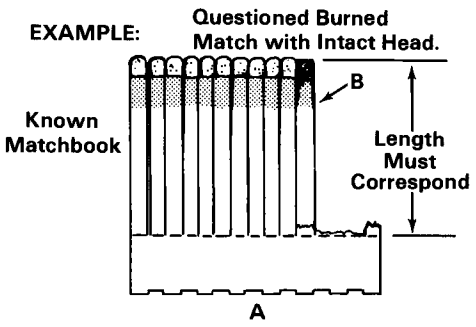

FIG. 1—*Example of questioned burned match with intact head.*

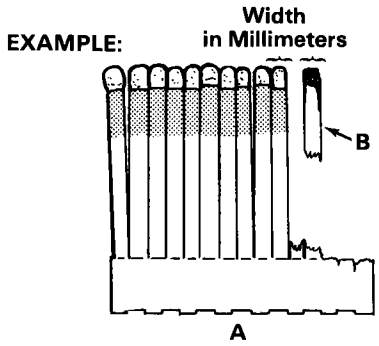

FIG. 2—*Example of width comparison between burned and unburned match.*

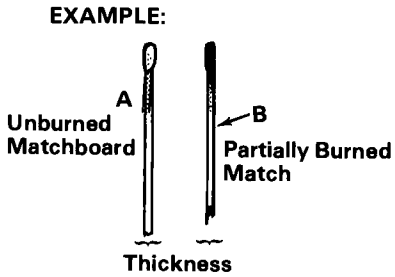

FIG. 3—*Example of thickness comparison between burned and unburned match.*

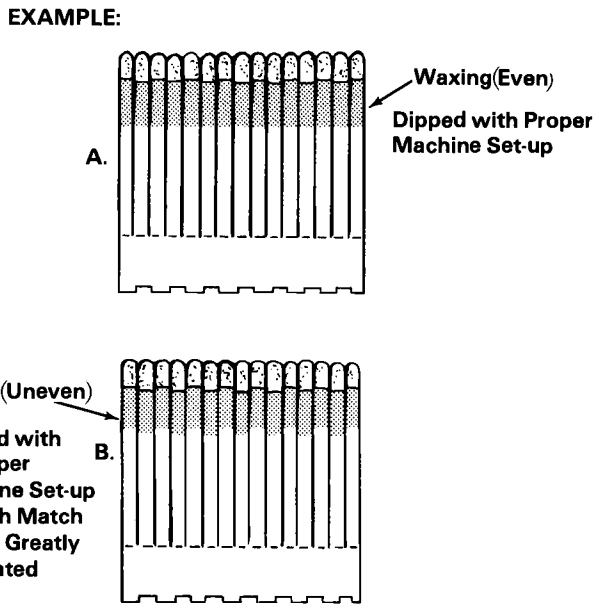

FIG. 4—*Examples of waxing:* (a) *even and* (b) *uneven.*

thickness of the paint, including the sizing materials, can vary greatly from matchbook to matchbook. Comparisons of the paint, dye, or stain on the questioned match should be made carefully by using a side-by-side comparison method under high magnification to determine if the thickness of the coloration of the matches is the same for both the questioned burned match and the remaining matches in the matchbook. Such examinations may reveal differences not visible to the unaided eye. If the thickness of this coloration is considerably different, then the chances are good that the match did not come from the matchbook under examination.

Minute changes in coloration may also be noted under magnification. In some cases, the coloration of a burned match will be changed from contamination by water, oil, gasoline, and the like, and the examiner should always take this into consideration when comparing colors of a questioned burned match to those in a matchbook.

Matches should also be checked by ultraviolet and infrared lighting techniques to ascertain whether the sizing, coloration, and so forth, are consistent. Again, the matches may appear to be different if contamination is present.

