Forensic Fiber Examination Guidelines: Fabric and Cordage

***Scientific* Working Group for Materials Analysis (SWGMAT)**

1.0 Scope

These guidelines are intended to assist individuals and laboratories that conduct examinations of fabric and cordage for the purposes of identifying types of fabric, cordage and damage, as well as potentially associating such damage with the implement that caused it.

2.0 Reference Documents

SWGMAT Trace Evidence Quality Assurance Guidelines (January 2000)

SWGMAT Trace Evidence Recovery Guidelines (October 1999)

ASTM Standard E2225-10, "Standard Guide for Forensic Examination of Fabrics and Cordage," ASTM International, West Conshohocken, PA, 2010, www.astm.org.

3.0 Terminology

Braid: The intertwining (not twisting) of 3 or more strands to make a rope/cord.

Cordage: Any type of rope, string, twine, etc. made from twisting or braiding yarns together to produce a long strand either with a single ply or multiple plies.

Cord: A thin rope made of several strands braided or twisted together with an overall diameter less than 3/16".

Core: Fibers, one or more filaments, or other material running lengthwise through the center of a rope or other cordage.

Course: The row of loops or stitches running across a knit fabric, corresponding to the weft in woven fabrics.

Crown: The raised portion of a strand in twisted cordage.

Knit fabric: A structure produced by interlooping one or more ends of yarn or comparable material.

Filament: A single continuous fiber extruded to an indefinite length.

Fusing: Uniting together as by melting together.

Nonwoven: Fabrics made directly from fibers held together by mechanical, chemical and/or thermal means.

Pitch: The number of crowns per inch along the length of the cordage.

Ply: One of the individual yarns that are twisted together to form a cord.

Rope: A heavy, strong cord made from natural or manufactured fibers with an overall diameter greater than 3/16".

Selvage: The narrow edge of woven fabric that runs parallel to the warp. It is made with stronger yarns in a tighter construction than the body of the fabric to prevent unraveling.

Staple: Natural fibers or manufactured fibers cut into short lengths.

Strand: The largest individual element used in the final rope making process and obtained by joining and twisting together several yarns or groups of yarns

Thermoplastic: A synthetic material that is semi-permanently fusible or softens at high temperatures.

Thread: A slender, strong strand or cord made by plying or twisting yarns, typically used for stitching.

Tracer: A yarn or yarns different in color, size and/or composition from that of the basic cordage found within or alongside a ply, strand or braid.

Twine: Two or more twisted strands or a single-strand yarn with an overall diameter less than 4 millimeters, made from natural fibers.

Twist, Direction of: The direction of twist in yarns is indicated by the capital letters S and Z. A yarn has an S-twist if, when it is held vertically, the spirals around its central axis slope in the same direction as the middle portion of the letter S, and Z-twist if they slope in the same direction as the middle portion of the letter Z.

Wale: A column of loops lying lengthwise in a knit fabric, corresponding to the warp in woven fabric.

Warp: The set of yarns in all woven fabrics that runs lengthwise and parallel to the selvage and is interwoven with the weft.

Weft (Filling): In a woven fabric, the yarn running from selvage to selvage at right angles to the warp.

Woven fabric: Generally used to refer to fabric that is formed by the perpendicular interlacing (weaving) of warp and weft (filling) yarns.

Yarn: A general term for a continuous strand of textile fibers, filaments or material in a form suitable for intertwining to form a textile structure via any one of a number of textile processes (e.g. knitting, weaving)

4.0 Summary of Guide

Due to their general availability, fabrics and cordage are often encountered by forensic scientists, who examine, identify and compare these types of evidence. Structural details such as design, construction, and composition can provide information that may assist the examiner in reaching a conclusion.

5.0 Significance and Use

The construction, composition and color of textiles contain useful comparative characteristics for forensic examinations. Textiles may appear in a variety of constructions: woven, knit, nonwoven or in combination. The range of colors in which textiles are offered in the marketplace is vast and constantly changing due to styles and seasons. A complete characterization of the fabrics, including their construction, and other materials used in the assemblage of a textile (e.g., sewing thread) is a critical component of a comprehensive forensic fabric or cordage examination.

6.0 Sample Handling

Photography of the item prior to conducting any analyses in order to provide documentation of original condition is recommended. Prior to textile analysis, other evidence (e.g., hair, blood, paint) that may require additional examination should be documented and collected. Any physical damage (e.g., worn, cut, broken, frayed) should also be documented at this time.

A questioned material (e.g., a piece of fabric, yarn, tuft of fibers) must not be brought in contact with the known fabric from which it is suspected to have originated until a preliminary examination of the questioned specimen has been performed.

