Journal of Criminal Law and Criminology

Volume 27
Issue 1 *May-June*

Article 8

Summer 1936

Police Microanalysis: III Cordage and Cordage Fibers

M. Edwin O'Neill

POLICE MICROANALYSIS

III. Cordage and Cordage Fibers*

M. Edwin O'Neill†

Because of the almost universal utilization of cordage in various human activities, its ubiquity, and the nature of its usage, it is not surprising that rope, cord, string or twine are found frequently in evidence in legal offenses of many kinds. Numerous cases have been reported in which the analytical study of such objects played an important part in the investigation, and a few cases are on record wherein the results of a scientific examination of string or rope were of such a positive nature as to furnish evidence equivalent to absolute proof. However, the investigating officer who wishes to obtain precise information as to the proper methods of dealing with objects of this kind, will find the necessary procedural data widely disseminated, fragmentary and unorganized. No one, it appears, has attempted a systematic and comprehensive mode of procedure for the analysis of cordage with special reference to the problems of criminal investigation. It is the purpose of the present paper to outline such a scheme, bringing together and systematizing the analytical methods which are applicable in the examination of cordage from this point of view.

Cordage in Criminal Investigation

Perhaps the most frequent problem arising in connection with cordage in criminal investigation is that concerning the determination of its source, and when the investigator is fortunate enough to have for examination a comparison sample found in the possession of a suspected person, it may be established with some degree of certainty in many instances. Several distinct procedures have been followed in the process of identification.

Conformity of Ends:

Cases have been described by a number of police technicians[1]

---

* The first two articles of this series appeared in the November-December, 1934, and the January-February, 1935, issues of this Journal.

† Instructor of Police Science, Scientific Crime Detection Laboratory of Northwestern University School of Law.

1 Reiss, R. A., *Manuel de Police Scientifique,* vol. 1, p. 455 (1911); Schatz, W., "Hilfs-Indizien," *Kriminalistische Monatshefte, 2* (12):271-274 (1928).

in which a piece of cordage recovered at the scene of a crime was identified with a sample submitted for comparison, by a demonstration of the agreement of the surface of the free ends, showing that the separate pieces were once continuous, constituting a single piece. In many instances the positive matching of ends will be found virtually impossible but nevertheless should always be attempted, particularly in those cases where a jagged or irregular section is presented. Points of agreement can be found not only in the general outline of the free end, including the irregularities of contour, but also in the yarns or strands composing the cord, and even in the individual fiber-bundles within the strands, where occasionally a dove-tailing effect can be found. It need scarcely be mentioned that the degree of success obtained with the application of this procedure depends to a large extent upon the care with which the specimens are handled from the time they are collected until they are submitted for examination, since the surfaces are easily altered by a careless handling. If small, the ends of the pieces to be matched should be placed in juxtaposition on the stage of a binocular microscope and manipulated carefully into a matching position. Photographic enlargements of the pieces are necessary, of course, in recording and demonstrating the points of agreement. The matching will be facilitated if the cut happens to be through a spot or stain, or fleck of foreign fibrous material on the surface, since the edges of these will be confluent across the line of section.

Structure and Composition:

If the foregoing procedure is inapplicable, presumptive proof of identity can be established if the samples show a similarity in all significant features of structure and composition, as, for example, the kind of fiber, number of strands, direction of twist, etc., particularly when one or more uncommon characteristics are possessed by both. Cases in which this method of approach was used have been described by Locard, Lucas, and others.[2] Notwithstanding the fact that similarity of all general characteristics of structure and composition does not indicate identity, the proof of type-identity will have some value as corroborative evidence.[3] It follows that

[2] Locard, E., *Traité de Criminalistique*, Vol. 2, p. 772 (1931); Lucas, A., *Forensic Chemistry and Scientific Criminal Investigation*, pp. 179-181 (1935).

[3] The writer recently had occasion to present testimony of this nature (pertaining to the similarity of specimens of string) in a criminal case, the appeal of which is now pending in the Supreme Court of Illinois: State v. McDonald and Robertson.

the presence of significant dissimilarities would constitute negative proof.

