

OSAC 2022-S-0019

Standard Guide for

Forensic Examination of

Fibers

*Trace Materials Subcommittee
Chemistry: Trace Evidence Scientific Area Committee
Organization of Scientific Area Committees (OSAC) for Forensic Science*



Draft OSAC Proposed Standard

OSAC 2022-S-0019 Standard Guide for Forensic Examination of Fibers

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Standard Guide for Forensic Examination of Fibers

1. Scope

1.1 This document is an introduction to the examination of textile fibers in forensic casework. It is intended to assist individuals who conduct forensic fiber analyses in their evaluation, selection, and application of tests that can be of value to their examinations. The goal is to provide a consistent approach to forensic fiber analysis. Detailed descriptions of procedures for many of the techniques are addressed in separate documents (E2224, E2225, E2227, E2228). This document is not intended as a detailed process description or rigid scheme for the analysis and comparison of fibers, but as a guide to the strengths and limitations of each analytical technique.

1.2 *This standard is intended for use by competent forensic science practitioners with the requisite formal education, discipline-specific training (see Practice E2917), and demonstrated proficiency to perform forensic casework.*

1.3 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:¹

D123 Terminology Relating to Textiles

D629 Standard Test Methods for Quantitative Analysis of Textiles

D4845 Terminology Relating to Wool

D4849 Standard Terminology Related to Yarns and Fibers

D7641 Guide for Textile Fibers

E620 Practice for Reporting Opinions of Scientific or Technical Experts

E1459 Guide for Physical Evidence Labeling and Related Documentation

E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory

E1732 Terminology Relating to Forensic Science

E2224 Guide for Forensic Analysis of Fibers by Infrared Spectroscopy

E2225 Guide for Forensic Examination of Fabrics and Cordage

E2227 Guide for Forensic Examination of Non-Reactive Dyes in Textile Fibers by Thin-Layer Chromatography

E2228 Guide for Microscopical Examination of Textile Fibers

E2917 Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs

WK78748 Practice for a Forensic Fiber Training Program

WK 78749 Guide for Microspectrophotometry in Forensic Fiber Analysis

2.2 AATCC Standards:²

AATCC Test Method 20: Qualitative Test Method 20–2013 Fiber Analysis: Qualitative

2.3 Other Documents:

¹ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

² Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709-2215, <http://www.aatcc.org>.

- 48 ANAB ANSI 3125³
49 ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories⁴
50 SWGMAT Introduction to Forensic Fiber Examination
51

52 3. Terminology 53

54 3.1 *Definitions*— For additional terms commonly employed for forensic fiber examinations, see E1732 and E2228.
55 For additional terms relating to textiles and wool, see D123, D4845, and D7641.

56 3.2 *Definitions of Terms Specific to This Standard:*

57 3.2.1 *animal fiber, n*—any natural protein-based fiber. See D7641

58 3.2.2 *generic class, n*—as used with *textile fibers*, a grouping having similar chemical compositions or specific
59 chemical
60 characteristics. D123

61 3.2.3 *inorganic fibers, n*—a class of fibers of natural mineral origin (for example, chrysotile asbestos) and
62 manmade
63 mineral origin (for example, fiberglass). E2228

64 3.2.4 *manufactured fiber, n*—a class name for various genera of fibers (including filaments) produced from fiber
65 forming substances which can be (1) polymers synthesized from chemical compounds [synthetic fibers], (2)
66 modified or transformed natural polymers [regenerated fibers], and (3) minerals, for example, glasses. E2228

67 3.2.4.1 *Discussion*—Acrylic, nylon, polyester, olefin, urethane, and polyvinyl are examples of fiber
68 synthesized from chemical compounds. Cellulose based fibers, such as acetate and rayons, and alginate fibers are
69 examples of modified or transformed polymers. D123

70 3.2.5 *natural fibers, n*—a class name for various genera of fibers (including filaments) of: (1) animal (that is,
71 silk and wool); (2) mineral (that is, asbestos); or (3) vegetable origin (that is, cotton, flax, jute, and ramie). E2228

72 3.2.6 *synthetic fibers, n*—a class of manufactured polymeric fibers, which are synthesized from chemical
73 compounds (for example, nylon and polyester).

74 3.2.7 *target fibers, n*—questioned fibers that an examiner selects for further examination based on their
75 resemblance to the known sample.