The condition of a questioned material (e.g., shape, position, layers or relation of one yarn to another) should not be altered before a preliminary examination for damage has been conducted.

A sample to be used for composition testing should not be cut from ends of yarn or edges of fabric if there is a possibility of physically matching a questioned item to a known item. It is recommended that the known sample be collected away from the existing edge(s) and the location marked.

All data collected on questioned and known samples should be placed into, or referenced within, the specific case file.

The information contained on tags in textiles should be recorded, especially the Registered Number (RN) and the Woolen Products Label number (WPL) when applicable. These refer to the manufacturer of the textile and can assist the examiner with tracking a particular textile or garment.

7.0 Analysis

Prior to any analysis of the fibers comprising a fabric or cordage, the fabric or cordage should be examined for physical matches, pattern evidence, damage such as thermoplastic fusions, cut/tear marks, etc. Any adhesives or other material used in bonding fabrics, carpet backings, etc., should also be noted.

7.1 Physical Match. Physical matches should be considered if two pieces of fabric or cordage having cut or torn ends are to be compared. A physical match must be documented by photography, sketching or through a thorough description of the condition of corresponding threads and their relative positions in the damaged areas on the questioned and known pieces (“longs and shorts”).

If a physical match is not possible, comparison of the color, pattern, construction and composition of the items in question should be undertaken to determine if they are similar and if the items could have originated from the same source.

7.2 Fabric. A fabric examination is primarily a process of deconstructing the fabric by dissecting its constituent elements. Each of these elements can have a number of sub-elements, all of

which must be characterized to complete the examination for comparison purposes. These elements include, but are not limited to, the following:

- Overall
  - Construction (woven, knit, nonwoven)
  - Yarn counts in warp and weft direction
  - Color(s) and design
  - Type of dyeing or printing
  - Sewing threads, buttons, decorations, etc.

- Yarns
  - Staple or filament fibers in yarns
  - Diameter
  - Yarn twist
  - Number of plies
  - Direction of twist of each ply
  - Number of filaments in each ply, if feasible
  - Composition of yarn
  - Blend of two or more types of fibers within each ply

7.3 Cordage. A cordage examination is primarily a process of deconstructing the rope or cordage by dissecting its constituent elements (see figure 1). Each of these elements can have a number of sub-elements, all of which must be characterized to complete the examination for comparison purposes. These elements include, but are not limited to, the following:

- Overall
  - Diameter
  - Braided or plied
  - Direction of twist
  - Number of crowns or turns per inch
  - Number of plies/strands/braids
  - Core, if any
  - Color(s)
  - Coatings, if any
  - Tracers, if any

- Plies / Strands / Braids
  - Staple or filament fibers
  - Twisted or non-twisted
  - Direction of twist for each
  - Crowns or turns per inch for each
  - Number of filaments in each, if feasible

After the construction has been established, then the constituent fibers should be analyzed with the appropriate microscopical and instrumental techniques. Additional characteristics may be used if necessary to adequately describe the cordage.

7.4 Fabric impressions
An impression made from an item of clothing, for example, in a vehicular accident or other situation may provide valuable evidence. The weave or knit pattern of a fabric impressed onto another surface or into blood, grease, etc. can be compared to the garment in question. Fabric impressions of a known fabric can be made with impression material used for footwear impressions and then transferred onto a piece of paper or digitally reproduced onto a clear sheet of plastic to use as an overlay for direct comparison with the evidence impression. Portions of a

garment that were stitched or have other identifying features may help align the patterns. The count of the warp and weft yarns per inch and any other identifying construction indicators must be comparable between the impression and the fabric. Fibers left in the impression should be recovered and examined further as they may add additional significance to the overall fabric and fiber examination.

7.5 Thermoplastic fusions
Fiber fusions may occur between textiles and various plastic or polymer coated surfaces due to the heat caused by the friction of impact, such as from high-speed impacts with a vehicle. Partially fused fibers may be found in a fabric impression on a vehicle hood, interior of a car, etc. Photographs with a scale should be taken prior to removing any fused fibers to preserve the impression. Care must be taken not to damage the impression when attempting to remove fibers partially fused to the surface. The removed fibers can then be compared to a known sample and, if necessary, the thermoplastic properties can be assessed (e.g., melting point).

7.6 Cut/Tear Fabric Damage
Examination of the cuts and tears in fabrics can offer information as to the implement that may have produced the damage. Analysis and documentation of the shape, pattern, and dimensions of the damage is followed by analysis of the edges of the cut/torn yarns. The analysis should be both visual and with the aid of magnification, either with a microscope or magnifying lens, to determine if the individual yarns of the fabric are cut or torn. A scanning electron microscope may add further detail to the examination of the cuts and tears of the individual fibers.