Adhering Debris:

The presence of foreign particles of one or more kinds on two specimens of cord might serve as an indication that both had come from the same source or were originally one. The importance of the findings in comparing debris, and the inferences that can be drawn from such an analysis, depend, of course, upon the number of kinds of similar objects in both specimens, and the rarity or exceptional nature of these objects. The presence of ordinary cotton fibers would mean little or nothing, but if each of the two samples being compared bore a number of pollen grains of *Vallisneria spiralis*[4] it would be a matter of considerable evidential significance. In a case reported by Vollmer,[5] Schneider analyzed the debris on a piece of string that had formed part of the wrapping around some sticks of dynamite, and, from his observations of the hairs, feather fragments, pollen grains and other minute objects, was able to describe the locality from which the dynamite came, including the description of the terrain and the animal and plant population. In an investigation of similar nature, Schatz[6] found that a piece of string had been carried, in all probability, in the right vest pocket of a suspect, because of the similarity of glass particles of several colors found in both places.

In addition to the foregoing, certain other problems may be presented which have some bearing on a particular investigation. The careful study of any knots present in the cord or rope may give some indication of the occupation of the person who made them if they should be of an uncommon type. In cases of simulated suicide by hanging, a study of the "lay" of surface fibers would show whether the rope used had been pulled over a beam or other supporting structure, as pointed out by Goddefroy.[7] The manner in which a rope or cord has been severed might be determined in certain instances. According to Goddefroy,[8] scissors will make a cut which in outline resembles the letter

[4] Schneider, A., "The Compound Microscope in Detective Work," *The Police Review,* (Hagerstown) *9*:29, (1930).
[5] Vollmer, A., "The Scientific Policeman," *American Journal of Police Science, 1* (1):9 (1930).
[6] *Supra* note 1.
[7] Goddefroy, E., *Manuel de Police Technique,* pp. 199-209 (1931).
[8] *Supra* note 7.

"X," whereas an incision made by an ax or hatchet will appear in profile to have the form of the letter "Y." In regard to studies of the latter type, any instrument suspected of being used should be examined microscopically for fibers of the same kind as those composing the cordage under consideration.

Composition and Uses of Cordage

The term, cordage, as used in the industry, is a general one, including all types of string, twine, cord, rope, cables, and hawsers made of twisted fibers, exclusive of those made of metal fiber or wire. In the manufacture of string or rope, the fibers are combed out and straightened by machine, drawn into parallel position, and then twisted together to form what is known as the *yarn*. String or twine may consist of a single yarn, or of two, three or more

Comparison of Common Cordage Fibers

Fiber	Source	Color of Raw Fiber	Uses
Cotton	Seed-hair of *Gossypium* species	White	Wrapping twine Braided cord
Flax	Bark of *Linum usitatissimum*	Silver-gray or Yellowish white	Shoe thread Sewing thread Bookbinding thread Wrapping twine Light-fixture cord Fishing lines
Hemp	Bark of *Canabis sativa*	Creamy white or gray	Fishing lines Yacht cordage Wrapping cord Small ropes
Jute	Bark of *Corchorus capsularis* or *C. olitorius*	Yellowish-brown to Yellowish-white	Cheap brown twines Small ropes Window cord Carpet binding thread
Manila hemp	Leaf of *Musa textilis*	Best grades—Light buff; Poorer grades—Yellow to Brown	Wrapping cord Ship cordage Drilling cables Hoisting cables
Sisal hemp	Leaf of *Agave species*	Light yellow or cream	Binder-twine Various types of wrapping cord
Mauritius hemp	Leaf of *Furcraea gigantea*	Light yellow	Used principally as a mixing fiber
New Zealand flax	Leaf of *Phormium tenax*	White	Binder-twine Baling rope Mixing fiber in medium-grade cordage

yarns twisted together. In the making of rope, three or more strands are twisted together, a *strand* consisting of two or more twisted yarns. A thick string is usually termed a *cord,* and a rope may be said to consist of three or more cords twisted together, but there are no fixed meaning for these terms. In the trade, cordage with a diameter greater than one-half inch is generally termed *rope.*