76 3.2.8 *textile, n*—a general term for fibers, yarn intermediates, yarns, fabrics, and products that retain all the
77 strength, flexibility, and other typical properties of the original fiber or filaments.

78 3.2.8.1 *Discussion—General*, a structure made from any combination of natural or manufactured fibers,
79 having either a measured staple length or a continuous filament length, that can be in the form of a woven,
80 nonwoven, braided, plaited, knitted, entangled or twisted product and which retains its characteristic flexibility and
81 drape. *Specific*, as applied to: (1) staple fibers and filaments suitable for conversion to or use as yarns, or for the
82 preparation of nonwoven fabrics, (2) yarns made from natural or manufactured fibers, (3) fabrics and other
83 manufactured products made from fibers as defined above, and form yarns, and (4) garments and other articles
84 fabricated wholly from one or more of the above, and articles made principally from the above when the products
85 retain the characteristic flexibility and drape of the original fabrics. D123

86 3.2.9 *textile fiber, n*—a generic term for the various types of matter that can be transformed into a yarn having a
87 length, at least 100 times its diameter, and which can be used to produce a flexible structure by weaving; knitting;
88 braiding; felting or any other means of processing.

89 3.2.9.1 *Discussion*—The matter transformed into a textile fiber can be either natural or manufactured. In
90 addition to having a high ratio of length to thickness, the textile fiber also needs to have sufficient strength,
91 cohesiveness, and flexibility.
92

93 4. Summary of Guide 94

95 4.1 The basic activities involved in a fiber examination include case assessment, the search for and collection of
96 fibers, preparation of the sample(s) for analysis, analysis using appropriate techniques, and evaluation of results.

97 4.2 The analysis of evidentiary fiber samples includes the examination of physical characteristics, optical

³ Available from ANSI National Accreditation Board, 330 E. Kilbourn Ave, Suite 926, Milwaukee, WI, 53202, <https://anab.ansi.org/2018-iso-iec-17025-forensic-accreditation-documents-0>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

98 properties, color, and chemical composition. The techniques described in this document provide complementary
99 information and should be selected and employed in an order that considers sample preservation and the amount of
100 discriminating information that can be obtained.

101 **5. Significance and Use**

102 5.1 Fibers are frequently encountered in casework, whether it be through the evidentiary item itself (e.g., clothing,
103 rope), or
104 through the processing and collection of fibers from evidentiary items. Fibers can be exchanged between
105 individuals, between individuals and objects, and between objects.

106 5.2 Fibers are subjected to a variety of manufacturing processes in order to produce textile materials for
107 application in a

108 wide range of industries (e.g., automotive, clothing, home furnishing). Factors such as end use, current trends, and
109 availability influence the type and color of fibers incorporated into textiles.

110 5.3 Fibers exhibit a wide range of microscopic characteristics and optical properties due to the manufacturing
111 process, end use, and exposure to various environmental conditions. These characteristics and properties are observed,
112 analyzed, and compared during a fiber examination.

113 **6. Case Assessment**

114 6.1 In the case assessment phase, the examiner determines what samples are to be compared or identified. Sample
115 size, sample variability, condition, environmental effects, relevant case circumstances, and collection and packaging
116 techniques are all taken into account and the examiner chooses analytical techniques, sample preparation schemes,
117 testing sequences, and degree of sample alteration and consumption that are suitable to the specific case.

118 6.2 As practicable, evaluate questioned fibers prior to known fiber samples during the examination process.

119 6.3 During case assessment, the examiner is cognizant of potential biasing effects resulting from task-irrelevant
120 information (1).

121 **7. Evidence Handling**

122 7.1 Follow the general requirements set forth in Practice E1492 and Guide E1459 if handling and tracking
123 evidence.

124 7.2 Each laboratory develops appropriate procedures concerning sample size, collection, packaging, preservation,
125 and order of examinations in order to prevent contamination and loss of fibers (2, 3).

126 7.2.1 Collect evidentiary items as soon as possible to mitigate the loss of fibers and other types of trace evidence.

127 7.2.2 Handling or transport can alter the location of a transferred fiber on a particular item of evidence (12).

