

Department of Forensic Science

TRACE EVIDENCE TRAINING MANUAL

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1 INTRODUCTION

1.1 Overview

- 1.1.1 The Trace Evidence Section performs physical and chemical analyses not generally conducted by any other discipline within the Department. Samples submitted to this Section range in size from 1 micron primer residue particles to entire automotive vehicles. Due to the diversity of the types of samples received and the types of analyses requested, virtually every type of analytical instrumentation within the Department is routinely utilized along with a wide variety of testing methodologies.
- 1.1.2 Each training section is not meant to be followed in exact order and overlap among and between sections is to be expected. Exposure to legal aspects and testimony will be continuous throughout the training.
- 1.1.3 Training will be summarized using a Training Completion Summary Form which has been modified to personalize training for new examiner trainees, forensic laboratory specialists, previously qualified examiners or those examiners needing refresher training.

An example of this form, listed in the Master Document List, may be provided by the Chemistry Program Manager to the trainer for modification. The signature of the Chemistry Program Manager indicates concurrence with the training plan outlined by the trainer on the date noted. The trainer will review the training plan with the trainee and each individual will sign and date the Training Completion Summary Form at the commencement of training.

1.2 New Examiner Trainees

- 1.2.1 New examiner trainees generally train in two of the following core subdisciplines of examination: Explosives, Fire Debris, Glass, Hairs and Fibers, Paint, Primer Residue.
- 1.2.2 Formal training will largely depend upon which subdiscipline(s) are selected for the trainee to pursue, the trainee's particular background and experience, and the available resources. The trainer will specify which sections of the training manual the trainee must complete and will provide the trainee with a training schedule, to include a Training Completion Summary Form for each area. The trainee must read all sections in their entirety in order to develop an overview understanding of the requirements.

1.3 Forensic Laboratory Specialists

- 1.3.1 Forensic Laboratory Specialists will follow the training manual to the extent that the sections selected are tailored to include the tasks they will be performing as a part of their duties. The trainer will determine which sections are appropriate and the order in which they will be completed. The laboratory specialist will be provided with a training schedule, to include a modified Training Completion Summary Form tailored to these duties.

1.4 Previously Qualified Examiners

- 1.4.1 Individuals who come to the Section as qualified examiners from another laboratory system or from another Section within DFS will generally move more quickly through the training program for their assigned sub-discipline(s). The trainer will review the individual's previous experience and training and will assess competency in each required area. This training generally involves a familiarization with the SOPs and instrumentation and proceeds quickly to competency testing if the individual is performing the same analysis in which he/she was previously certified. In this instance, the individual would not be required to complete a sub-discipline presentation but would be required to successfully complete a final oral examination which may or may not be held in conjunction with the mock trial. Generally speaking, a modified Training Completion Summary Form will be used to document the training.

1.5 Refresher Training

- 1.5.1 Members of the Section who are identified as those who would benefit from refresher training will be given a written outline of the areas to be covered by the trainer. Generally speaking, a modified training completion summary form will be used to document the training.

1.6 Length of Training Program

- 1.6.1 The length of the training period is highly variable and will be left to the determination of the Chemistry Program Manager with input from the Supervisor. Certain individuals may require less time than others depending upon education, experience, or learning ability. Generally speaking, the training program for a new examiner with little to no experience should require 12 months or less to complete. A longer training period may be necessary, for example, if a large number of instruments are necessary for the training of the subdiscipline (e.g., explosives).

1.7 Evaluation

- 1.7.1 The written answers to the training questions will be provided to the trainer and will continue to be modified until the trainer is satisfied with the final answers. These final answers serve as a reference for the trainee throughout the training program and after the trainee is qualified as an examiner.
- 1.7.2 Oral quizzes for individual training sections may be conducted informally by the trainer with the trainee and other attendees as selected by the trainer, if desired. Oral quizzes for instrument training sections (e.g., FTIR, GC-MS, SEM-EDS) will be conducted with the Section/Group Supervisor, the instrument operator(s), and may include other qualified examiners. The demonstration of knowledge in these sessions will either be satisfactory or not satisfactory.
- 1.7.2.1 As there is no separate section for training for the pH meter, refer to the pH subsection of the Explosives section for this block of instruction.
- 1.7.3 At their discretion, the trainer may issue a written examination(s). Written examinations will be assessed as either satisfactory or not satisfactory.

1.8 Responsibilities of the Trainee

- 1.8.1 The trainee will maintain a training notebook which will contain the completed information specified for their training program arranged by section and number as they appear on the Training Completion Summary Form.
- Additionally, the training notebook will contain the completed Training Completion Summary Form (or a copy of same), the answers to training questions, and any other documentation generated as a part of the training.
- 1.8.2 Trainees should maintain an informal log of completed training activities for review by the trainer as requested. Weekly email updates to the trainer may also be used to track progress.
- 1.8.3 Required readings are listed as such because they must be read by the trainee for an adequate understanding of the subject matter. The relevant portion(s) of the Trace Evidence Procedures Manual will also be imperative reading, even if not listed as required reading.
- Instrument manufacturer's manuals along with numerous other references are not necessarily specified as required readings but are available to the trainee and the trainee should familiarize themselves with these.
- 1.8.4 Written answers to the training questions will be prepared and given to the trainer upon their completion. Modifications or additional questions may be suggested by the trainer and the trainee will complete these in a timely fashion and turn them in to the trainer upon completion.

1.9 Responsibilities of the Trainer

- 1.9.1 The trainer will work in conjunction with the Chemistry Program Manager to establish the training program and timeline for training. This is especially important when modifications are made to personalize the training program based upon an individuals' experience or Section requirements.
- 1.9.2 The trainer will prepare the Training Completion Summary Form for the Chemistry Program Manager's review and concurrence.
- 1.9.3 The trainer will review the Training Completion Summary Form with the trainee and both trainer and trainee will sign the form at the commencement of training.
- 1.9.4 The trainer will ensure that all aspects of the training are documented as completed.
- 1.9.5 The performance of the trainee will be evaluated during the course of training. The trainer must submit regular evaluations of the trainee's progress (using the Qualtrax Workflow) to the trainee's direct Supervisor, Section Supervisor, Chemistry Program Manager, and Laboratory Director. The trainer is to discuss this evaluation with the trainee prior to forwarding it to the appropriate reviewers. Any relevant comments by either the trainee or trainer are to be included with the report.
- 1.9.6 The trainer will orient the trainee as to the location of the required and supplemental reading materials.
- 1.9.7 The trainer will discuss the pertinent points of each required reading with the trainee.
- 1.9.8 The trainer will review the written answers to the training questions, suggest expanded answers as applicable, and review and discuss the answers with the trainee.
- 1.9.9 The trainer will provide the trainee with appropriate practical exercises. The trainer will coordinate with the Section Supervisor to determine if materials from previous exercises are available for use.

1.10 Competency Exam

All technical training will culminate in a three-part assessment of the trainee's ability to perform independent work.

1.10.1 Technical Final

- 1.10.1.1 The technical final is an oral examination to ascertain the technical knowledge of the trainee.
- 1.10.1.2 Attendees will generally include: the Chemistry Program Manager, Section/Group Supervisors, the trainer, and examiners qualified in the subdiscipline. The Laboratory Director and/or QA Section Supervisor may choose to attend.
- 1.10.1.3 This oral examination will not exceed three hours.
- 1.10.1.4 After the oral examination, management/supervision will assess the trainee's performance which will either be deemed satisfactory or not satisfactory.
 - 1.10.1.4.1 If the panel determines that the trainee's performance was not satisfactory, then specific details will be afforded the trainee about the deficiency, additional training provided within a specified time frame and another oral examination will be conducted regarding this area(s).

1.10.2 Practical Test

- 1.10.2.1 A final mock case will be issued to the trainee to be worked without assistance or consultation.

1.10.2.2 The final mock case will be prepared by the training coordinator and approved by the Chemistry Program Manager.

1.10.2.3 The case file for this final mock case will be that used for the trainee's mock trial.

1.10.3 Mock Trial

1.10.3.1 This is a recorded, formal presentation where the trainee will defend the results of their practical test in a simulated court setting.

1.10.3.2 The mock trial will typically be scheduled for a date about two weeks after the technical final.

1.10.3.3 The mock trial will not exceed two hours and be attended by those outlined in the Quality Manual.

1.10.3.4 The role of the prosecutor will be assumed by the trainer.

1.10.3.5 There may be one or two defense attorneys who will be determined by the Chemistry Program Manager.

1.10.3.6 After the mock trial, the Evaluation Committee will assess the trainee's performance which will either be deemed satisfactory or not satisfactory.

1.10.3.6.1 If the panel determines that the trainee's performance was not satisfactory, then specific details will be afforded the trainee about the deficiency, additional training provided within a specified time frame and another mock trial will be conducted.

1.10.3.6.2 The trainee will be informed of their satisfactory or unsatisfactory performance and a short performance critique will follow.

1.10.3.7 The recording of the mock trial will be reviewed by the trainer with the trainee in a timely fashion.

1.10.3.7.1 Other participants/observers should provide their comments to the trainer as soon as possible after the completion of the mock trial.

1.10.4 Certification

1.10.4.1 Following the successful completion of the practical test, technical final, and mock trial, the Chemistry Program Manager will issue a memorandum recommending that the trainee be certified.

1.10.4.1.1 For examiners who are completing a block of training that was not originally a part of their subdiscipline training (e.g., initially trained in fire debris and paint; completed XRD training to enable assignment of cases requiring interpretation of data from this instrumentation and/or permitting use of the instrument for casework, as applicable):

1.10.4.1.1.1 The oral quiz will be considered the equivalent of the technical final.

1.10.4.1.1.2 A practical test and a mock trial will not be required.

2 ADMINISTRATION

2.1 Orientation

- 2.1.1 The employee will be introduced to the local operating facilities and personnel to include the assignment of a work and an office area.
- 2.1.2 The trainer will ensure that the trainee has been given an orientation to emergency evacuation procedures and the location of safety equipment.
- 2.1.3 Administrative in-processing will be conducted with appropriate personnel.
- 2.1.4 The trainer will ensure that the trainee studies and becomes familiar with the:
 - DFS Quality Manual,
 - Departmental Administrative Policies,
 - Regional Operating Procedures (ROPs),
 - Trace Evidence Procedures Manual,
 - DFS Safety Manual, and
 - Organization of the Department of Forensic Science.
- 2.1.5 The trainer will:
 - discuss the technical capabilities of the regional laboratories, including definitions of the regional boundaries and areas of overlap,
 - explain the purpose of the training program, including an insight into the course of events and what the trainee is expected to accomplish,
 - explain the operation of local, state and federal law enforcement agencies and court systems,
 - clarify the duties of a trace evidence examiner, and
 - introduce the trainee to the LIMS system.