6. Sizing—This refers to the filler materials in the paper matchboard, which may give it a smoother appearance and help to make it resistant to the penetration of liquids (particularly water) or vapors. This sizing of the matchboard may also be observed under high magnification, and should be used as a point of comparison for the texture and so forth of the matches being compared. The sizing materials in the matchboard may also display different fluorescent colors, as described in the section on coloration above, when viewed under ultraviolet light.

7. Cut edges—These are the vertical edges of the individual match bodies, which are cut automatically by machine. The blades of the paper cutting machine may become somewhat dull or develop small burrs that show up as irregular cut edges, and may be very useful as points of comparison in certain cases (see Fig. 5).

8. Torn edge—This, of course, refers to the actual torn edge of the questioned burned match in relation to the torn edges in the matchbook under consideration (see Fig. 6). In some situations, an extremely unusual tear (which may be a high angle tear and leave tabs or flaps of fibers on one or both sides of a torn edge) may under close examination allow a positive identification of a match and a matchbook based on the torn edge alone. This is a relatively rare occurrence, and of course all of the possible ten areas of comparison mentioned in this paper should also be checked and compared before one reaches a final conclusion.

Crosscut or torn fiber relationships should also be studied, as vertical fibers may sometimes be seen crossing these tears, and cuts in horizontal fibers may be seen at the crossing between match stems. Crosscut and torn fiber relationships will be discussed at some length later in this paper.

9. Inclusions—This refers to foreign matter such as dirt, small rocks, styrofoam, or other debris that may be included in the matrix of the paper matchboard at the time of manufac-

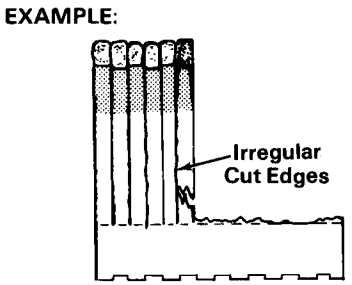

FIG. 5—*Example of irregular cut edges.*

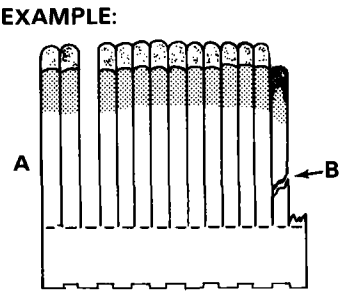

FIG. 6—*Example of high-angle tear on edge.*

ture. These inclusions can become extremely important later when, in the process of paper match manufacture, these inclusions are literally cut into by the paper cutting machine that cuts the individual match stems. Inclusions are fairly common and can become extremely good points of comparison when examining burned torn matches that were torn from positions adjacent to matches still left in the matchbook (see Fig. 7). Under high magnification it is often possible to identify one half of the inclusion in the cut edge of the torn match, and one half of the inclusion in the adjacent match still in the matchbook. This greatly facilitates a positive identification of the questioned burned match.

10. Crosscut (horizontal) and torn (vertical) fiber relationships—This refers to the recognition under magnification of rather large dark colored or very light colored fibers in the paper matchboard that were either cut horizontally during manufacture by the paper cutter used to cut the individual match stems, or torn into in the vertical direction when the match is torn out of the matchbook at the time of use (see Fig. 8). It is imperative to understand that the identification of individual cut or torn fibers is a very exacting, tedious, and time-consuming type of examination; extreme caution must always be exercised in making such examinations, because of the possibility of aligning the wrong cut or torn fibers. This could result in an incorrect identification because of the large number of fibers that may be seen under ×10 to ×25 power magnification; the correct alignment of the proper dark colored or light colored crosscut (horizontally) or torn (vertically) fibers is very difficult.