128 7.3 Multiple kinds of evidence requiring the expertise of different forensic disciplines can be present on a single
129 item. This can include various types of trace materials (e.g., hairs, fibers, paint, glass, explosives), as well as
130 fingerprints and DNA. Prior to processing an item, consider the types of evidence potentially present and the impact
131 that fiber examinations have on the ability of other examiners to perform future analyses. Examiners should confer
132 before work is undertaken to ensure proper examination order and recovery of evidence. Unless circumstances
133 dictate otherwise, the trace materials are collected and preserved prior to other examinations (2, 3).

134 7.4 Samples are collected in a manner consistent with generally-recognized and accepted sampling techniques.

135 **8. Types of Exams**

136 8.1 During a forensic fiber examination, two basic types of analysis are conducted. These analyses include fiber-
137 type identification and fiber comparison (13-15).

138 8.2 Fiber-type identifications are performed to provide investigative leads and possible end-use information. The
139 Federal Trade Commission has defined classifications to include manufactured fiber definitions (Table 1), and fibers
140 are analyzed to determine to which generic class (e.g., cotton, polyester) they belong (16). This analysis requires a
141 sufficient number of analytical techniques to unequivocally place the questioned fiber into one and only one generic
142 class. There are two broad categories of classification: natural fibers and manufactured fibers. Each can be further
143 broken down into sub-classifications.

144 8.2.1 Natural fibers are obtained from plants, animals, or geological materials.

153 8.2.2 Manufactured fibers can be further described as regenerated, synthetic, or mineral based on the
154 starting materials used to form the fibers.

155 8.3 Fiber comparisons are conducted to determine if (a) questioned fiber(s) exhibit(s) the same physical
156 characteristics, optical properties, color, and chemical composition as fiber(s) comprising part or all of a known
157 sample in order to assess whether the known sample can or cannot be included as a possible source. The same
158 process can also be used to compare two or more questioned fibers in order to determine if they could share a
159 common source.

160 8.4 The fiber types found at a crime scene or on a person of interest affects their evidential value.

161 8.4.1 Certain types of fibers, such as colorless cotton and indigo-dyed blue cotton (denim), are so common as to
162 be of limited evidential value, except in rare cases (e.g., colorless cotton fibers embedded or fused on to a deployed
163 airbag or a scrap of blue denim fabric caught on the undercarriage of a vehicle suspected to be involved in a hit-and-
164 run).

165 8.4.2 *Natural Fiber Use in Textile Production*

166 8.4.2.1 Cotton fibers are the most commonly-used plant fibers in textile production. The type of cotton, cross-
167 sectional shape, length, and the degree of twist contribute to the diversity found in cotton fibers. Processing
168 techniques, such as mercerization, and color applications also influence the comparative value of cotton fibers. The
169 presence of other less-common plant fibers recovered at a crime scene or on the clothing of a person of interest can
170 increase the significance of the fiber evidence.

171 8.4.2.2 The most common animal fiber used in textile production is wool originating from sheep. The
172 fineness or coarseness of woolen fibers often dictates the end use of wool. In general, the finer woolen fibers are
173 used in the production of clothing, whereas the coarser fibers are found in carpet. The diameter and the degree of
174 scale protrusion of the fibers are other important characteristics. Woolen fibers from other animals, including camel,
175 alpaca, goat (cashmere and mohair), and rabbit (angora) are also found in textiles. The identification of less-common
176 animal fibers at a crime scene or on the clothing of a person of interest can have increased significance as compared
177 to that of sheep's wool.

178 8.4.3 *Manufactured Fiber Use in Textile Production*

179 8.4.3.1 Over half of all fibers used in the production of textile materials are manufactured (17, 18). Certain
180 types of manufactured fibers are encountered in casework more often than others. The amount of production, the end
181 use, the cross-sectional shape, microscopic characteristics, and other traits of the fiber affect the significance of a
182 particular fiber type.

183 9. Procedure

184 9.1 Select known sample(s) representative of the observed variation (e.g., color, texture, luster) within the textile.
185 Differences could arise in measurements of fiber samples from the same garment or textile because of differences in
186 weathering (e.g., sunlight exposure), spot staining/bleaching, or repaired areas (e.g., use of a fabric marker to cover a
187 discolored area, application of a patch).

188 9.2 Techniques for the identification and comparison of fibers (19-24) are found in Table 2 (shaded boxes represent
189 techniques which are highly recommended) and are presented in no particular order. Some techniques allow greater
190 discrimination between apparently similar samples than others (25-33). The particular technique(s) employed by each
191 examiner or laboratory will depend upon available equipment and the nature and extent of the fiber evidence in each
192 specific case.