3 HANDLING OF PHYSICAL EVIDENCE

3.1 Handling of Physical Evidence

3.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- Compliance with the Department of Forensic Science Quality Manual as it relates to security, trace evidence and individual locked storage areas;
- The factors influencing the deterioration of evidence as related to proper versus improper packaging, handling and storage, loss and contamination of evidence;
- Evidence handling procedures, including request for laboratory examinations (RFLE), preservation of chain of custody, use of the laboratory information management system and inter- and intra-laboratory transfer of evidence;
- Court procedures involving identification and introduction of evidence and general testimony;
- Detailed, comprehensive notes/documentation to include:
 - Date, initials and FS#
 - Abbreviations and common symbols
 - Condition and description of evidence
 - Number of items/packages
 - Procedures conducted
 - Use of drawings
- Appropriate labeling of evidentiary materials;
- The DFS definition of a seal;
- The need for good communication skills, written and verbal, regarding evidence handling with both forensic examiners and outside agencies; and,
- Handling evidence in a safe manner to include biohazards and chemical hazards.

3.1.2 Required Readings

- 3.1.2.1 Virginia Department of Forensic Science, Quality Manual, Evidence Handling.
- 3.1.2.2 Virginia Department of Forensic Science, Quality Manual, Records and Case Files.
- 3.1.2.3 Virginia Department of Forensic Science, Evidence Handling and Laboratory Capabilities Guide.
- 3.1.2.4 Virginia Department of Forensic Science Safety Manual.
- 3.1.2.5 Handbook of Forensic Services, FBI Laboratory, Washington, D.C., <https://www.fbi.gov/file-repository/handbook-of-forensic-services-pdf.pdf/view>
- 3.1.2.6 Moenssens, Andre A., et al., Scientific Evidence in Criminal Cases, 3rd Ed., The Foundation Press, Mineola, NY, 1986, pp. 1-74.

3.1.3 Questions

The trainee will provide written answers to the following questions:

- Describe the DFS seal and how does that maintain integrity of evidence.
- Describe chain of custody.
- Describe the lockbox system and how that maintains chain of custody of evidence.
- Describe proper evidence documentation.

3.1.4 Practical Exercises

- 3.1.4.1 The trainer and the trainee will discuss the topics listed in the objectives as they relate to evidence handling.
- 3.1.4.2 The trainee will demonstrate proficiency with the DFS LIMS System.
- 3.1.4.3 The trainee will spend a half day at a minimum observing Forensic Evidence Specialists receive evidence for their laboratory.
- 3.1.4.4 The trainee will observe for a minimum of one week the evidence handling duties performed for Trace Evidence Administrative Storage.
- 3.1.4.5 The trainee will perform the evidence handling duties for Trace Evidence Administrative Storage for a minimum of one week under the direction of their trainer or another qualified examiner.

3.1.5 Evaluation

- 3.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 3.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 3.1.5.3 Review of practical exercises.
- 3.1.5.4 The trainee will provide oral answers to general court-type questions related to evidence handling.

4 LEGAL ASPECTS AND TESTIMONY

4.1 Introduction to Legal Aspects

4.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The Federal Rules of Evidence as related to expert testimony;
- The Code of Virginia as related to admissibility of Certificates of Analysis;
- The admissibility of scientific tests to include the difference between “Frye” and “Daubert”;
- Types of subpoenas;
- Types of evidence, to include: direct evidence, circumstantial evidence, physical evidence, and scientific evidence;
- The difference between individual characteristics and class characteristics and types of evidence displaying each; and,
- Courtroom procedures, to include:
 - Oath,
 - Sequestering of witnesses,
 - *Ex parte* communications of witnesses,
 - Examination:
 - Direct examination,
 - Cross examination,
 - Qualifying questions,
 - Court acceptance as a qualified examiner,
 - Use of reference materials,
 - Use of literary articles,
 - Use of visual aids,
 - Use of opposing expert witnesses,
 - Recognition and Identification of Evidence,
 - Chain of custody,
 - Certificate of Analysis,
 - Explanations of examinations,
 - Conclusions

4.1.2 Required Readings

4.1.2.1 The Code of Virginia, <https://law.lis.virginia.gov/vacode>.

- § 9.1-1101. Powers and duties of the Department.
- § 9.1-1104. Rights of accused person or his attorney to results of investigation or to investigation.
- § 9.1-1105. Reexamination by independent experts.
- § 9.1-1109 through 9.1-1113. Forensic Science Board and Scientific Advisory Committee.
- § 19.2-187. Admission into evidence of certain certificates of analysis.
- § 19.2-187.01. Certificate of analysis as evidence of chain of custody of material described therein.
- § 19.2-187.2. Procedure for subpoena duces tecum of analysis evidence.
- § 19.2-187.1. Procedures for notifying accused of certificate of analysis; waiver; continuances.
- § 54.1-3431. Admission into evidence of certain certificates of analysis.
- Subdiscipline specific sections (e.g., Statewide Fire Prevention Code Act)

4.1.2.2 Federal Rules of Evidence on expert testimony, Article VII.

4.1.3 Questions

The trainee will provide written answers to the following questions:

- Define the following terms:
 - Direct evidence
 - Circumstantial evidence
 - Physical evidence
 - Scientific evidence
 - Individual characteristics
 - Class characteristics
 - Subpoena duces tecum
- Describe the difference between testimony by a lay witness and testimony by an expert witness.
- Describe the difference between an objection that has been overruled and one that has been sustained.

4.1.4 Practical Exercises

- 4.1.4.1 The trainer and the trainee will discuss the topics listed in the objectives as they relate to legal aspects.
- 4.1.4.2 The trainee will search the Legislative Information System at a minimum using “forensic science” on the search line.
- 4.1.4.3 The trainee will search the Code of Virginia for sections pertaining to their subdiscipline training.

4.1.5 Evaluation

- 4.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 4.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 4.1.5.3 Review of practical exercises.

4.2 Introduction to Testimony Skills

4.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Present appropriate courtroom demeanor as it relates to direct eye contact with the trier of fact;
- Present appropriate courtroom demeanor as it relates to protocol in addressing the trier of fact;
- Dress professionally;
- Maintain composure on the witness stand;
- Be aware of verbal inflections and body language;
- Respond to questions in a clear, concise and accurate manner;
- Answer technical questions in layman’s terms;
- Maintain unquestionable ethical standards and conduct;
- Prepare for court with good note taking and documentation skills;
- Prepare for court with good communication skills; and

- Understand the purpose and protocol of pretrial conferences.

4.2.2 Required Readings

- 4.2.2.1 Burke, J. L., “Testifying in Court,” *The Legal Digest*, September 1975, pp. 8 – 13.
- 4.2.2.2 Hodge, E. and Blackburn, B. “Courtroom Demeanor,” *AFTE Journal*, pp. 7–14.
- 4.2.2.3 Kogan, J.D., “On Being a Good Expert Witness in a Criminal Case”, *Journal of Forensic Science*, Vol. 23, No. 1, January 1978, pp. 190-200.
- 4.2.2.4 Kuzmack, Nicholas T., “Legal Aspects of Forensic Science,” Forensic Science Handbook, Saferstein, Richard, ed., Prentice-Hall, New York, NY, 1982, pp. 1-27.
- 4.2.2.5 Moenssens, A. A., Moses, R. E., Inbau, F. E., Scientific Evidence in Criminal Cases, The Foundation Press, Inc., Mineola, 1973, pp. 1-58 and 267-280.
- 4.2.2.6 National District Attorneys Association, Trial Technique: Predicate Questions, 2nd ed, N.A.D.A., Alexandria, VA, 1998, pp. 32-38.
- 4.2.2.7 Tanton, R. L., “Jury Preconceptions and Their Effect on Expert Scientific Testimony,” *Journal of Forensic Science*, 1979, Vol. 24, p. 681-691.

4.2.3 Questions

The trainee will provide written answers to the following questions:

- Define voir dire.
- State your name.
- Where are you employed?
- What position do you hold?
- How long have you been employed by the Department of Forensic Science?
- What are your duties?
- What is your educational background?
- Do you have any specialized training in forensic science?
- Have you ever testified as an expert in Virginia courts?

4.2.4 Practical Exercises

- 4.2.4.1 The trainer and the trainee will discuss the topics listed in the objectives as they relate to testimony.
- 4.2.4.2 The trainee will complete an electronic version of the Statement of Qualifications form (Qualtrax 100-F134).
- 4.2.4.3 The trainee will prepare the answers to the section 4.2.3 questions in a format suitable for distribution to attorneys as qualifying questions.
- 4.2.4.4 The trainee will complete mini-mock trial questioning involving qualifying information.

4.2.5 Evaluation

- 4.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 4.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

4.2.5.3 Review of practical exercises.

5 COLOR ANALYSIS

5.1 Introduction to Color

5.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- Color / color analysis definitions, terminology and theory.
- Color classification and measurement systems.

5.1.2 Required Readings

- 5.1.2.1 Minolta publication PCC 410-B2, Precise Color Communication, Minolta Camera Co., Ltd., Japan, no date.
- 5.1.2.2 Berns, Roy S., Billmeyer and Saltzman's Principles of Color Technology, 2nd ed., New York, New York, John Wiley and Sons, 2000, Chapters 1 and 2.
- 5.1.2.3 Cousins, D. R., "The Use of Microspectrophotometry in the Examination of Paints", *Forensic Science Review*, Vol. 1, No. 2, Dec. 1989, pp.142-162.
- 5.1.2.4 Fouweather, C., May, R.W., and Porter, J., "The Application of a Standard Color Coding System to Paint in Forensic Science", *Journal of Forensic Sciences*, Vol. 21, 1976, pp. 629-635.
- 5.1.2.5 Locke, J., Cousins, D. R., Russell, L. W., Jenkins, C. M., and Wilkinson, J. M., "A Data Collection of Vehicle Topcoat Colours. 1. Instrumentation for Colour Measurements", *Forensic Science International*, Vol. 34, 1987, pp.131-142.
- 5.1.2.6 Macbeth brochure, "SpectraLight® Color Matching Booths and Luminaries," no date.
- 5.1.2.7 SWGMAT's Standard Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis, www.swgmat.org.