Test cuts may be made with questioned implements to see if they make cuts or tears that are consistent with the shape, pattern and dimensions of those found on the evidence. These test cuts should be made after all other forensic examinations, such as DNA and latent fingerprint analyses, have been conducted on the item. Test cuts are made in an undamaged portion of the item corresponding to where the damage originally was noted or, if it is too damaged, in a similar type of fabric or garment. The fabric should be placed on an appropriate substrate prior to producing the test cuts/tears. Examples of suitable substrates include cardboard boxes of sufficient strength to withstand the insertion of a blade or other cutting implement, styrofoam, gel blocks and body replicas. In addition to comparing the test cuts/tears to those found in the evidence, the orientation of a knife in relation to the cut mark may be determined. This can be done if a single-edged blade was used, by finding the characteristic “V” shaped notch at one end of a cut/tear mark, which corresponds to where the flat portion of the blade entered the fabric. It should be noted that the dimension of the test cut/tear may not correlate on a one-to-one basis with the knife due to fabric stretch.

8.0 Report Documentation

If a physical match is found, it should be reported in a manner that will indicate that the two or more pieces of material were at one time a continuous piece of fabric or cordage. If no physical match is possible/found, a complete fabric/cordage comparison, including construction and composition, can be performed. If, during this examination, the items are found to be the same in all tested characteristics, then the examiner reports that the two objects exhibit the same color, construction, and composition and are consistent with originating from the same source.

Fabric impressions associated to a known sample should be reported as consistent in all points of comparison between the questioned and known impressions; however, the results should not be limited to that specific garment as having produced the impression due to the bulk manufactured nature of textile material. It is rare that a positive identification can be made for fabric impression evidence and care should be taken to account for possible fabric stretch or distortion. Fabric impressions without fiber transfer associations generally do not rise to the same level of significance as those with a transfer.

In fabric damage cases, when comparing test cuts/tears to documented damage, and an association is found, the report wording should be limited to a statement that the cut/tear marks are consistent in size, shape and general appearance with having been made by that weapon or another implement of similar characteristics and dimensions. If a transfer of fibers has been found on the weapon, the significance of the conclusion in the report may be strengthened. However, the report wording concerning the fabric damage should still be limited to the cut/tear analysis wording without overstating the results or precluding other possible weapons of similar nature from having produced the damage.

9.0 Bibliography

Budworth G, *Knots and Crime*, London, UK: Police Review Publishing Co., 1985.

Complete Textile Glossary. Charlotte, NC: Celanese Acetate LLC. 2001.

Griffin, H "Glass Cuts in Clothing" 2007 Trace Evidence Symposium http://projects.nfstc.org/trace/docs/final/Griffin_paper_GlassCuts.pdf

Hatch KL, *Textile Science*. Minneapolis, MN: West Publishing Company, 1993.

Hearle, J.W.S., Lomas, B., Cooke, W.D. and Duerden, I.J., *Fibre failure and wear of materials - An atlas of fracture, fatigue and durability*. New York, NY: John Wiley and Sons, Inc., 1989.

Himmelfarb D, *The Technology of Cordage Fibres and Rope*, Metuchen, NJ: Textile Book Service, 1957.

-, The Cordage Directory.

-, *RN/WPL Encyclopedia*, New Providence, NJ: Reed Reference Publishing, 1996.

-, *Davison's Textile Blue Book*, Nealy BW (ed), Concord, NC: Davison Publishing Company, 1996.

Jochem, G. "Fiber-Plastic Fusions and Related Trace Material in Traffic Accident Investigation" in *Trace Evidence Analysis - More Cases in Mute Witnesses*, ed. Houck,MM, Elsevier 2004.

Koch, SL and KL Deaver, "The Effects of Scavenging and Weathering on Fabric Damage" 2007 Trace Evidence Symposium http://projects.nfstc.org/trace/docs/Trace%20Presentations%20CD-2/koch.pdf

Mahall K, *Quality assessment of textiles - Damage detection by microscopy*. New York, NY: Springer-Verlag, 1993.

Masakowski, S. et al, Fiber-Plastic Fusions in Traffic Accident Reconstruction, *Journal of Forensic Sciences*, 1986, pp.903-912.

Monahan, DL and HWJ Harding, "Damage to Clothing – Cuts and Tears," *Journal of Forensic Sciences*, 35/4 (901-912).

Oelsner GH, *A Handbook of Weaves*, New York, NY: Dover Publications, Inc., 1952.

Pelton, WR, "Distinguishing the Cause of Textile Fiber Damage Using the Scanning Electron-Microscope (SEM)," *Journal of Forensic Sciences*, 1995, 40/5, (874-882).