It is probable that several thousand varieties of fibers have been used at some time in the manufacture of cordage, but less than twenty are widely utilized at the present time. Because of the relatively greater cost of certain types of fiber, some manufactures consist of mixtures of two or more kinds, this being especially true of Manila cordage. The following fibers are in common use in this country: Cotton, flax, hemp, jute, Manila hemp, Sisal hemp, Mauritius hemp, and New Zealand flax.

These varieties may be grouped in two classes according to their size and stiffness, which in turn depend upon the cellular composition. The first four are composed chiefly of cellulose and may be classed as "soft" fibers. With the exception of cotton, which is a seed-hair, the "soft" fibers are obtained from the barks of dicotyledonous plants. The other fibers listed are "hard" fibers and are composed of sclerenchyma elements closely bound together in bundles. They are obtained from the leaves of monocotyledonous plants, where they are found associated with vascular tissues.

Analysis

Before proceeding to the microscopic identification of the fiber constituents of the string or rope, the technician should begin his investigation by examining the cord *per se,* to determine the gross similarities or dissimilarities in the samples for comparison. Frequently, two samples of cordage, which, upon superficial inspection, appear to be of the same type, will show variations not only in the kind of fiber but also in the number of yarns, direction of twist, etc. The analysis may be undertaken, therefore, in two steps, the first of which is concerned with the string or rope as such, and the second with the nature and properties of its fiber components.

Macroscopic Examination:

In the examination of a string or rope, the features to be noted and the order in which the observations are to be made will depend upon the relation of the material at hand to other factors in the investigation, and the objective to be attained. Therefore, it is impossible to formulate a fixed system of procedure for various studies which can be made. However, the following outline should be applicable in cases where a detailed comparison is to be made, or where it is desirable to obtain as much information as possible from a sample, the observations being made in the order here given:

1. Measure the length and diameter of the cord as accurately as possible.

2. Observe the general appearance of the specimen, noting such features as color, odor, indications of wear, evidence of burning, etc. With the aid of a hand magnifier, examine the surface for spots, stains or foreign material, and the direction or disposition of the projecting surface fibers.

3. Examine the free ends to discover, if possible, the manner in which the cord was severed. If a comparison-sample is available, an effort should be made to match the ends as described above.

4. If knots of an uncommon type are present, determine their nature and kind.

5. If it is at all likely that a study of adhering debris may be helpful, immerse the specimen (or a portion of it) in distilled water for several hours. Agitate the container at frequent intervals and then allow the suspended material to settle. Decant and examine microscopically. Before immersing in water, the specimen may be examined in filtered ultra-violet light, which occasionally will give some indication of the kind of debris present, or its localization.

6. If the surface of the cord appears to be waxed or coated, remove the coating from a portion of the specimen by treating it with appropriate solvents such as alcohol, ether, benzene, etc.[9] The material is then examined to determine its properties or general nature, or, by means of suitable tests, its chemical composition.

7. Observe the direction of twist of the yarns or strands of which the cord is composed. If, when the cord is held in a vertical position, the strands slope in the direction of the central portion of the letter "S," the cord is said to have an "S-twist"; if the direction corresponds to the central portion of the letter "Z," the cord is said to have a "Z-twist."

8. Count the number of strands, and determine their average diameter.

9. Count the number of yarns per strand, and determine the mean diameter of each; examine all yarns for variations in color.

[9] One per cent aqueous solution slightly acidulated with dilute sulphuric acid.

10. With certain types of cordage the number of fibers or fiber-bundles in the yarn are more or less constant. With such types the average number per yarn can be used as an additional point of comparison.