5.1.3 Questions

The trainee will provide written answers to the following questions:

- Briefly describe the following in layman's terms:
 - o Visual and instrumental color
 - o Reflected, transmitted and scattered light
 - o Primary colors
 - o Light source, sample/standard and observer/instrument
 - o Hue, Value and Chroma
- List and describe the three things required to produce color (from a purely physical point of view)
- As compared with daylight, what part of the visible spectrum is skewed with typical incandescent lighting? Florescent lighting?
- Concisely describe the following:
 - o Metamerism
 - o Refraction
 - o Color Systems (CIE Yxy, L*a*b* and Munsell)
- Technically describe:
 - o Reflected, transmitted and scattered light
 - o Primary colors

- o Hue, Value, Chroma

5.1.4 Practical Exercises

- 5.1.4.1 The trainee will view the samples in the Macbeth Daylighting Metamerism Test Kits #2 and #3 and record their observations.
- 5.1.4.2 The trainee will draw a wavelength (nm) scale showing electromagnetic radiation.
- 5.1.4.3 The trainee and trainer will discuss color measurement systems.

5.1.5 Evaluation

- 5.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 5.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 5.1.5.3 Review of practical exercise.
- 5.1.5.4 The trainee will be quizzed on the subject matter.

5.2 Munsell Color System

5.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the Munsell Color System and the Munsell Book of Color; and
- Visually and/or microscopically determine the location/closest match of samples within the Munsell Book of Color.

5.2.2 Required Readings

- 5.2.2.1 Macbeth/Munsell publication 7m JUL 90, Munsell Color (Munsell Color Space).
- 5.2.2.2 Macbeth/Munsell written pages in the front of the R-G volume of the Munsell Book of Color (Glossy Finish Collection Removable Samples in Two Binders), Macbeth Division of Kollmorgen Instruments Corporation, Baltimore, Maryland.

5.2.3 Questions

The trainee will provide written answers to the following questions:

- The approximate spacing of color chips is based upon what criteria in the Munsell system?
- Approximately, how many color chips are in the Munsell Glossy Book of Color?
- What are the end points that limit the “value scale”?
- What are the tolerances for the color standards?
- How could the Munsell Book of Color be useful in a hit and run case?

5.2.4 Practical Exercises

- 5.2.4.1 The trainee will physically study the Book of Color as a 3D color tree to familiarize the trainee with the 3D format.

- 5.2.4.2 The trainee will select at least two objects of each color: nonmetallic red, green, and blue and will determine their approximate color location in the Munsell Book of Color (unaided eye, 15 minutes total time). Find two other examiners to do the same. Record all results.
- 5.2.4.3 The trainee will be given test sample #1 which consists of a minute paint particle removed from a pedestrian's clothing in a hit and run case (no suspect vehicle). Examine this sample with the stereomicroscope in the presence of the trainer. Immediately afterwards, find a Munsell Book of Color chip that you feel is close to your sample (unaided eye, without looking at your sample again). Based solely upon these observations, describe the color to the trainer. Repeat above and find the best match in the Munsell Book of Color using your stereoscope and side-by-side comparisons. Record results.
- 5.2.5 Evaluation
 - 5.2.5.1 The trainer will review the written answers to the questions with the trainee.
 - 5.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
 - 5.2.5.3 Review of practical exercises.

6 EXPLOSIVES

6.1 Introduction to Explosives

6.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The history and development of explosives;
- The terminology and vocabulary of explosives;
- The manufacturing process of explosives;
- Safety considerations in manufacturing and handling explosives;
- Compositions of explosives to include chemical formulations and structures and manufacturing formulations;
- The relationship between chemical structure and properties of sensitivity, stability, etc.;
- The basic construction of commercial devices;
- The basic construction of improvised devices;
- The use of household products in improvised devices;
- Physical evidence encountered in submissions and the potential value of that evidence (logos, endcaps, paper, writings, etc.); and,
- Fireworks, model rocket engines, and other pyrotechnics.

6.1.2 Required Readings

- 6.1.2.1 Davis, Tenny L., The Chemistry of Powder and Explosives, Angriff Press: Hollywood, CA, 1975, pp.1-122, 141-153, 195-214, 287-367.
- 6.1.2.2 Ellern, Herbert, Military and Civilian Pyrotechnics, ed. 2, Chemical Publishing Company: New York, New York, 1968, pp. 131-144.
- 6.1.2.3 Fordham, S., High Explosives and Propellants, 2nd ed., Pergamon Press: Oxford, England, 1980, pp. 1-28, 35-74, 93-131, 164-196.
- 6.1.2.4 Meidl, J. H., Explosive and Toxic Hazardous Materials, Glencoe Press: Beverly Hills, CA, 1970, pp. 31-74.
- 6.1.2.5 Midkiff, Charles R., "Arson and Explosive Investigation," Forensic Science Handbook, Saferstein, Richard, ed., Forensic Science Handbook. Prentice-Hall, Upper Saddle River, NJ, 2002, pp.498-524.
- 6.1.2.6 National Bomb Data Center, F.B.I., Introduction to Explosives, Picatinny Arsenal: Dover, NJ, 1973.
- 6.1.2.7 Oxley, Jimmie C.; Marshall, Maurice; Lancaster, Sarah L., "Principles and Issues in Forensic Analysis of Explosives," Forensic Chemistry Handbook, Koblinsky, Lawrence, ed. Forensic Chemistry Handbook Wiley, Hoboken, NJ, 2012, pp. 23-40.
- 6.1.2.8 Saferstein, Richard, Criminalistics: An Introduction to Forensic Science, ed. 5, Prentice-Hall, Inc: Englewood Cliffs, NJ, 1995, pp. 314-344.
- 6.1.2.9 Scott, Lee, Pipe and Fire Bomb Designs, Paladin Press: Boulder, CO, 1994.
- 6.1.2.10 Stoffel, J., Explosives and Homemade Bombs, ed. 2, Charles C. Thomas Publishers: Springfield, Ill., 1972, pp. 35-108, p. 191-226.

- 6.1.2.11 Stromberg, Maehly, Chemical Criminalistics, O. Brandstetter: Wiesbaden, Germany, 1981, pp. 65-85.
- 6.1.2.12 U.S. Treasury, Firearms and Explosives Tracing Guidebook, revised May, 1990, Publication number ATFP7520.1 (11-88), pp. 51-107.

6.1.3 Questions

The trainee will provide written answers to the following questions:

- What is an explosion? What are the three types of explosions?
- What is an explosive?
- What is an explosive device?
- What is an IED?
- What is a low explosives?
- What is a high explosive?
- What is meant by detonation?
- What is a low order detonation?
- What is a high order detonation?
- What is meant by deflagration?
- What is the composition of single/double/triple base smokeless powder?
- What is the composition of black powder?
- What is the composition of Pyrodex?
- What is the composition of Black Canyon Powder?
- What is the composition of Triple 7 powder?
- What are the compositions of some common pyrotechnic mixtures (road/air fusee, sparklers, etc.)?
- What are the three primary effects of an explosion?
- What is shrapnel?
- What is the difference between an explosive mixture and an explosive compound?
- How is a high explosive detonated?
- Give an example of a two-step low explosive train.
- What are primary explosives and how are they used? List examples.
- What is a secondary high explosive? List examples.
- Give an example of a three-step high explosive train.
- What are the ingredients in commercial dynamite?
- What is a binary explosive and how does it work?
- What is a chemical reaction bomb? Give examples of chemicals used.
- What is a hypergolic reaction?
- What is ANFO?

6.1.4 Evaluation

- 6.1.4.1 The trainer will review the written answers to the questions with the trainee.
- 6.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.1.4.3 The trainee will be quizzed on the subject matter.

6.2 Recognition, Collection, Packaging and Controls

6.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe to an investigator the proper way to collect explosives evidence;
- Recommend proper packaging for explosives evidence; and
- Detail the proper controls that are to be taken and why.

6.2.2 Required Readings

- 6.2.2.1 Midkiff, Charles, R., “Arson and Explosive Investigation,” Saferstein, Richard, Forensic Science Handbook Vol. 1, 2nd ed., Pearson Education Inc.:Upper Saddle River, NJ, 2002, pp. 498-524.
- 6.2.2.2 Virginia Department of Forensic Science Laboratory Capabilities and Evidence Handling Guide

6.2.3 Questions

The trainee will provide written answers to the following questions:

- How should chemical reaction bombs be packaged?
- Will the laboratory analyze explosive devices which have not been rendered safe?
- Where at a bomb scene is it most likely to find unconsumed explosive material?
- What types of materials/debris should be collected from a bomb scene and how would you recommend they be submitted to the laboratory for analysis?

6.2.4 Evaluation

- 6.2.4.1 The trainer will review the written answers to the questions with the trainee.
- 6.2.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.2.4.3 The trainee will be quizzed on the subject matter.

6.3 Stereomicroscopic Evaluation of Explosives

6.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Take appropriate notes;
- Use a stereomicroscope properly;
- Work with small samples;
- Recognize morphology of various explosive powders and residues; and
- Recognize and recover intact low explosive particles in debris.

6.3.2 Required Readings

- 6.3.2.1 De Forest, Peter R., “Foundations of Forensic Microscopy,” Saferstein, Richard, Forensic Science Handbook Vol. 1, 2nd ed., Pearson Education Inc.:Upper Saddle River, NJ, 2000, pp. 231-232.
- 6.3.2.2 Saferstein, Richard, Criminalistics: An Introduction to Forensic Science, ed. 5, Prentice-Hall, Inc, Englewood Cliffs, NJ, 1995, pp. 180-182.

6.3.3 Questions

The trainee will provide written answers to the following questions:

- The stereomicroscope is the least frequently used microscope in a typical crime laboratory. (True or False)
- The stereomicroscope offers a large _____ between the objective lens and the specimen.
- The stereomicroscope is actually two monocular _____ microscopes properly spaced and aligned to present a three-dimensional image of a specimen.
- Describe how to differentiate between a physical reaction bomb and a chemical reaction bomb.