The author has made the majority of the torn match examinations in the FBI laboratory for a number of years, and anyone who has made these types of examinations will agree that they are tedious comparisons, even if the torn edge is at a very high angle. When the tear is straight across, as intended by the match manufacturer, there has to be some other method for making a positive identification. As stated earlier in this paper, there are ten major areas

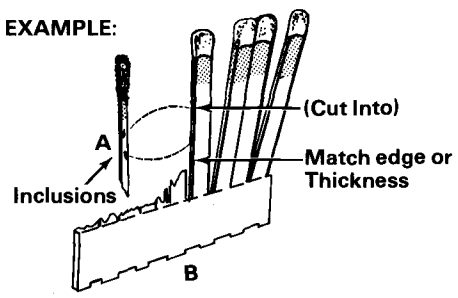

FIG. 7—*Example of cut-into inclusions in matchboard.*

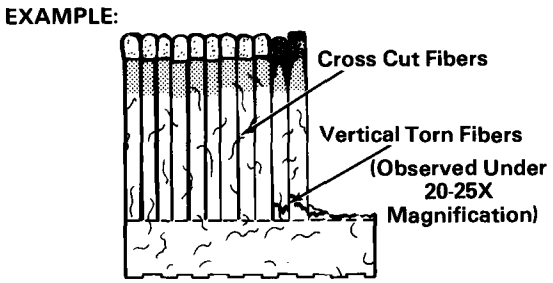

FIG. 8—*Examples of crosscut and torn fibers.*

of comparison, all of which should be considered before reaching any type of conclusion. However, even with the first eight elements in agreement, there are usually insufficient points of comparison for a positive identification if the torn edge is a straight-across tear.

The author has decided upon two other elements that he has shown to have major significance as an aid in reaching a positive identification in this type of case. (It is not known by the author if independent work in these areas of comparison has been, or is being done, by other examiners. Papers covering these types of comparisons have not been located, although it is possible that there has been work done and something written.) The ninth element for consideration, as discussed previously, is the possibility of inclusions in the matchboard which may be cut at the time of manufacture; and in certain cases where one or more inclusions may be observed, this alone would be sufficient for a positive identification without consideration being given to finding additional points of comparison.

The tenth element, which the author considers to be of the greatest help in the case of the straight-across tear, is being able to identify and properly align recognizable dark or light colored crosscut or torn fibers. When a number of these (four or more, in the author's opinion) are correctly aligned (either two or more on the back side and two or more on the front side of the torn match are correctly aligned to an adjacent match in the matchbook, or four or more on only one side of the match), coupled with the other points of comparison, it is believed that they represent sufficient points of identification to eliminate the probability that there could be any other match torn from this position, and allow a positive identification to be made. Even in cases where there is a high angle tear or an inclusion as a point of identification, the crosscut or torn fibers may be immensely helpful in making an identification. However, all ten examination areas mentioned in this paper should be considered before reaching a final conclusion.

It is reemphasized that the author believes a minimum of four crosscut or torn fiber relationships must be established for a positive identification with a straight-across tear, but this is true only if all other points of comparison are similar. If the head has been burned away, destroying the length comparison and waxing, or the coloration has been altered by contamination with water or oil, then more than four crosscut and torn fiber relationships would be necessary for a positive identification.

A recent case involving torn burned matches and utilizing one of the last two techniques above was an attempted prision escape in the state of Pennsylvania in 1980. Two inmates used a metal bar to break a small piece of safety glass from a fire exit door in the cell block area. After knocking a small hole in the glass, the inmates used matches and pieces of cardboard to ignite a fire and melt the reinforcing plastic laminate between the layers of glass. They succeeded in burning a 102-mm (4-in.) diameter hole in the window area of the door and attempted to remove the window to escape the correctional facility. However, before the final escape, the attempt was discovered. There were a number of torn burned matches found in the debris of glass and burned plastic near the door. Two matchbooks were found

