Introduction to Forensic Fiber Examination

1.0. Scope

This document is an outline of fiber analysis methods intended for use by forensic fiber examiners. The particular methods employed by each examiner, laboratory, or both will depend upon sample size, sample suitability, laboratory equipment, and examiner training.

2.0. Reference Documents

SWGMAT Quality Assurance Guidelines
SWGMAT Trace Evidence Handling Guidelines

3.0. Terminology

Known (Sample): A subset of a larger population or sample originating from a verifiable source, collected as representative of that larger grouping; for example, a 2" x 2" section of carpet from a suspect's living room.

Questioned (Sample): Materials collected as or from items of evidence that may have a known location, but an unknown origin; for example, loose fibers collected from a victim's clothing.

Class Characteristics: Traits that define a group of items collectively.

Class: A group of items that share properties or characteristics.

Individual Characteristics: Traits that define and identify an item as unique and exclusive of all other items.

Target fibers: Fibers that an examiner looks for to possibly establish that a transfer has taken place.

4.0. Summary of Fiber Analysis Guidelines

The various analytical methods available for fiber analysis yield different kinds of information. It is highly desirable to select a combination of methods and apply them in an order that provides the most exclusionary information first. By doing this, the examiner optimizes accuracy, precision, and production while most effectively using the laboratory's resources.

5.0. Significance and Use

According to Locard's exchange principle, when two objects come into contact, there is always a transfer of material. Textile fibers can be exchanged between individuals, between individuals and objects, and between objects. When fibers are associated with a specific source, such as fabric from the victim, suspect, or scene, a value is placed on that association. The strength of the association is dependent upon many factors. The following subsections describe those factors.

5.1. Fiber type or types found;
5.2. Fiber color or colors;
5.3. Number of fibers found;
5.4. Fiber location or locations;
5.5. Fabric type or types;
5.6. Multiple fiber associations;
5.7. Nature of contact; and
5.8. Fiber transfer and persistence.

Whether a fiber is transferred and detected is also dependent on the nature and duration of the contact between the suspect, the victim, or both and the persistence of the fibers after they have been transferred.

5.1. Fiber Type or Types. The rarity or commonness of the fiber types found at a crime scene or on a victim or suspect affects their probative value. Certain types of fibers such as colorless cotton and blue denim are so common as to be of limited forensic value, except in rare cases.

Cotton fibers are by far the most commonly used plant fibers in textile production. The type of cotton, the fibers' length, and the degree of twist contribute to the diversity found in cotton fibers. Processing techniques, such as mercerization, and color applications also influence the value of cotton fiber identifications. The presence of other less common plant fibers at a crime scene or on the clothing of a victim or suspect increases its significance.

The most common animal fiber used in textile production is wool originating from sheep. The fineness or coarseness of woolen fibers often dictates the end use of wool. The finer woolen fibers are used in the production of clothing, whereas the coarser fibers are found in carpet. The diameter and the degree of scale protrusion of the fibers are other important characteristics. Woolen fibers from other animals may also be found, including camel, alpaca, cashmere, and mohair. The identification of less common animal hairs, fibers, or both at a crime scene or on the clothing of a suspect or victim would have increased significance.

Over half of all fibers used in the production of textile materials are manufactured. Some manufactured fibers, such as regenerated cellulosics, originate from natural materials whereas others originate from synthetic materials. Certain types of manufactured fibers are encountered in casework more often than others. The amount of production, the end use, the cross-sectional shape, microscopic characteristics, and other traits of the fiber help to influence the degree of rarity of a particular fiber type.

5.2. Fiber Color or Colors. One of the greatest variations seen in textiles is color. Thus, color and its shade greatly influence the significance of a fiber comparison. Synthetic dyes and pigments belong to numerous different chemical categories with more than a dozen different application methods. Color is a highly discriminating characteristic due to the variety of dye productions, batch variations, and the multitude of colors available. The significance of color increases as the array of colors are spread out over the range of garments and carpeting produced in any one year and even more so when multiplied by the number of garments and carpets produced in previous years.

Individual fibers can be colored before being spun into yarn, yarns can be dyed after being spun, or the fabric can be dyed after its construction as a fabric or garment. Color can also be applied to the surface of a fabric by printing. The absorption of the dye along the fiber length suggests the dyes and dyeing method used. Fading and discoloration may also add increased significance to a fiber association.

5.3. Number of Fibers. The number of questioned fibers associated with a known source is important in estimating actual contact. The greater the number of fibers, the more likely that direct contact occurred between fiber sources. The converse is not necessarily true, however, and even one fiber association can have probative and scientific value. Additionally, finding no fibers does not de facto mean that no contact occurred. Each case is different, and the examiner must weigh all of the relevant factors before determining the significance of the evidence.

5.4. Fiber Location. Where the fibers are found can affect the probative value of a particular fiber association; however handling of the evidence may alter that location. The location of fibers on different areas of the body or on specific items at the scene can influence the significance of the fiber association.