6.3.4 Practical Exercises

- 6.3.4.1 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for explosives analysis.
- 6.3.4.2 The trainee will at a minimum view the following samples using the stereomicroscope, record their observations and prepare sketches as appropriate:
- Different grades of black powder
 - Pyrodex and other black powder substitutes
 - Smokeless powder (tube, perforated tube, disc, perforated disc, ball, flattened ball, lamels, etc.)
 - Flash powder
 - Pyrotechnic safety fuse
- 6.3.4.3 If possible, the trainee will observe the construction of devices under the supervision of qualified personnel.
- 6.3.4.4 If possible, the trainee will recover device debris after initiation of devices by qualified personnel. The trainee will observe and document all surviving device components and all unaccounted for device components.
- 6.3.4.5 The trainee will view items associated with high explosives, such as blasting caps, detonation cord, and boosters.
- 6.3.4.6 The trainer will provide a “debris” sample with intact low explosive particles present. The trainee will search the debris and isolate and report any intact particles found. The trainer may also include other materials, such as pyrotechnic safety fuse, which might typically be encountered in a debris sample and request that the trainee recover and list these as well.
- 6.3.4.7 The trainee will observe devices of known construction in post-blast condition.
- 6.3.4.8 The trainee will examine at least five secondary high explosives and record their observations.
- 6.3.4.9 The trainee will burn samples of at least five black powder and/or black powder substitutes and record all observations. Samples will be retained for further analysis.
- 6.3.4.10 The trainee will burn samples of at least three smokeless powders and record all observations. Samples will be retained for further analysis.
- 6.3.4.11 The trainee will burn a small amount of pyrotechnic safety fuse and record all observations.
- 6.3.4.12 The trainee will burn a small amount of at least two pyrotechnic mixtures and record all observations. Samples will be retained for further analysis.

6.3.4.13 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.

6.3.4.14 The trainee will successfully complete the Fracture Match Section of the Trace Evidence Training Manual.

6.3.5 Evaluation

6.3.5.1 The trainer will review the written answers to the questions with the trainee.

6.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

6.3.5.3 Review of practical exercises.

6.4 Extractions

6.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to follow the extraction scheme as outlined in the Trace Evidence Procedures Manual.

6.4.2 Required Readings

6.4.2.1 Parker, R.G., "Analysis of Explosives and Explosive Residues, Part 3: Monomethylamine Nitrate," *Journal of Forensic Sciences*, Vol. 20, No. 2, 1975, pp. 257-260.

6.4.2.2 Beveridge, A.D., Development in the Detection and Identification of Explosive Residues, Central Police University Press: Vancouver, BC, Canada, 1992, pp. 33-42.

6.4.3 Questions

The trainee will provide written answers to the following questions:

- Prepare a flow chart of the extraction scheme as outlined in the Trace Evidence Procedures Manual.
- Why are the extracts performed in the order noted on the flow chart?
- What type of extraction would be performed on a suspected acid/aluminum reaction bomb?

6.4.4 Practical Exercises

6.4.4.1 Using the flow chart of the extraction scheme from 6.4.3, explain to the trainer the reasoning behind each step.

6.4.4.2 The trainee will follow the prescribed extraction scheme on at least one of the retained burned black powders and any burned black powder substitutes from Sections 6.1.4.1, as well as at least one of the retained burned smokeless powders from Section 6.1.4.2. (A methanol and ether extraction are not necessary.)

6.4.5 Evaluation

6.4.5.1 The trainer will review the written answers to the questions with the trainee.

6.4.5.2 The trainer and trainee will review and discuss the pertinent points of each of the required reading.

6.4.5.3 The trainee will be quizzed on the subject matter.

6.4.5.4 Review of practical exercises.

6.5 pH Meter

6.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of pH measurement and be able to explain the function of the major components of the instrument;
- Explain and be able to perform appropriate quality checks; and,
- Prepare samples for analysis.

6.5.2 Required Readings

6.5.2.1 Orion A+ Instruction Manual, 2000, Orion Research, Inc.

6.5.2.2 Electrode Handbook, 5th Edition, Fisher Scientific.

6.5.2.3 Thermo Orion 2002 Laboratory Products Catalog, pp. 52-63.

6.5.2.4 pH Meter Handbook

6.5.3 Questions

The trainee will provide written answers to the following questions:

- What is pH?
- How does the instrument work?
- In what types of explosives cases will the pH meter most likely be used?

6.5.4 Practical Exercises

6.5.4.1 The trainee will perform a typical calibration of the pH meter.

6.5.4.2 The trainee will measure the pH of five solutions provided by the trainer and record results.

6.5.5 Evaluation

6.5.5.1 The trainer will review the written answers to the questions with the trainee.

6.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

6.5.5.3 Review of practical exercises.

6.6 Microchemical Testing

6.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Safely prepare microchemical reagents;

- Determine the microchemical properties of explosives and explosives residues; and
- Recognize the limitations and specificity of microchemical tests.

6.6.2 Required Readings

- 6.6.2.1 Anger, V., and Feigl, F., Spot Tests in Inorganic Analysis, ed. 6, Elsevier Publishing Company: Amsterdam, The Netherlands, 1972.
- 6.6.2.2 Bureau of Alcohol Tobacco and Firearms, Spot Tests- Systematic Analysis of Low Explosives, revised 6/1988.
- 6.6.2.3 Feigl, F., Spot Tests in Organic Analysis, ed. 7, Elsevier Publishing Company: Amsterdam, The Netherlands, 1966.
- 6.6.2.4 Jungreis, Ervin, Spot Tests Analysis, John Wiley and Sons, Inc.: New York, New York, 1985.
- 6.6.2.5 Parker, R.G., Stephenson, M.O., McOwen, J.M., Cherolis, J.A., “Analysis of Explosives and Explosive Residues. Part 1: Chemical Tests,” *Journal of Forensic Sciences*, Vol. 20, 1975, pp. 133-140.

6.6.3 Questions

The trainee will provide written answers to the following questions:

- Why are microchemical tests referred to as “presumptive” tests?
- What do the following microchemical tests check for and how would you interpret their results?
 - DPA
 - BaCl plus HOAc
 - AgNO₃ plus NH₄OH
 - Brucine
 - Nessler
 - 1-Naphthol
 - Acetone plus 2N NaOH
 - Triphenylselenium chloride
- How do you know if your reagent is working properly?

6.6.4 Practical Exercises

- 6.6.4.1 The trainee will assemble the necessary solvents and acids and prepare the necessary reagents. The trainee will become familiar with the requirements and will perform appropriate QC checks.
- 6.6.4.2 The trainee will take known samples containing bromide, carbonate, chlorate, chloride, iodide, nitrate, nitrite, perchlorate, and sulfate, and react each with barium chloride, brucine, diphenylamine, silver nitrate, and triphenylselenium chloride. Additionally, add acetic acid to any precipitate formed by reaction with barium chloride and conc. ammonium hydroxide to any precipitate formed by reaction with silver nitrate. Note whether the precipitate remains or dissolves. The trainee will make a table containing the results of each test and compare these results to literature.
- 6.6.4.3 The trainee will react 1-naphthol followed by conc. sulfuric acid with sugar and record results.
- 6.6.4.4 The trainee will react ammonium nitrate with Nessler’s reagent and record results.
- 6.6.4.5 The trainee will test HTH pool chlorinator for the hypochlorite ion and record results.

- 6.6.4.6 The trainee will react TNT with acetone and 2N NaOH and record results.
- 6.6.4.7 The trainee will react a chlorate-containing sample with aqueous aniline sulfate followed by conc. sulfuric acid and record results.
- 6.6.4.8 The trainee will perform the EM Quant Phosphate Test on a known sample of phosphoric acid and record results.
- 6.6.4.9 The trainee will perform the EM Quant Ascorbic Acid Test on a known sample of ascorbic acid and record results.
- 6.6.4.10 The trainee will perform microchemical tests on black powder, black powder substitutes (including Pyrodex), smokeless powder, and pyrotechnic mixtures, generating a low explosives microchemical test worksheet for each.
- 6.6.4.11 The trainee will perform microchemical tests as specified in the Trace Evidence Procedures Manual on the extracts obtained in 6.4.4.2. (Do not consume the entire extracts, as they will be needed for further analysis.)
- 6.6.4.12 The trainer will provide the trainee with at least ten unknown samples. The trainee will perform microchemical tests to determine what ions are present in the samples, generating a low explosives microchemical test worksheet for each sample. The samples may include mixtures.

6.6.5 Evaluation

- 6.6.5.1 The trainer will review the written answers to the questions with the trainee.
- 6.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.6.5.3 Review of practical exercises.

6.7 X-Ray Diffraction (XRD)

6.7.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of XRD and be able to explain the function of the major components of the instrument;
- Explain and be able to perform appropriate quality checks;
- Explain the strengths and limitations of this technique;
- Prepare samples for analysis using a variety of methods; and,
- Interpret the results obtained using library searches and/or comparison to known standards.

6.7.2 Required Readings

- 6.7.2.1 Midkiff, Charles, R., "Arson and Explosive Investigation," Saferstein, Richard, Forensic Science Handbook Vol. 1, 2nd ed., Pearson Education Inc.: Upper Saddle River, NJ, 2002, pp. 513-515.
- 6.7.2.2 Saferstein, Richard, Criminalistics: An Introduction to Forensic Science, ed. 5, Prentice-Hall, Inc, Englewood Cliffs, NJ, 1995, pp. 168-170.

6.7.3 Questions

The trainee will provide written answers to the following questions:

- What kinds of explosive residues would be expected when analyzing deflagrated black powder?
- What are some organic compounds that might be analyzed via XRD?
- In general, in what percentage must a component of a mixture be present in order to be identified on XRD?

6.7.4 Practical Exercises

- 6.7.4.1 The trainee will successfully complete the X-Ray Diffraction Section of the Trace Evidence Training Manual.
- 6.7.4.2 The trainee will analyze common explosive materials and combustion products using different sampling techniques available. Include as a minimum burned and unburned black powder, burned and unburned Pyrodex®, Triple7®, potassium nitrate, potassium sulfate, sulfur, potassium chloride, potassium perchlorate, and sucrose.

6.7.5 Evaluation

- 6.7.5.1 The trainer will review the written answers to the questions with the trainee.
- 6.7.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.7.5.3 Review of practical exercises.

6.8 Ion Chromatography (IC)

6.8.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of IC and be able to explain the function of the major components of the instrument;
- Explain and be able to perform appropriate quality checks;
- Explain the strengths and limitations of the technique and of the different detectors; and,
- Prepare samples for analysis and interpret the results obtained in comparison to known standards.