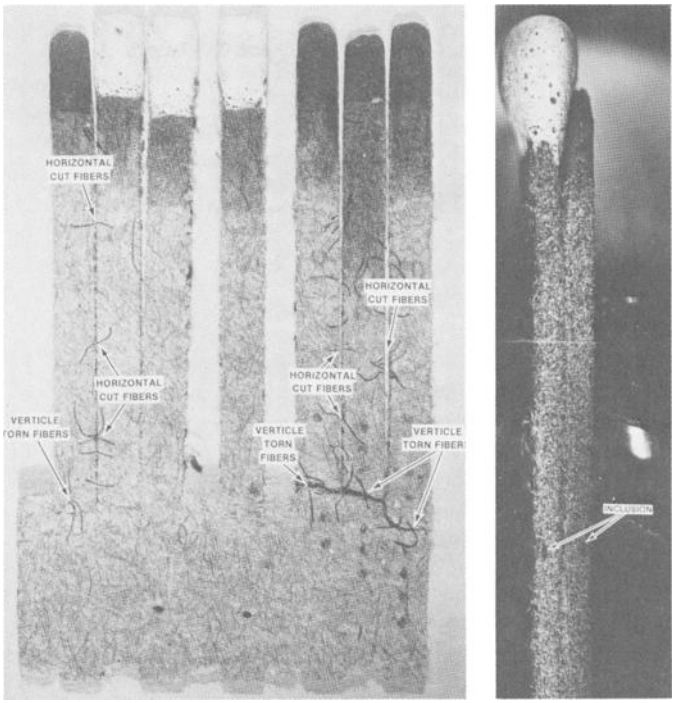

FIG. 9—*Actual photographs of match comparison, showing* (LEFT) *crosscut and torn fiber identification and* (RIGHT) *a cut-into inclusion.*

above a cell door header near the cell of the inmates suspected of attempting the escape. One of the matchbooks contained a fingerprint that was identified with one of the suspect inmates. Although positive identifications were not made because of the gross fiber disturbances involved in the burned matches found near the door, it was concluded that two burned matches from the debris were probably torn from one of the matchbooks located in the cell block, and four burned matches from the debris were probably torn from the second matchbook found in the cell block. The suspect inmates were convicted of attempted escape and arson.

Some matchboard is composed of paper fibers that are fairly uniform in color, and distinguishing dark or light colored fibers is more difficult. Because of this, the thought occurred to the author that the possibility exists of differentially dying or staining the paper fibers in the known matchboard and questioned match stems being compared, thus greatly facilitating the identification of individual crosscut or torn fibers, and simultaneously making the positive identification of torn burned matches much easier.

A considerable amount of time has been spent by the author in testing various types of fiber staining agents, dyes, and so forth, with little success in this area to date. Two of the staining agents tried with very limited results were the Herzberg stain and the Silleger stain.

The Herzberg stain used was an iodide-iodine solution using 0.25 g of iodine and 5.25 g of potassium iodide dissolved in 12.5 mL of water.

The Selleger stain used was 100 g of calcium nitrate dissolved in 50 mL of water. This was added to 3 mL of a solution of 8 g of potassium iodide dissolved in 90 mL of water. Iodine (1 g) is added and the solution is allowed to stand for approximately one week [*2*].

Although the author has not yet been successful in finding a staining agent that produces satisfactory differential fiber staining in paper matchboard material, it is believed that this is

still an excellent area for doing further research. If a satisfactory stain is found, it will make the problem of positive identification of the torn burned matches by crosscut or torn fiber comparisons a great deal easier.

Conclusion

The ten elements of comparison listed in this paper, and especially the two techniques discussed last, can be of great significance in making torn burned match identifications; in particular, where the match has been torn straight across with insufficient points of identification, the use of inclusions and crosscut or torn fiber comparisons will significantly aid in positive identifications (see Fig. 9).

References

[1] Kowarsky, I., "Matches," *Encyclopedia of Industrial Analysis*, Vol. 15, Wiley, New York, May 1972.

[2] Browning, B. L., *Analysis of Paper*, Marcel Dekker, New York, 1969, pp. 50-52.

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