193 9.3 For any given fiber identification and comparison, not all the techniques listed in Table 2 are necessary. Fiber
194 type, sample size, and condition should be considered if determining which techniques to use. Those requiring more
195 sample preparation or consumption should be performed after less-destructive techniques. If sample size is limited,
196 nondestructive techniques are exhausted before subjecting the sample to tests which could permanently alter or
197 destroy the sample [e.g., Fourier-transform infrared (FTIR) spectroscopy, pyrolysis]. If an exclusionary difference is
198 found at any point during the fiber comparison process, then no further analysis is necessary.

199 9.4 The analytical tests performed are left to the discretion of the examiner; however, at a minimum, a fiber examiner
200 employs a stereomicroscope, light microscope, and a polarized light microscope for identification. In addition, the
201 fiber examiner uses a comparison microscope and at least one other color comparison technique if performing fiber
202 comparisons.

203 9.4.1 Using the comparison microscope, an examiner views fibers side-by-side at the same magnifications in
204 visible light, and by alternative lighting, such as polarized light or fluorescence, if the equipment allows. For color
205 comparison, an examiner employs at least one analytical test [e.g., microspectrophotometry (MSP), thin layer
206
207

208 chromatography (TLC)] along with comparison microscopy. Fourier-transform infrared spectroscopy (or another
209 technique which provides comparable chemical information) is strongly recommended for the characterization of
210 manufactured fibers.

211 9.4.2 A typical fiber examination workflow is shown in Figure 1. This figure represents one of several possible
212 workflows used to identify and compare fibers and does not preclude the use of other workflows to perform fiber
213 examinations. General descriptions of techniques employed during a fiber examination are listed in sections 9.5
214 through 9.8 in order to provide additional guidance for the selection of appropriate techniques.

215 9.5 Microscopical Examinations

216 9.5.1 Microscopical examinations provide information about the physical and optical properties of a fiber,
217 allowing for the determination of general fiber type and the differentiation of fiber samples.

218 9.5.1.1 Low-magnification stereomicroscopy is used for the search, recognition, manipulation, and collection
219 of apparent textile fibers. This technique also offers a limited characterization of the fiber's physical characteristics.

220 9.5.1.2 High-magnification light microscopy is employed to characterize the fiber's physical and microscopic
221 characteristics (e.g., color, diameter, cross-sectional shape, pigment, voids, inclusions).

222 9.5.1.3 Comparison microscopy allows the examiner to view two fiber samples side-by-side while employing
223 the same magnification and lighting conditions. Comparison using polarized light or fluorescence is performed if the
224 equipment allows.

225 9.5.1.4 Polarized light microscopy (PLM), an essential part of the fiber examination process, is used to observe
226 and measure the optical properties of a fiber. These properties are imparted during the manufacturing process and are
227 used to determine the general fiber type (e.g., acrylic, nylon, polyester).

228 9.5.1.5 Fluorescence microscopy is a technique used to observe the optical properties of the fiber itself as well
229 as those imparted to the fiber by various dyes, optical brighteners, chemical treatment/damage or contaminants.

230 9.5.2 Strengths of microscopical examination techniques include:

- 231 ● Highly discriminating and reliable;
- 232 ● Generally non-destructive;
- 233 ● Rapid; and
- 234 ● Requires minimal sample preparation.

235 9.5.3 Limitations of microscopical examination techniques include:

- 236 ● Physical and optical properties of fibers can be impacted by sample handling, physical
237 damage or environmental factors.
- 238 ● Very dark fibers can impede the ability of these techniques to resolve physical and optical
239 properties of fiber samples.
- 240 ● Potential for quenching of fiber samples when performing fluorescence microscopy.

241 9.5.4 For more detailed information regarding microscopical examination of fibers, refer to ASTM E2228 Guide
242 for Microscopical Examination of Textile Fibers.

243 9.6 Color Examinations

244 9.6.1 Color is highly variable among textiles. Dyes and pigments belong to numerous chemical categories with
245 more than a dozen different application techniques (34, 35). Color is a highly discriminating characteristic due to the
246 variety of dye productions, batch variations, and the multitude of colors available. Individual fibers can be colored
247 before being spun into yarn, yarns can be dyed after being spun, or the fabric can be dyed after its construction as a
248 fabric or garment (35-37). Color can also be applied to the surface of a fabric by printing. The absorption of the dye
249 along the fiber length can vary based on the dyes, dyeing processes used, and the fiber type.