6.8.2 Required Readings

- 6.8.2.1 Beveridge, A.D., Development in the Detection and Identification of Explosive Residues, Central Police University Press: Vancouver, BC, Canada, 1992, p. 25.
- 6.8.2.2 Reutter, D.J., Buechele, and R.C., Rudolph, T.L., "Ion Chromatography in Bombing Investigations," *Analytical Chemistry*, American Chemical Society, 1983, pp. 1468A-1472A.
- 6.8.2.3 Green, M. "Ion Chromatographic Analysis of Perchlorate in Perchlorate/Sugar Explosive Devices," *LC*, Vol. 3, Number 10, pp. 894-896.
- 6.8.2.4 McCord, B., Hargadon, K., Hall, K., and Burmeister, S., "Forensic Analysis of Explosives using Ion Chromatographic Methods," *Analytica Chimica Acta*, 1994, pp. 43-56.
- 6.8.2.5 Midkiff, Charles, R., "Arson and Explosive Investigation," Saferstein, Richard, Forensic Science Handbook Vol. 1, 2nd ed., Pearson Education Inc.: Upper Saddle River, NJ, 2002, pp. 513-515.

- 6.8.2.6 Rudolph, T., "The Characterization of Some Low Explosive Residues by Ion Chromatography," FBI Laboratory, Washington, D.C., pp. 213-219.

6.8.3 Questions

The trainee will provide written answers to the following questions:

- What anions are commonly present in water extracts of:
 - Black powder?
 - Black powder substitutes?
 - Pyrotechnic mixtures?

6.8.4 Practical Exercises

- 6.8.4.1 The trainee will successfully complete the Ion Chromatography Section of the Trace Evidence Training Manual.
- 6.8.4.2 The trainee will analyze water extracts from a variety of known explosive standards and explosive residues. These water extracts will at a minimum include black powder and black powder substitutes.
- 6.8.4.3 The trainee will analyze the water extracts from Section 6.4.4.2.

6.8.5 Evaluation

- 6.8.5.1 The trainer will review the written answers to the questions with the trainee.
- 6.8.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.8.5.3 Review of practical exercises.

6.9 Fourier Transform Infrared Spectrophotometry (FTIR)

6.9.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of FTIR and be able to explain the function of the major components of the instrument;
- Explain and be able to perform appropriate calibration procedures and/or quality checks as well as routine instrument maintenance; and,
- Prepare samples for analysis choosing the techniques most appropriate to the sample. Interpret the results obtained using library searches or comparison to known standards.

6.9.2 Required Readings

- 6.9.2.1 Midkiff, Charles, R., "Arson and Explosive Investigation," Saferstein, Richard, Forensic Science Handbook Vol. 1, 2nd ed., Pearson Education Inc.: Upper Saddle River, NJ, 2002, p. 511.
- 6.9.2.2 Pristera, F., Halik, M., Castelli, A., Fredericks, W. "Analysis of Explosives Using Infrared Spectroscopy," *Analytical Chemistry*, Vol. 32, No. 4, pp. 495-508.

- 6.9.2.3 Washington, W.D., Midkiff, C.R., “Forensic Applications of Diamond Cell-Infrared Spectroscopy. I: Identification of Blasting Cap Leg Wire Manufacturers,” *Journal of Forensic Sciences*, Vol. 21, No. 4, pp. 862-867.

6.9.3 Questions

The trainee will provide written answers to the following questions:

- Describe how a sample of smokeless powder would be prepared for FTIR analysis.
- Describe how a sample of whole black powder or black powder substitute would be prepared for FTIR analysis.
- Describe how a water extract of a device would be prepared for FTIR analysis.
- What is the main band expected in an FTIR spectrum of whole black powder?

6.9.4 Practical Exercises

- 6.9.4.1 The trainee will successfully complete the Fourier Transform Infrared Spectrophotometry Section of the Trace Evidence Training Manual.
- 6.9.4.2 The trainee will analyze samples from many types of explosives available including black powder and post-combustion black powder, black powder substitutes, smokeless powder, and other explosives commonly encountered.
- 6.9.4.3 The trainee will analyze dried water and acetone extracts from Section 6.4.4.2.

6.9.5 Evaluation

- 6.9.5.1 The trainer will review the written answers to the questions with the trainee.
- 6.9.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.9.5.3 Review of practical exercises.

6.10 Gas Chromatography-Mass Spectrometry (GC-MS)

6.10.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of GC-MS and be able to explain the function of the major components of the instrument;
- Explain and be able to perform appropriate calibration procedures and/or quality checks;
- Prepare samples for analysis choosing the technique most appropriate to the sample; and
- Interpret the results obtained using library searches and comparison to known standards or published data.

6.10.2 Required Readings

- 6.10.2.1 Martz, R. M., Lasswell, L.D. III, “Smokeless Powder Identification,” *Proceedings of the International Symposium On the Analysis and Detection of Explosives*, 1983, pp. 245-254.
- 6.10.2.2 Nowicki, J., Pauling, S., “Identification of Sugars in Explosive Residues by Gas Chromatography-Mass Spectrometry,” *Journal of Forensic Sciences*, JFSCA, Vol. 33, No. 5, Sept. 1988, pp. 1254-1261.

6.10.3 Questions

The trainee will provide written answers to the following questions:

- Using electron impact GC-MS, will nitroglycerin be identified in double-base smokeless powders? Why or why not?

6.10.4 Practical Exercises

- 6.10.4.1 The trainee will successfully complete the Gas Chromatography and Mass Spectrometry Sections of the Trace Evidence Training Manual.
- 6.10.4.2 The trainee will analyze both single base and double base smokeless powders by GC-MS.
- 6.10.4.3 The trainee will analyze the acetone extracts of the smokeless powder from Section 6.4.4.2.

6.10.5 Evaluation

- 6.10.5.1 The trainer will review the written answers to the questions with the trainee.
- 6.10.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 6.10.5.3 Review of practical exercises.

6.11 Scanning Electron Microscopy-Energy Dispersive X-Ray (SEM-EDS)

6.11.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of SEM-EDS and be able to explain the function of the major components of the instrument;
- Discuss the strengths and limitations of the technique including factors which may affect the resulting spectrum, such as escape peaks, sum peaks, etc.;
- Prepare samples for analysis; and,
- Interpret the results obtained.

6.11.2 Required Readings

- 6.11.2.1 Mosher, P.V., McVicar, M.J., Randall, E.D., Sild, E.H., "Gunshot Residue-Similar Particles Produced by Fireworks," *Can.Soc. Forens. Sci. Journal*, Vol. 31, No. 2, 1998, pp. 157-168.
- 6.11.2.2 Stromberg, Maehly, Chemical Criminalistics, O. Brandstetter: Wiesbaden, Germany, 1981, pp. 185-200.

6.11.3 Questions

The trainee will provide written answers to the following questions:

- When analyzing black powder via SEM-EDS, what elements would be expected to be identified? Pyrodex? Pyrotechnic mixtures?
- When analyzing ammonium nitrate, which elements would be expected to be identified?
- Why would certain elements present in a compound not be identified via SEM-EDS?

6.11.4 Practical Exercise

6.11.4.1 The trainee will successfully complete the Scanning Electron Microscopy-Energy Dispersive X-Ray Section of the Trace Evidence Training Manual.

6.11.4.2 The trainee will analyze common explosive materials and combustion products to include at a minimum black powder, black powder substitutes, flash powder and granulated pool chlorine/sugar.

6.11.4.3 The trainee will analyze the dried water extracts from Section 6.4.4.2.

6.11.5 Evaluation

6.11.5.1 The trainer will review the written answers to the questions with the trainee.

6.11.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

6.11.5.3 Review of practical exercises.

6.12 Supervised Work-Along

6.12.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.

6.12.2 The "Training Completion Summary Form" form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.

6.12.3 The trainee shall work at least five forensic cases as a technician for a qualified explosives examiner. The trainer should ensure as much variety in the work-along as is practicable.

6.13 Forensic Significance of Explosives Analysis

The trainer and the trainee will discuss the interpretation of explosives evidence and its relevance and weight in reports and in testimony.

6.14 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

6.15 Explosives Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified explosives examiners, the Chemistry Program Manager, and the Section/Group Supervisor.

The presentation may cover either: the general theory and application of the instrumentation used in explosives analysis; the analytical methodology of explosives and explosive residues; or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic explosives community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee's training program.

6.16 Technical Final

The trainee will field questions related to any/all aspects of their explosives training.

6.17 Competency Evaluation and Mock Trial

- 6.17.1 As the trainee progresses through explosives training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these "case" files completed prior to issuance of the final practical test.
- 6.17.2 Using one or all of the "cases" from 6.17.1, the trainee will undergo a series of "mini-mock trial" practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.
- 6.17.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

- 6.17.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

6.18 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

7 FIBERS**7.1 Introduction to Synthetic and Natural Fibers****7.1.1 Objectives**

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The history and use of synthetic and natural fibers;
- Fiber terminology;
- Manufacturing processes for fibers, fabrics and cordage;
- Chemical formulations and compositions of synthetic fibers; and
- The origin of common natural fibers.

7.1.2 Required Readings

- 7.1.2.1 MacArthur, Stanley and Hemmings, Fergusson J., "Fibres, Yarns and Fabrics: An Introduction to Production, Structure and Properties", Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor & Francis, 2017, pp. 1-61.
- 7.1.2.2 Rouen, "A Comparison & Evaluation of Techniques for Identification of Synthetic Fibers", *Journal of Forensic Sciences*, 15(3), 1970, pp. 410-432.

7.1.3 Questions

The trainee will provide written answers to the following questions:

- What is the difference between man-made fibers and synthetic fibers?
- Give a brief definition of the chemical composition of the following generic fiber classes:
 - Acetate
 - Triacetate
 - Acrylic
 - Modacrylic
 - Polyamide:
 - Aramid
 - Nylon 6
 - Nylon 6.6
 - Olefin
 - Polyester
 - Rayon
 - Viscose
 - Lyocell
 - Spandex
 - Polyolefins
 - Chlorofibers
 - Fluorofibers
- Discuss, in general, synthetic fiber manufacturing processes.
- Give brief definitions for the following terms:
 - Filament
 - Yarn
 - Tow
 - Staple
 - Wet spinning
 - Dry spinning

- Melt spinning
- Name three types of weave patterns.
- Describe the difference between a dye and a pigment.
- Name three categories of natural fibers and discuss each category.
- What are the most common plant fibers encountered in casework?
- What are the two most common animal fibers encountered in casework?

7.1.4 Evaluation

- 7.1.4.1 The trainer will review the written answers to the questions with the trainee.
- 7.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.1.4.3 The trainee will be quizzed on the subject matter.

7.2 Recognition, Collection, Packaging and Controls

7.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe to an investigator the proper way to collect fiber evidence;
- Recommend proper packaging for fiber evidence; and,
- Detail the proper controls that are to be taken and why.