5.5. Fabric Type. Fabric construction affects the number and types of fibers that may be transferred. For example, tightly woven or knitted fabrics shed fewer fibers than loosely knit or woven fabrics. Fabrics composed of filament fibers shed less than fabrics composed of staple fibers. The condition and wear of the fabric also affects the degree of fiber transfers: Newer fabrics may have an abundance of loosely adhering fibers on the surface of the fabric, whereas worn fabrics may have damaged areas that easily shed fibers. Damage to a fabric caused during physical contact greatly increases the likelihood of fiber transfer.

5.6. Multiple Fiber Associations. If many different fiber types are associated between known and questioned sources, then the likelihood that contact occurred between these items is greatly increased. Each associated fiber transfer is considered to be an independent event, and multiple associations reduce the likelihood that the fibers were all deposited by coincidence.

5.7. Nature of Contact. The type of physical contact between two sources influences the number of fibers transferred and the value placed on their discovery. Violent physical contact of an extended duration may result in many fiber transfers. Brief contact will be less likely to transfer multiple fibers than extended and more forceful contact.

5.8. Fiber Transfer and Persistence. Textile fibers are transferred either by direct (primary) transfer or indirect (secondary) transfer. The likelihood of transfer depends on the types of fabric involved in the contact and the nature and duration of the contact. Studies have shown that transferred fibers are lost at an exponential rate, depending on the types of fabrics involved and on the movement of the clothing after contact. For example, the clothing of a homicide victim may retain transferred fibers for a longer period of time than someone who is actively moving. It is difficult to predict precisely how many fibers might remain on the clothing of a living individual after a given period, but it is important for investigators to retrieve clothing as soon as possible.

The discovery of cross transfers between sources dramatically increases the likelihood that two items came into contact and greatly reduces the likelihood of a chance occurrence.

Background information regarding the sources involved and any possible prior contact may affect the significance of the association.

6.0. Sample Handling

Samples are adequate for analysis when they are taken in a manner consistent with generally recognized and accepted sampling techniques and practices within the context of the proposed analyses. If sample size is limited, nondestructive methods must be exhausted before subjecting the sample to any destructive tests (e.g., pyrolysis).

7.0. Analysis

There are four basic activities involved in an analysis: overall case assessment, collection of fibers, preparation of the sample for analysis, and analysis using appropriate methods (see Table 2).

Although these activities are independent of each other, any one can have a significant effect on another. Ultimately, it is the examiner's responsibility to choose an analytical scheme that provides the greatest discrimination between samples.

7.1. Fiber Identification/Comparison

Fiber identifications consist of determining the generic class of a fiber, which generally follows the Federal Trade Commission Guidelines. This analysis requires a sufficient number of examinations to unequivocally place the fiber in question into one and only one generic class (see Table 1).

Fiber comparisons consist of determining if a questioned fiber(s) exhibits the same color, chemical, microscopical, and optical properties as fiber(s) comprising part or all of a known sample. Recommended techniques for the analysis and comparison of fibers are found in Table 2. It should be noted that some techniques allow greater discrimination than others between apparently similar samples.

The analyst should perform a combination of methods that have the greatest potential for discrimination between samples. The methods are presented in no particular order.

In order to perform an identification/comparison, the number of analytical tests performed is left to the discretion of the analyst; however, at a minimum, a fiber examiner must employ a stereomicroscope, a comparison microscope, and a compound light microscope equipped with polarized light capability. Using the comparison microscope an examiner must view questioned and known fibers side by side at the same magnifications in visible light, and alternative lighting, such as polarized light or fluorescent lighting, if the equipment allows.

For color comparison an examiner must employ compound comparison microscopy along with one analytical test (ie. msp or tlc).

8.0. Documentation, Interpretation and Reporting

Laboratory results should be reported in a uniform and consistent manner. Format, units of measurement, and accepted calculations should all be documented in the laboratory's manuals. The contributor of the evidence must be able to "interpret the results and understand their significance" (1). The International Organization for Standardization (ISO) recommends that reports be clear, accurate, and unambiguous in the presentation of results. Refer to the appropriate sections of the SWGMAT Quality Assurance Guidelines for further information.