250 9.6.2 For color comparison, an examiner employs comparison microscopy along with another analytical
251 technique, such as microspectrophotometry or TLC. If another analytical technique is not performed, the reason is
252 documented.

253 9.6.3 Microspectrophotometry is an instrumental technique that provides color measurement data for fibers using
254 transmitted light. During fiber examinations, the absorption of visible light is measured and compared. If samples are
255 compared and no differences are detected in the visible region, they can be further analyzed in the UV region using
256 MSP. For more detailed information regarding MSP, refer to ASTM WK78749 Guide for Microspectrophotometry in
257 Forensic Fiber Analysis.

258 9.6.3.1 Strengths of this technique:

- 259 ● Provides objective color measurement data.

- 260 ● Generally considered to be non-destructive (note potential for photobleaching below).
261 9.6.3.2 Limitations of this technique include:
262 ● Absorption can be impacted by sample handling, physical damage or environmental factors.
263 ● Very dark or very light fibers may display data of limited value in the visible region.
264 ● Certain fiber types naturally absorb in the UV region (e.g., wool, polyester), limiting data collection and
265 interpretation.
266 ● Inability to differentiate between individual dye components.
267 ● Potential for photobleaching of fiber samples.
- 268 9.6.4 Thin layer chromatography is a dye analysis technique requiring the extraction of dye from the colored fiber.
269 Different dye mixtures can produce similarly-colored fibers that are difficult to distinguish by optical techniques such
270 as MSP. By first extracting the dye and then separating the individual dye components, TLC provides complementary
271 information to further discriminate between fiber colorants. For more detailed information regarding TLC, refer to
272 ASTM E2227 Guide for Forensic Examination of Non-Reactive Dyes in Textile Fibers by Thin-Layer
273 Chromatography.
- 274 9.6.4.1 Strengths of this technique include:
275 ● Simple dye analysis technique; and
276 ● Provides complementary information to MSP.
- 277 9.6.4.2 Limitations of this technique include:
278 ● Destructive; and
279 ● Limited by the small amount of dye present in a single fiber.
- 280 *9.7 Fourier-Transform Infrared Spectroscopy*
- 281 9.7.1 Fourier-transform infrared spectroscopy is an instrumental technique that employs the use of infrared
282 radiation to obtain information about the chemical structure of fibers in order to determine the fiber-type (e.g., nylon,
283 polyester), sub-type (e.g., identification of acrylic fiber co-polymers), and inorganic fillers (if present). FTIR
284 spectroscopy is typically employed following microscopical and color examination due to potential alteration of fiber
285 morphology. For more detailed information regarding FTIR spectroscopy, refer to ASTM E2224 Guide for the
286 Forensic Analysis of Fibers by Infrared Spectroscopy.
- 287 9.7.2 Strengths of this technique:
288 ● Provides chemical structure and fiber-type information; and
289 ● Requires minimal sample preparation.
- 290 9.7.3 Limitations of this technique include:
291 ● Sample preparation can alter the physical shape and characteristics of the fiber; and
292 ● The presence of surface contaminants can interfere with spectral interpretation.
- 293 *9.8 Additional techniques*
- 294 9.8.1 Capillary Electrophoresis (CE) is a chromatographic technique used to analyze very small amounts of dye
295 from colored fibers.
- 296 9.8.1.1 Strengths of this technique include:
297 ● Provides complementary information to MSP; and
298 ● More efficient than TLC.
- 299 9.8.1.2 Limitation of this technique:
300 ● Destructive.
- 301 9.8.2 Pyrolysis (Py) is an instrumental technique in which fibers are thermally decomposed, followed by analysis
302 using either gas chromatography (Py-GC), mass spectrometry (Py-MS) or a combination of both (Py-GC-MS) to
303 identify the fiber-type and sub-type.
- 304 9.8.2.1 Strength of this technique:
305 ● Provides fiber-type and sub-type information.
- 306 9.8.2.2 Limitation of this technique:
307 ● Destructive.
- 308 9.8.3 Raman spectroscopy is an instrumental technique that uses a monochromatic source (i.e., a laser emitting a
309 wavelength in the ultraviolet, visible or near-infrared spectral range) to produce an inelastic light scattering effect
310 which provides information primarily about fiber dyes, pigment components, the polymer, delustrants, and fillers.
- 311 9.8.3.1 Strengths of this technique include:

- 312 • Provides complementary information to FTIR; and
313 • Requires minimal sample preparation.
- 314 9.8.3.2 Limitation of this technique:
315 • Analysis can be hindered by background fluorescence or thermal degradation of the
316 sample.
- 317 9.8.4 High performance liquid chromatography (HPLC) is a chromatographic technique used to analyze dyes
318 extracted from short lengths of colored fibers. High performance liquid chromatography employs a micro-extraction
319 process that is effective for a wide range of fiber types, dye types, and dye mixtures.
- 320 9.8.4.1 Strengths of this technique include:
321 • Provides quantitative data;
322 • Offers better resolution of dyes than TLC;
323 • Effective for a wide range of fiber types, dye types and dye mixtures; and
324 • Provides complementary information to further discriminate between fiber colorants.
- 325 9.8.4.2 Limitations of this technique include:
326 • Destructive; and
327 • Separation of various dye types on a single chromatographic system can be difficult.
- 328 9.8.5 Elemental analysis techniques such as scanning electron microscopy/energy dispersive X-ray spectroscopy
329 (SEM/EDX) and X-ray fluorescence (XRF) can provide information about the elemental composition of fibers.
- 330 9.8.5.1 Strengths of these techniques include:
331 • Provide information about inorganic components imparted to a fiber through the
332 manufacturing process, additives/finishing agents, and environmental contaminants.
333 • SEM-EDX and XRF are complementary techniques; however, XRF is more sensitive to
334 higher atomic weight elements.
- 335 9.8.5.2 Limitations of these techniques include that:
336 • X-ray production for SEM-EDX is dependent on beam energy, composition and density of
337 the sample, and energy of the X-rays; and
338 • XRF is less sensitive to lower atomic weight elements.
- 339 9.8.6 Techniques such as cross-sectioning, melting point and solubility can be used to obtain information about the
340 physical characteristics and chemical properties of a manufactured fiber. It is important to consider the sequence of
341 analysis when incorporating these destructive techniques into a fiber examination.
- 342 9.8.6.1 Strength of these techniques:
343 • Provide information about a manufactured fiber's physical and chemical properties.
- 344 9.8.6.2 Limitation of these techniques:
345 • Can physically alter or destroy the fiber sample.
- 346 9.8.7 Additional techniques specific to natural fibers include the drying twist test, ashing, and staining. Cross-
347 sectioning can also be used to obtain additional information about a natural fiber's cross-sectional shape and type. As
348 with previously-mentioned techniques, consideration is given to the amount of sample available, and the destructive
349 nature of the techniques employed.

351 **10. Results**

352
353 10.1 In a fiber case, the forensic examiner analyzes the evidence, interprets the data and observations, and reports
354 an opinion of the findings.

355 10.2 The comparative analysis of two or more fibers involves the evaluation of physical characteristics, optical
356 properties, color, and chemical composition.

357 10.2.1 If one or more exclusionary differences are recognized between compared fibers based on the measured or
358 observed characteristics, the sources of these fibers are distinguishable. In fiber comparisons, this is described as an
359 exclusion or elimination: two or more fibers are excluded as having originated from the same source based on the
360 sample provided (38).

361 10.2.2 If no exclusionary differences are recognized between compared fibers based on the measured or observed
362 characteristics, the sources of these fibers cannot be distinguished by these techniques. In fiber comparisons, this is
363 described as a source association based on class characteristics, indicating the possibility that the fibers originated
364 from the same source. Since different fiber sources can share class characteristics, this opinion does not indicate that

365 the fibers came from a specific source.

366

367 **11. Evaluation of the Results**

368

369 11.1 When a specific item, such as fabric from a person of interest or a scene, is included as a possible source of a
370 questioned fiber, or if two or more questioned fibers could share a common source, the evidential value is dependent
371 upon many factors.

372 11.1.1 Source factors

373 11.1.1.1 Fiber type;

374 11.1.1.2 Intra-source variability (e.g. trunk liner, patchwork garment);

375 11.1.1.3 Fiber characteristics;

376 11.1.1.4 Condition of a specific source (e.g., shirt recovered from a hit-and-run victim exhibiting damage); and

377 11.1.1.5 Presence of contaminants, damage, or other acquired characteristics (e.g., the questioned fiber exhibits
378 characteristics of heat exposure and the victim clothing is burned or singed).