7.2.2 Required Readings

- 7.2.2.1 Biermann, Thomas W., “Fibre Finder Systems”, Robertson, J. and Grieve, M., Forensic Examination of Fibres, 2nd ed., Taylor & Francis, 1999, pp. 135-152.
- 7.2.2.2 Robertson, J. and Roux, C., “From Crime Scene to Laboratory”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 99-140.
- 7.2.2.3 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide.

7.2.3 Questions

The trainee will provide written answers to the following questions:

- Describe three ways of collecting foreign fibers from clothing.
- Describe the advantages and disadvantages of each the three techniques.
- What type of textile material has good fiber shedding characteristics?
- What type of textile material has good fiber retention properties?
- Why are control fiber samples important?
- How is evidence handled in terms of contamination prevention?

7.2.4 Practical Exercises

- 7.2.4.1 Demonstrate the druggist or paper fold to the trainer.
- 7.2.4.2 Demonstrate how you would use post-it-notes to collect loose fibers.

- 7.2.4.3 Explain to the trainer the information given to an officer over the phone if asked what evidence should be collected in an abduction case where the victim was transported in the suspect's car.
- 7.2.4.4 Explain to the trainer the information given to an officer regarding evidence to be collected in a rape case where there was contact between the victim and suspect.
- 7.2.4.5 Explain to the trainer the information given to an officer regarding evidence to be collected in a breaking and entering case where loose fibers can be seen on the edges of the broken window.

7.2.5 Evaluation

- 7.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.2.5.3 Review of practical exercises.

7.3 Stereomicroscopic Evaluation of Fibers (and Fabric)

7.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Use a stereomicroscope properly;
- Work with extremely small samples;
- Identify fibers as natural fibers versus synthetic fibers;
- Discern colors accurately, including pastels;
- Discern unique features and/or surface characteristics;
- Determine the twist of yarns;
- Discern blends of fibers in yarns;
- Recognize and recover fibers from debris, clothing and from tools;
- Describe the weave and knit patterns of a textile/fabric; and,
- Make cross-sections of fibers.

7.3.2 Required Readings

- 7.3.2.1 Palenik, S.J., "Instruments for Forensic Fibre microscopy", Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp. 148.
- 7.3.2.2 MacArthur, Stanley and Hemmings, Fergusson J., "Fibres, Yarns and Fabrics: An Introduction to Production, Structure and Properties", Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 39-61.
- 7.3.2.3 Gaudette, B., "The Forensic Aspect of Textile Fiber Examination", Saferstein, R., ed., Forensic Science Handbook, Vol. II, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1988, pp. 209-214 and 239-241.
- 7.3.2.4 Palenik, S.J., "Microscopic Examination of Fibres", Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 148.

- 7.3.2.5 Palenik, S. and Fitzsimons, Forensic Microscopy, “Fiber Cross-Sections: Part II”, *Microscope*, 1990 (38) pp. 313-320.
- 7.3.2.6 Robertson, J. and Roux, C. “4.4: Protocols for Fibre Examination and Initial Preparation”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 119-140.
- 7.3.2.7 Saferstein, R., “The Microscope,” Criminalistics: An Introduction to Forensic Science, 8th ed., Pearson Prentice Hall, New Jersey, 2004, pp. 169-176.
- 7.3.2.8 SWGMAT, “Forensic Fiber Examination Guidelines,” *Forensic Science Communications*, 1(1), 1999, chapter 7: Fabrics and Cordage.
- 7.3.2.9 Wiggins, K.G., “Ropes and Cordage,” Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor & Francis, 2017, pp. 89-98.
- 7.3.2.10 Koch, Sandra, and Nehse, Kornelia, “Fibers”, Desiderio, V. J., Taylor, C. E., and Daéid N. N., eds., Handbook of Trace Evidence Analysis, Wiley, 2021, pp 367-368.

7.3.3 Questions

The trainee will provide written answers to the following questions:

- What characteristics can be observed from a microscopic examination of synthetic fibers?
- How does one compare the colors of known and questioned fibers under the stereomicroscope?
- What influence does fiber diameter have at this point in the examination?
- What other fiber characteristics can play a major role in the stereomicroscopic “search” process?
- How does one ensure that the fiber samples will not be contaminated?
- What characteristics cause fibers to be eliminated at this stage?

7.3.4 Practical Exercises

- 7.3.4.1 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for fiber analysis.
- 7.3.4.2 At the stereomicroscope, the trainer will demonstrate/discuss color, luster, diameter (coarse/medium/fine) and any other applicable observed characteristics of different fiber samples (animal and plant). Demonstration by the trainer will include manipulation of single fibers to remove and mount them in an applicable mounting medium.
- 7.3.4.3 The trainer will provide several fiber samples that are large enough to allow the trainee to familiarize themselves with the manipulation of fibers using the stereomicroscope.
- 7.3.4.4 The trainee will use the 7.3.4.3 fibers and make cross-sections using different techniques.
- 7.3.4.5 The trainer will provide a “debris” sample with a known number of fibers. The trainee will search the debris and report the number and color of the fibers recovered.
- 7.3.4.6 The trainer will provide the trainee with an article of clothing and with a tool or other rigid object, like a piece of glass or plastic, containing foreign fibers for the trainee to recover the fibers.
- 7.3.4.7 The trainer will provide a variety of fibers and mounting media to the trainee. The trainee will mount the same fibers in each of the mounting media. The trainee should be able to discuss the advantages and disadvantages of the different mounting media.
- 7.3.4.8 The trainee will identify and diagram/draw different weave and knit patterns.

7.3.4.9 The trainee will be given a variety of cordage to examine. The trainee will determine the diameter, construction and twist of the cordage.

7.3.4.10 The trainee will successfully complete the Fracture Match Section of the Trace Evidence Training Manual.

7.3.5 Evaluation

7.3.5.1 The trainer will review the written answers to the questions with the trainee.

7.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

7.3.5.3 Review of practical exercises.

7.4 Microsolubility and Microchemical Testing

7.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Safely prepare microchemical test reagents;
- Correctly describe the color reactions and/or the solubility of fibers when subjected to different chemicals and reagents; and,
- Correctly identify the generic class of a fiber through microsolubility tests.

7.4.2 Required Readings

7.4.2.1 The Textile Institute, Identification of Textile Materials, 7th ed., Manchester, England: The Textile Institute, 1985, pp. 28-29 and 181-187.

7.4.3 Questions

The trainee will provide written answers to the following questions:

- What is the difference between a microsolubility test and a microchemical test?
- What does it mean when a certain fiber dissolves in conc. HCl, but not in 15% HCl?
- What is LeRosen used for in microchemical testing of fibers?
- Should two fibers that have different reactions to any chemical or reagent be eliminated or should more testing be done on the fibers?

7.4.4 Practical Exercises

7.4.4.1 The trainee will assemble the necessary reagents. The trainee will become familiar with the requirements and will perform appropriate QC checks.

7.4.4.2 The trainer will provide the trainee with known samples of fibers including: acetate, acrylic, modacrylic, nylon 6, nylon 6.6, nitril, olefin, polyester, rayon, and spandex. These knowns will be tested using acetone, chloroform, m-cresol, DMF, conc. HCl, conc. HNO₃, 75% H₂SO₄, LeRosen, 15% HCl, Acetonitrile and HFIP. The results will be recorded on the fiber microchemical worksheet.

7.4.4.3 The trainer will provide the trainee with known samples of dyed natural fibers including those visually close in color. These knowns will be tested using 75% Sulfuric Acid, concentrated

nitric acid, concentrated hydrochloric acid and LeRosen. The results will be recorded on the fiber microchemical worksheet.

- 7.4.4.4 The trainer will provide the trainee with a “K” and a “Q” fiber sample. The trainee will examine the fibers and characterize as to colors, solubility, microchemical reactions class and determine whether there are meaningful differences. Record results on fiber microchemical worksheets.

7.4.5 Evaluation

- 7.4.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.4.5.3 Review of practical exercises.

7.5 Polarized Light Microscopy (PLM)

7.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Use the polarized light microscope properly;
- Communicate the principle of polarized light;
- Set up Köhler illumination on the polarized light microscope;
- Determine the optical properties of fibers;
- Determine the “optical cross-section” of fibers;
- Recognize unique features and/or characteristics in fibers;
- Determine whether a fiber is pigmented or dyed;
- Determine the diameter of a fiber; and,
- Observe and identify bicomponent fibers.

7.5.2 Required Readings

- 7.5.2.1 Introduction to Hairs and Fibers Training Course Materials, F.B.I., March 2007 (only fiber sections).
- 7.5.2.2 McCrone, Walter C., et al., Polarized Light Microscopy, McCrone Research Institute, Chicago, IL, 1987, sections 1-5, 7, and 9.
- 7.5.2.3 Murphy, Douglas B., Fundamentals of Light Microscopy and Electronic Imaging, Wiley-Liss Inc., New York, NY, 2001, pp. 117-147.
- 7.5.2.4 Palenik, Samuel J., “Microscopic Examination of Fibres”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 146-176.
- 7.5.2.5 Saferstein, R., “The Microscope,” Criminalistics: An Introduction to Forensic Science, 8th ed., Pearson Prentice Hall, New Jersey, 2004, pp. 176-178.

7.5.3 Questions

The trainee will provide written answers to the following questions:

- Define polarized light.
- Describe the steps of setting up Köhler illumination.
- How are interference colors produced?
- Define refractive index.
- Define birefringence.
- Define extinction.
- Define sign of elongation.
- Define pleochroism/dichroism.
- Define compensation.
- How and why are fibers delustered?
- Can the generic class of a fiber be identified with PLM?
- What are bi-component fibers? How are some of them manufactured?

7.5.4 Practical Exercises

- 7.5.4.1 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.
- 7.5.4.2 The trainer will demonstrate to the trainee setting up Köhler illumination on the polarized light microscope, which will include centering the objectives.
- 7.5.4.3 After a period of practice, the trainee will demonstrate setting up Köhler illumination on the polarized light microscope, which will include centering the objectives.
- 7.5.4.4 The trainer will issue the trainee with a known set of fibers, including acetate, triacetate, acrylic, modacrylic, nylon 6, nylon 6.6, olefin, polyester, rayon, viscose, lyocell, spandex, and polyolefin. The trainee will determine the optical and physical properties of the fibers and record the results on the fiber worksheet.
- 7.5.4.5 The trainer will issue the trainee with a set of unknown fibers. The trainee will determine the physical and optical properties of each fiber and identify the fibers according to generic class.
- 7.5.4.6 The trainer will issue the trainee with a set of fibers with different cross-sectional shapes. The trainee will attempt to identify the cross-sectional shape of each fiber without making cross sections.