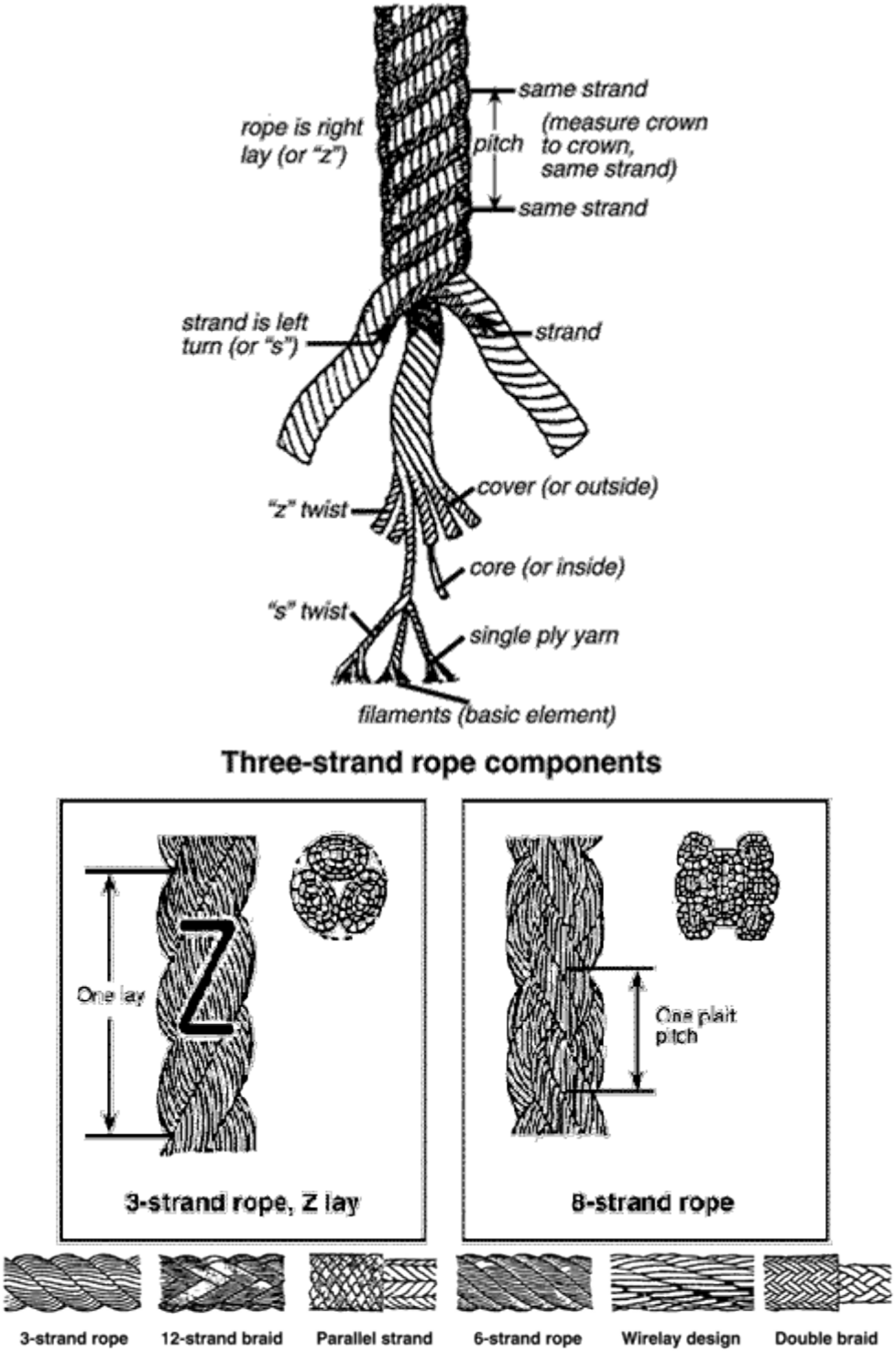
Taupin, JM, "Testing Conflicting Scenarios – A role for simulation experiments in damage analysis of clothing," *Journal of Forensic Sciences*, 1998, 43/4 (891-896).

Taupin, JM, F-P Adolf and J Robertson "Examination of Damage to Textiles" *Forensic Examination of Fibres 2nd Ed,* Robertson and Grieve, eds. London: Taylor and Francis Publishing, 1999.

Taupin, JM, Cwiklik, C. *Scientific Protocols for Forensic Examination of Clothing*. Boca Raton: CRC Press, 2011.

Wiggins, K., Recognition, Identification and Comparison of Rope and Twine, *Science and Justice*, 1995, 35(1), pp. 53-58.

Figure 1: Fiber Rope Components and Constructions



Note: From *The Cordage Directory*, published by The Cordage Institute, Hingham, Massachusetts, 1998.