379 11.1.2 Activity or case-related factors (e.g., transfer [4-7], persistence [8-11], efficiency of recovery) (13, 14)

380 11.1.2.1 Location, quantity, and acquired characteristics of the recovered fibers (e.g., fibers embedded in a
381 deployed airbag, fibers embedded in blood on a weapon);

382 11.1.2.2 Number and types of fibers associated to single or multiple sources (e.g., multiple black polyester fibers
383 associated to a shirt, multiple blue cotton fibers and multiple blue polyester fibers associated to a single shirt, apparent
384 cross transfer of fibers between two shirts);

385 Note 1: A greater number of associated questioned fibers provides increased support for recent and direct contact
386 occurring with the known fiber source. The converse is not necessarily true, however, and even one fiber association
387 can have evidential value. Finding no fiber associations does not necessarily mean that no contact occurred.

388 11.1.2.3 Nature of contact;

389 Note 2: The type of physical contact between two sources can influence the number of fibers transferred and the
390 value placed on their discovery. Brief contact is less likely to transfer multiple fibers than extended and more forceful
391 contact.

392 11.1.2.4 Composition, construction and condition of a textile;

393 Note 3: Tightly-woven or tightly-knit fabrics shed fewer fibers than loosely-knit or loosely-woven fabrics.
394 Likewise, fabrics composed of filament fibers shed less than fabrics composed of staple fibers. Newer fabrics can
395 have an abundance of loosely-adhering fibers on the surface of the fabric, while worn fabrics can have damaged areas
396 that easily shed fibers. Damage to a fabric caused during physical contact can greatly increase the potential of fiber
397 transfer.

398 11.1.2.5 And environmental factors (e.g., fading, discoloration, singeing).

399 11.2 The ability to discriminate between similar types and colors of recovered fibers is important when assessing
400 the significance of an association (25, 26, 29, 30).

401 11.3 If information about the relevant fiber population is available (e.g., published discrimination studies, product
402 manufacturing and distribution information), the significance of the features recorded during the examination can be
403 evaluated.

404 11.4 The analytical scheme an examiner employs directly impacts the ability to discriminate between fibers and,
405 ultimately,

406 the significance of findings. If an analytical scheme is not inclusive of the assessment of the physical characteristics
407 and

408 optical properties, analysis of color, and analysis of chemical composition when applicable, then a qualifying
409 statement is
410 warranted.

411 11.5 Background information regarding the potential sources involved, possible prior contact, and the environment
412 where

413 questioned fibers were recovered affects the significance of the association. Be cognizant of potential biasing effects
414 resulting from task-irrelevant information (39, 40).

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416 **12. Documentation**

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418 12.1 Contemporaneously record all observations made during the examination. Ensure the examination notes
419 accurately reflect all observations, the evidence analyzed, the techniques employed, and all results. Notes should be
420 sufficient to allow an independent analyst to understand and evaluate all the work performed, analyze and interpret
421 the data, and reach independent opinions.

422 12.2 Case notes include acquired instrumental data that was used to reach a finding.

423 12.3 Reports are written in accordance with ASTM standards (E620) and include the results of the analysis, an
424 interpretation of the results, and qualifying statements that further describe the strengths and limitations of the
425 evidence.

426 12.4 Examiners follow all accreditation guidelines as appropriate (e.g., ISO/IEC 17025 [2, 41]) as well as their
427 laboratory's standard operating procedures and quality assurance guidelines.

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429 **13. Keywords**

430 Forensic science, fiber, fiber comparison, instrumental analysis.

431
432 **Table 1 Federal Trade Commission Rules and Regulations Under the Textile Products Identification Act, 16**
433 **CFT Part 303** Pursuant to the provisions of Section 7 of the Act, the following generic names for manufactured
434 fibers, together with their respective definitions, are hereby established (16):
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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 least 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 crosslinked 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 where 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 crosslinked 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.

436 **Table 2** Techniques for the identification and comparison of fibers. Shaded boxes represent techniques which
437 are highly recommended.