7.5.5 Evaluation

- 7.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.5.5.3 Review of practical exercises.

7.6 Fluorescence

7.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Operate the fluorescence microscope properly;
- Discern and describe fluorescence colors accurately;
- Communicate the principles of fluorescence microscopy; and,
- Communicate the difference between the fluorescence cubes.

7.6.2 Required Readings

- 7.6.2.1 Rost, F.W.D., Fluorescence Microscopy, Vol. 1, Cambridge University Press, Great Britain, 1996, pp. 1-63 and 104-128.

7.6.3 Questions

The trainee will provide written answers to the following questions:

- What is fluorescence?
- Is fluorescence microscopy a sensible technique to use in synthetic and natural fiber comparisons?
- Is fluorescence microscopy suitable for undyed natural fibers?
- Is a difference in fluorescent properties a basis for elimination of two fiber samples?
- What are the most suitable mounting media for fluorescence microscopy and why?

7.6.4 Practical Exercises

- 7.6.4.1 The trainer will provide the trainee with a minimum of ten fibers for the determination of their fluorescent properties. The fibers should include dyed and non-dyed samples, as well as animal and plant fibers. All four fluorescent cubes will be used and the results recorded using the fluorescence worksheet.
- 7.6.4.2 The trainer will issue the trainee a minimum of five sets of K & Q fiber samples for comparison of their fluorescence properties. All four fluorescent cubes will be used and the results recorded using the fluorescence worksheet.
- 7.6.4.3 The trainee will mount fibers from the same source in Xylene substitute, glycerin, Permout, Pro-Texx and Norland Optical adhesive. All four fluorescent cubes will be used and the results recorded using the fluorescence worksheet.

7.6.5 Evaluation

- 7.6.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.6.5.3 Review of practical exercises.

7.7 Microspectrophotometry (MSP)

7.7.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Communicate the principles of microspectrophotometry;
- Operate the microspectrophotometer in transmittance and reflectance modes;
- Obtain transmittance spectra of fibers in the visible region;
- Discuss the effect of fiber cross-section on the reproducibility of the results; and
- Discuss the effect of focus on the reproducibility of the results.

7.7.2 Required Readings

- 7.7.2.1 Gaudette, Barry D., “The Forensic Aspects of Textile Fiber Examination”, Saferstein, R., Forensic Science Handbook, Vol. 2, Prentice Hall, Englewood Cliffs, NJ, 1988, pp. 245-248.
- 7.7.2.2 Biermann, T.W. and Wiggins, K.G., “Color Analysis of Fibres”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 180-242.
- 7.7.2.3 Grieve M., Dunlop J., Haddock P., “An Investigation of Known Blue, Red, and Black Dyes Used in the Coloration of Cotton Fibers”, *Journal of Forensic Sciences*, 35 (2), 1990, pp. 301-315.
- 7.7.2.4 Palenik, Christopher S., Beckert, Jason C., Palenik, Skip, “Microspectrophotometry of Fibers: Advances in Analysis and Interpretation”, December 2016, <https://www.ncjrs.gov/pdffiles1/nij/grants/250437.pdf>
- 7.7.2.5 Killinger, Kialani, “Discrimination of Colorless Fibers by UV-VIS Microspectrophotometry and Microspectrofluorimetry”, Virginia Commonwealth University Thesis, March 2020.

7.7.3 Questions

The trainee will provide written answers to the following questions:

- Define microspectrophotometry.
- Define metamerism.
- What is necessary to perform MSP in the UV region? Can the CRAIC 2030 PV instrument do this?
- Is a difference in spectral curves a basis for elimination of K and Q fibers?
- Describe how to overcome heterogeneity in a sample when analyzing via MSP?
- How many sample scans should be performed on a single fiber?
- Are lighter colors or darker colors better for MSP purposes?
- Is MSP a good technique for undyed synthetic fibers? for undyed natural fibers?
- Discuss the expected results from near colorless fibers and near opaque fibers.
- How can weathering affect a fiber’s color?
- Would MSP ever be done to compare a pink fiber to a red fiber? Why or why not?
- What is data stitching and why is it performed?
- What is a stitching artifact and how can it be distinguished from a spectral feature?

7.7.4 Practical Exercises

- 7.7.4.1 The trainee will successfully complete the Microspectrophotometry Section of the Trace Evidence Training Manual.
- 7.7.4.2 The trainer will issue the trainee with a set of fibers, varying in color. The trainee will obtain 10 transmittance spectra along the length of each fiber. The trainee will evaluate the reproducibility of the spectra and give reasons for possible differences.
- 7.7.4.3 The trainer will issue the trainee sets of fibers, to include a wide variety of colors. (Example: 3X red fibers, 3X yellow fibers, 3X green fibers, 3X blue fibers....) The trainee will obtain 10 spectra along the length of each fiber. The trainee will evaluate the spectra and notice the different spectral curves of the different fibers. Plotting the mean spectra from 10 readings on each fiber will greatly assist the trainee in evaluating the spectra from different fibers.
- 7.7.4.4 The trainer will issue the trainee with a set of fibers with a range of cross-sectional shapes. The trainee will obtain 10 spectra along the length of each fiber and evaluate the spectra.

7.7.5 Evaluation

- 7.7.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.7.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.7.5.3 Review of practical exercises.

7.8 Fourier Transform Infrared Spectrophotometry (FTIR)

7.8.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Operate the FTIR properly;
- Correctly identify the generic class of a fiber by its IR spectra;
- Obtain consistent spectral data from different samples from the same source;
- Prepare fiber samples using the micro compression cell with diamond windows;
- Interpret spectral data from different fibers in order to reach a conclusion whether the fibers have a meaningful difference; and,
- Communicate the limitations of FTIR.

7.8.2 Required Readings

- 7.8.2.1 Grieve, M.C., “Another look at the classification of acrylic fibres using FTIR microscopy”, *Science & Justice*, 1995, 35, pp. 179-190.
- 7.8.2.2 Kirkbride, K.P., “Infrared Microspectroscopy of Fibres” Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 245-286.
- 7.8.2.3 Tungol, M. W., et al., “Forensic Examination of Synthetic Textile Fibers by Microscopic Infrared Spectrometry”, Humecki, H., ed. Practical Guide to Infrared Microspectroscopy, Marcel Dekker, 1995, pp. 245–285.

7.8.3 Questions

The trainee will provide written answers to the following questions:

- Describe how differences in the pressure applied to the microcompression cell with diamond windows can affect the spectral data.
- Can modacrylic and acrylic fibers be differentiated solely by using FTIR?
- Define generic class and subgeneric class.
- What percentage of a copolymer needs to be present to determine its presence?
- In the characterization of what type of contaminants might FTIR be useful?

7.8.4 Practical Exercises

- 7.8.4.1 The trainee will successfully complete the FTIR section of the Trace Evidence Training Manual.
- 7.8.4.2 The trainer will provide the trainee with a set of known fiber samples including acetate, triacetate, acrylic, modacrylic, nylon 6, nylon 6.6, olefin, polyester, rayon, viscose, lyocell, spandex, and polyolefin. The trainee will mount these fibers using the microcompression cell with diamond windows and obtain IR spectra of each fiber type. The trainee will then compare the obtained spectra to known spectra in the IR libraries.

- 7.8.4.3 The trainee will be given a set of unknown fibers for which they will obtain IR spectra and attempt to identify the fibers by their generic class and, if possible, subclass.

7.8.5 Evaluation

- 7.8.5.1 The trainer will review the written answers to the questions with the trainee.
- 7.8.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 7.8.5.3 Review of practical exercises.

7.9 Natural Fibers

7.9.1 Stereomicroscopic Evaluation of Fibers (and Fabric)

7.9.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Identify fibers as natural fibers versus synthetic fibers;
- Discern unique features (i.e., scale patterns, root shapes, spiral elements);
- Determine the twist of yarns;
- Discern blends of fibers in yarns;
- Make cross-sections of fibers;
- Perform the dry twist test; and,
- Prepare and view scale patterns.

7.9.1.2 Required Readings

- 7.9.1.2.1 Mauersberger, Herbert R., ed. Matthew's Textile Fibers: Their Physical, Microscopic, and Chemical Properties, 6th ed., John Wiley & Sons, Inc., New York, 1954, pp. 257-438.

7.9.1.3 Questions

The trainee will provide written answers to the following questions:

- What characteristics can be observed from a microscopic examination of natural fibers?
- What other fiber characteristics can play a major role in the stereomicroscopic "search" process?
- What characteristics cause fibers to be eliminated at this stage?
- What material can be used to make scale casts?

7.9.1.4 Practical Exercises

- 7.9.1.4.1 The trainer will provide several natural fiber samples that are large enough to allow the trainee to familiarize themselves with the manipulation of fibers using the stereomicroscope.
- 7.9.1.4.2 The trainer will provide many vegetable fiber samples and the trainee will make cross-sections using different techniques. Record observations with regards to distinguishing features.

7.9.1.4.3 The trainee will be provided with a minimum of six animal hair samples from which they will make scale casts. Record/sketch observations of the scale patterns under the stereomicroscope.

7.9.1.4.4 The trainer will demonstrate the dry twist test. The trainee will perform the dry twist test on a minimum of six plant fibers provided by the trainer. Record observations.

7.9.1.5 Evaluation

7.9.1.5.1 The trainer will review the written answers to the questions with the trainee.

7.9.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

7.9.1.5.3 Review of practical exercises.

7.9.2 Polarized Light Microscopy (PLM)

7.9.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Recognize unique features and/or characteristics in natural fibers;
- Identify most common plant fibers; and
- Identify animal hair fibers as such.

7.9.2.2 Required Readings

7.9.2.2.1 Wildman, A.B., The Identification of Animal Fibers; Wool Industries Research Association: Leeds, England, 1960.

7.9.2.2.2 Hicks, John, Microscopy of Hair, F.B.I., Issue 2, January 1977.

7.9.2.2.3 Introduction to Hairs and Fibers Training Course Materials, F.B.I., March 2007.

7.9.2.2.4 McCrone, Walter C., et al., Polarized Light Microscopy, McCrone Research Institute, Chicago, IL, 1987, sections 1-5, 7, and 9.

7.9.2.2.5 Palenik, S. J., "Microscopic Examination of Fibres", Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 146-176.