11. Before undertaking a microscopic study of the fibers, the individual yarns should be untwisted and examined with reference to the purity of fiber composition by means of a few preliminary tests. Many kinds of cordage are made of mixtures of two or more kinds of fibers, cheaper grades being used as adulterants to lower the cost of the finished product. By means of suitable macroscopic tests the approximate percentage of each component can be determined with little time and effort. Identifications by such tests can be verified subsequently by microscopic examination. Occasionally a preliminary separation can be effected on the basis of the physical appearance, e. g., color, lustre, degree of stiffness, etc.

Treatment with aniline sulphate will serve to distinguish jute (golden yellow coloration) from Sisal and true hemp (pale yellow); also from flax and cotton (no coloration). A useful test for detecting mixtures of Manila and adulterants has been devised by Swett,[10] and is applied as follows: Wash the sample in ether to remove oils, immerse in bleaching powder solution[11] for twenty seconds, rinse immediately in water, then in alcohol, and hold in fumes of concentrated ammonium hydroxide. Manila will turn yellow or brown; other hard fibers will become cherry-red in color. The color in each case will persist long enough to permit a separation of the different fibers.

Microscopic Examination:

The fibers in most samples of cordage, with the exception of cotton cordage, do not occur in a solitary condition, but instead are closely bound together in "fiber-bundles" of varying size. To properly observe the microscopic characteristics upon which a positive identification is based, it is essential that the bundles be separated into their ultimate elements. In certain cases this may be done simply by mounting a few bundles in a drop of water on a glass slide, and by means of dissecting needles, teasing them apart. In other cases, however, the sample first must be treated with cer-

[10] Swett, C. E., Jour. Ind. and Eng. Chem., *10*:227 (1918).

[11] The bleaching powder solution is made by adding one part chloride of lime to seven parts water; filter and store in dark bottle. To use, take 30 cc. and add 2 cc. glacial acetic acid.

tain reagents before the individual fibers can be separated.[12] Occasionally other preliminary treatment is necessary. Solvents, such as alcohol, ether, or benzene, are used to remove superficial oils or waxes, and bleaching agents, such as ammonia, hydrogen peroxide or bleaching powder solution, are required when dealing with dyed specimens. It must be remembered, however, that the use of such reagents may interfere later with the color reactions used as diagnostic criteria, so that tests must be made upon untreated material, or samples variously treated, as a check. In any case, diagnosis based upon chemical reactions is generally less reliable than that founded upon microscopic structure, and is employed principally as a secondary means of identification.

The dissected fibers, in a water mount, are examined under low and high magnification, particular attention being given to width and uniformity of the lumen (central canal), width of walls, the nature of the extremities of the fibers, presence or absence of superficial markings, and occurrence of associated cells[13] or cell debris.

Key to Fibers

1. Fibers occurring solitary, never in bundles; fiber flattened, ribbon-like, twisted upon its axis.............................COTTON
   Fibers in bundles; not flattened and twisted................(See 2)
2. Fibers with crosswise-markings, fissures and knots; jointed in appearance, somewhat resembling bamboo..........................(3)
   Fibers not as above..(4)
3. Ends of fibers pointed, never forked; lumen narrow, thread-like near middle of fiber..FLAX
   Ends of fibers blunt, many of them forked; lumen as wide as walls or wider near middle of fiber...............................HEMP
4. Fiber bundles yellow or brown with Swett's test; broad uniform lumen....................................MANILA HEMP
   Fiber bundles cherry-red with Swett's test; lumen either narrow or irregular in width..(5)
5. Lumen narrower than wall, very uniform in width..NEW ZEALAND FLAX
   Lumen broad, irregular in width.............................(6)
6. Fibers commonly white or yellow, coarse and stiff; spiral shaped elements present; light yellow with aniline sulphate...SISAL HEMP
   Fibers commonly yellowish brown; spiral elements absent; golden-yellow with aniline sulphate..............................JUTE

[12] Treat for a few minutes with cold chromic acid applied directly to the mount, or boil gently in 2% sodium hydroxide for about 30 minutes. Wash well in water before dissecting.

[13] Especially epidermal cells, and spiral elements (thickenings resembling a corkscrew).