Physical Characterization	Optical Properties	Microchemical Analysis	Color/Dye/Pigment Analysis	Instrumental Analysis
Stereomicroscopy	PLM	Solubility	Comparison Microscopy	FTIR (Manufactured Fibers)
Light Microscopy/ Comparison Microscopy	Light Microscopy/ Comparison Microscopy	Staining (Natural Fibers)	MSP, TLC or a combination of both	SEM-EDS/XRF
SEM	Fluorescence Microscopy		CE	PyGC/PyGCMS
Melting Point			Raman	Raman
Physical Test (Dry Twist, Ashing, etc.)			HPLC	

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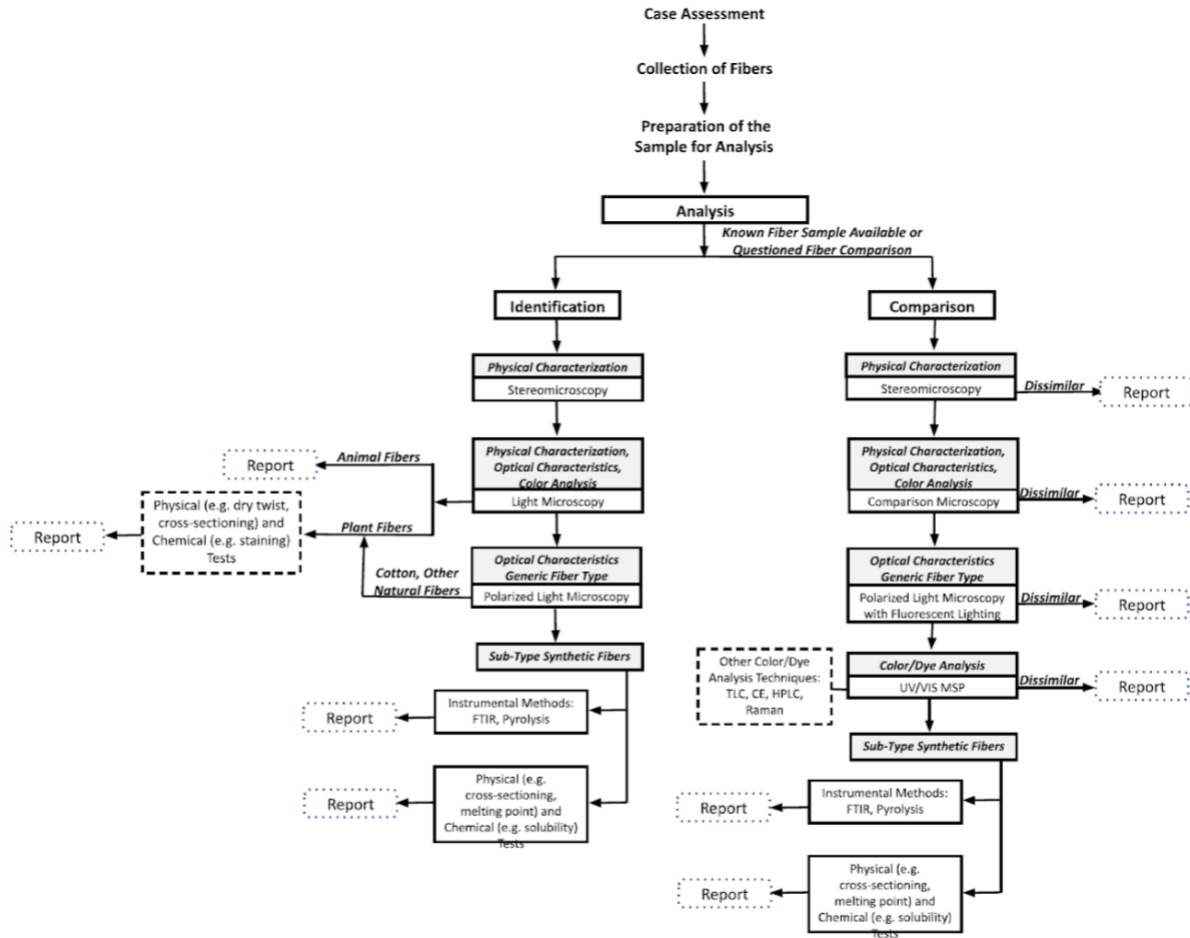


Figure 1. Visual representation of a typical workflow used to identify and compare fibers. This does not preclude the use of other workflows to perform forensic fiber examinations.

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