9.0. References

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Table 1

Federal Trade Commission Rules and Regulations Under the Textile Products Identification Act, 16 CFT Part 303

Pursuant to the provisions of Section 7 of the Act, the following generic names for manufactured fibers, together with their respective definitions, are hereby established:

Fiber Name	Definition
Acetate	A manufactured fiber in which the fiber-forming substance is cellulose acetate. Where not less than 92% of the hydroxyl groups are acetylated the term triacetate may be used as a generic description of the fiber.
Acrylic	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of acrylonitrile units.
Anidex	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 50% by weight of one or more esters of a monohydric alcohol and acrylic acid.
Aramid	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings.
Azlon	A Manufactured fiber in which the fiber-forming substance is composed of any regenerated naturally occurring proteins.
Elastoester	A manufactured fiber in which the fiber-forming substance is a long chain synthetic polymer composed of at least 50% by weight of aliphatic polyether and at lest 35% by weight of polyester, as defined in 303.7(c).
Fluoropolymer	A manufactured fiber containing at least 95% of a long chain polymer synthesized from aliphatic fluorocarbon monomers.
Glass	A manufactured fiber in which the fiber-forming substance is glass.
Lyocel	A manufactured fiber composed of precipitated cellulose and produced by a solvent extrusion process where no chemical intermediates are formed.
Melamine	A manufactured fiber in which the fiber-forming substance is a synthetic polymer composed of at least 50% by weight of a cross-linked melamine polymer.
Metallic	A manufactured fiber composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal.
Modacrylic	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of less than 85% but at least 35% by weight of acrylonitrile units.
Nylon	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polyamide in which less than 85% of the amide linkages are attached directly to two aromatic rings.

Nytril	A manufactured fiber containing at least 85% of a long chain polymer of vinylidene dinitrile whiere the vinylidene dinitrile content is no less than every other unit in the polymer chain.
Novoloid	A manufactured fiber containing at least 85% by weight of a cross-linked novolac.
Olefin	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of ethylene, propylene, or other olefin units.
PBI	A manufactured fiber in which the fiber-forming substance is a long chain aromatic polymer having reoccurring imidazole groups as an integral part of the polymer chain.
PLA	A manufactured fiber in which the fiber-forming substance is composed of at least 85% by weight of lactic acid ester units derived from naturally occurring sugars.
Polyester	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalate units and parasubstituted hydroxybenzoate units. Where the fiber formed by the interaction of two or more chemically distinct polymers (of which none exceeds 85% by weight), and contains ester groups as the dominant functional unit (at least 85% by weight of the total polymer content of the fiber), and which, if stretched at least 100%, durably and rapidly reverts substantially to its unstretched length when the tension is removed, the term elasterell-p may be used as a generic description of the fiber.
Rayon	A manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups. Where the fiber is composed of cellulose precipitated from an organic solution in which no substitution of the hydroxyl groups takes place and no chemical intermediates are formed, the term lyocell may be used as a generic description of the fiber.
Rubber	A manufactured fiber in which the fiber-forming substance is comprised of a natural or synthetic rubber, including the following categories: (1) A manufactured fiber in which the fiber-forming substance is a hydrocarbon such as natural rubber, polyisoprene, polybutadiene, copolymers of dienes and hydrocarbons, or amorphous (noncrystalline) polyolefins. (2) A manufactured fiber in which the fiber-forming substance is a copolymer of acrylonitrile and a diene (such as butadiene) composed of not more than 50% but at least 10% by weight of acrylonitrile units. The term lastrile may be used as a generic

	description for fibers falling within this category. (3) A manufactured fiber in which the fiber-forming substance is a polychloroprene or a copolymer of chloroprene in which at least 35% by weight of the fiber-forming substance is composed of chloroprene units.
Saran	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 80% by weight of vinylidene chloride units.
Spandex	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% of a segmented polyurethane.
Sulfar	A manufactured fiber in which the fiber-forming substance is a long chain synthetic polysulfide in which at least 85% of the sulfide linkages are attached directly to two aromatic rings.
Vinal	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 50% by weight of vinyl alcohol units and in which the total of the vinyl alcohol units and any one or more of the various acetal units is at least 85% by weight of the fiber.
Vinyon	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of vinyl chloride units.

Table 2

Analysis of Fibrous Materials

The analyst should perform a combination of methods that have the greatest potential for discrimination between samples. The methods are presented in no particular order.

In order to perform an identification/comparison, the number of analytical tests performed is left to the discretion of the analyst; however, at a minimum, a fiber examiner must employ a stereomicroscope, a comparison microscope, and a compound light microscope equipped with polarized light capability. Using the comparison microscope an examiner must view questioned and known fibers side by side at the same magnifications in visible light, and alternative lighting, such as polarized light or fluorescent lighting, if the equipment allows.

For color comparison an examiner must employ compound comparison microscopy along with one analytical test (e.g. MSP or TLC).

FTIR is highly recommended for manufactured fibers.

Shaded boxes = highly recommended or required.

Physical Characterization	Optical Characteristics	Chemical analysis	Color/Dye analysis	Instrumental analysis
Stereomicroscopy	PLM	Solubility	Comparison microscopy	FTIR
Light microscopy/ comparison microscopy	Light microscopy/ comparison microscopy	Staining (natural fibers)	MSP or TLC	SEM-EDS/XRF
SEM	Fluorescence		CE	PyGC/PyGCMS
Melting point			Raman	XRD
Physical test (dry twist, ashing, etc)				Raman

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