7.9.2.3 Questions

The trainee will provide a written answer to the following question:

- Can natural fibers be identified by PLM alone?

7.9.2.4 Practical Exercises

7.9.2.4.1 The trainer will issue the trainee a known set of natural plant fibers, including cotton, kapok, flax, jute, hemp, ramie, sisal, abaca and coir. The trainee will determine the physical and optical properties of these fibers and record the results on a fiber worksheet.

- 7.9.2.4.2 The trainer will issue the trainee a set of unknown natural plant fibers. The trainee will determine the physical and optical properties of each fiber and identify the fibers.
- 7.9.2.4.3 The trainer will issue the trainee a known set of natural animal fibers (hair and silk) including wool, cashmere, mohair, camel, alpaca, llama, vicuna, rabbit, horse, silk (Bombay Mon) and silk (Tussah). The trainee will determine the physical and optical properties of the fibers. The trainee will record the results on the fiber worksheet.
- 7.9.2.4.4 The trainer will issue the trainee a set of unknown animal hair fibers. The trainee will determine the physical and optical properties of each animal hair fiber and identify the animal hair fibers.
- 7.9.2.5 Evaluation
 - 7.9.2.5.1 The trainer will review the written answers to the questions with the trainee.
 - 7.9.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
 - 7.9.2.5.3 Review of practical exercises.

7.10 Supervised Work-Along

- 7.10.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.
- 7.10.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.
- 7.10.3 The trainee shall work at least ten forensic cases as a technician for a qualified fiber examiner. The trainer should ensure as much variety in the work-along as is practicable.

7.11 Forensic Significance of Fibers

The trainer and the trainee will discuss the interpretation of fiber evidence and its relevance and weight in reports and in testimony. Discussions will include probabilities versus possibilities.

- 7.11.1 Required Readings
 - 7.11.1.1 Champod, Christophe and Taroni, Franco, “10.3 A Probabilistic Approach to the Evaluation of Fibre Evidence”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 395-423.
 - 7.11.1.2 Grieve, Michael, “10.1 Factors Influencing Interpretation”, Robertson J., Roux C., and Wiggins K.G., eds., Forensic Examination of Fibres, 3rd ed., Taylor and Francis, 2017, pp 346-371.
 - 7.11.1.3 Pounds, C.A. and Smalldon, K.W., “The Transfer of Fibres Between Clothing Materials During Simulated Contacts and Their Persistence During Wear: Part I – Fibre Transference”, *Journal of Forensic Sciences*, 1975, 15, pp. 17-27.

- 7.11.1.4 Pounds, C.A. and Smalldon, K.W., “The Transfer of Fibres Between Clothing Materials During Simulated Contacts and Their Persistence During Wear: Part II – Fibre Persistence”, *Journal of Forensic Sciences*, 1975,15, pp. 29-36.
- 7.11.1.5 Pounds, C.A. and Smalldon, K.W., “The Transfer of Fibres Between Clothing Materials During Simulated Contacts and Their Persistence During Wear: Part III – A Preliminary Investigation of the Mechanisms Involved”, *Journal of Forensic Sciences*, 1975, 15, pp. 197-207.
- 7.11.1.6 Webb-Salter, Martin and Wiggins, Kenneth G., “10.2 Aids to Interpretation”, Robertson J., Roux C., and Wiggins K.G., eds., *Forensic Examination of Fibres*, 3rd ed., Taylor and Francis, 2017, pp 375-392.

7.12 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

7.13 Fiber Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified fiber examiners, the Chemistry Program Manager, and the Section/Group Supervisor.

The presentation may cover either: the forensic examination of fibers or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic fiber community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee’s training program.

7.14 Technical Final

The trainee will field questions related to any/all aspects of their fiber training.

7.15 Competency Evaluation and Mock Trial

- 7.15.1 As the trainee progresses through fiber training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these “case” files completed prior to issuance of the final practical test.
- 7.15.2 Using one or all of the “cases” from 7.15.1, the trainee will undergo a series of “mini-mock trial” practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.

- 7.15.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

- 7.15.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

7.16 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

8 FIRE DEBRIS

8.1 Introduction to the Refinery Process and the Chemical Composition of Petroleum Products

8.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- History of petroleum products;
- Composition of various petroleum fractions; and,
- Manufacturing processes of petroleum distillates and the end use of products.

8.1.2 Required Readings

- 8.1.2.1 Dehaan, J. D., Kirk's Fire Investigation, 4th Ed., Upper Saddle River, NJ, Prentice-Hall, Inc., 1997, pp. 7-17.
- 8.1.2.2 Dolan, J. A., "Refinery Operations for the Fire Debris Chemist," Workshop notes from MAAFS, April 24, 2001.
- 8.1.2.3 Fultz, M. L. and Dehaan, J. D., "Gas Chromatography in arson and explosives analysis", Gas Chromatography in Forensic Science, Tebbett, Ian, ed., Chapter 5, Ellis Horwood Ltd., Chichester, UK, 1992, pp. 109-147.
- 8.1.2.4 Mann, D. C., "Comparison of Automotive Gasolines Using Capillary Gas Chromatography I: Comparison Methodology," *Journal of Forensic Sciences*, Vol. 32, No. 3, May 1987, pp. 606-615.
- 8.1.2.5 Mann, D. C., "Comparison of Automotive Gasolines Using Capillary Gas Chromatography II: Limitations of Automotive Gasoline Comparisons in Casework," *Journal of Forensic Sciences*, Vol. 32, No. 3, May 1987, pp. 616-628.
- 8.1.2.6 Speight, J. G., The Chemistry and Technology of Petroleum, 5th edition, Boca Raton, FL, CRC Press, 2014.
- 8.1.2.7 Stauffer, E., Dolan, J., and Newman, R., Fire Debris Analysis, Burlington, MA, Elsevier, Inc., 2008, pp. 199-233.

8.1.3 Questions

The trainee will provide written answers to the following questions:

- Briefly explain how petroleum crude oil is formed.
- Does geographic origin affect the final products? How?
- What is the general composition of crude oil and what are some variations?
- What are physical separation processes and how do they work?
- What is distillation?
- What distillation fractions are generally used? What types of products are produced by each fraction?
- What are the physical and chemical properties of these distillation fractions?
- What are the chemical conversion processes? What does each chemical conversion process do and how are they performed?
- What is blending?
- What are additives?
- How is gasoline made?

- What types of hydrocarbons are present in petroleum products?
- Define octane level and describe its impact on gasoline.
- Is it possible to determine the brand name of a gasoline sample? Common source?
- Briefly describe how an internal combustion engine operates and how the composition of gasoline is optimized as a fuel for use in an internal combustion engine.
- Why is ethanol added to gasoline? How much is added?
- What are some other additives used with gasoline?
- What does cetane level refer to?
- What type of engine uses diesel fuel as the fuel? Briefly describe how this engine functions.
- How are the engines that burn gasoline and diesel fuel different from one another?
- What happens if the incorrect fuel is used in each of the above engines?
- What are pristane and phytane? Pristane and phytane can be found in what petroleum product(s)?
- Define paraffinic.
- Why are dyes used in some fuels (i.e. heating fuels vs. transportation fuels)? Can the dye be used to distinguish between different sources?
- For each of the following, provide the definition and properties, draw a basic structure, and list some examples (including their structure):
 - Alkanes
 - Aromatics
 - Cycloalkanes
 - Alkenes
 - Alkynes
 - Indanes/indenes
 - Oxygenates (alcohols, ketones, ethers)
- For the examples you listed above, determine their molecular weights.
- What is the IUPAC nomenclature used for aliphatic hydrocarbons?
- Describe how the number of carbons is related to boiling point and flash point of a homologous series of alkanes.
- Describe the stability of aromatic compounds in terms of their molecular structure.
- What are the general nomenclature rules for naming aromatic compounds? Include compounds with one and more than one functional group attached to the aromatic ring.
- What are polynuclear aromatic compounds?

8.1.4 Evaluation

8.1.4.1 The trainer will review the written answers to the questions with the trainee.

8.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

8.1.4.3 The trainee will be quizzed on the subject matter.

8.2 Introduction to Fire and Arson Investigation

8.2.1 Objectives

Through completion of this module the trainee will develop the theoretical knowledge to be conversant in:

- Arson and accelerant terminology;
- General knowledge of fire scene investigations; and,
- Proper techniques in recovery, collection, preservation and packaging of fire debris evidence.

8.2.2 Required Readings

- 8.2.2.1 Bowen, J. E., “Phenomenon of Spontaneous Ignition is Still Misunderstood by Some,” Fire Engineering, May 1982, pp. 23-24.
- 8.2.2.2 Dehaan, J. D., Kirk’s Fire Investigation, 4th Ed., Upper Saddle River, NJ, Prentice-Hall, Inc., 1997, pp. 1-6, 18-284, 315-327, 394-418.
- 8.2.2.3 Hine, G. A., “Fire Scene Investigation: An Introduction for Chemists,” Analysis and Interpretation of Fire Scene Evidence, Almirall, J., and Furton, K., eds., CRC Press, Florida, 2004, pp. 33-74.
- 8.2.2.4 Mann, D. C., “In Search of the Perfect Container for Fire Debris Evidence,” Fire & Arson Investigator, April 2000, pp. 21-25.
- 8.2.2.5 NFPA 921, Guide for Fire & Explosion Investigations, National Fire Protection Association, Massachusetts, 2014, Chapters 5, 6 and 16.
- 8.2.2.6 Stauffer, E., Dolan, J., and Newman, R., Fire Debris Analysis, Burlington, MA, Elsevier, Inc., 2008, pp. 85-195, 533-534.
- 8.2.2.7 Virginia Department of Forensic Science, Evidence Handling and Laboratory Capabilities Guide, Trace Evidence: Fire Debris.

8.2.3 Questions

The trainee will provide written answers to the following questions:

- Define the following terms:
 - Arson
 - Autoignition
 - Backdraft
 - Combustible
 - Flammable
 - Conduction
 - Convection
 - Fire
 - Fire Load
 - Flame Point
 - Flash point
 - Overhaul
 - Pyrolysis
 - Point of Origin
 - Trailers
 - Vapor density
 - Vapor pressure
 - Volatile
- What is an ignitable liquid?
- What is an accelerant?
- What is a petroleum product?
- Are all ignitable liquids accelerants?
- Are all ignitable liquids petroleum products?
- Explain the four essential components necessary for a fire to occur (fire tetrahedron). What happens if one of these components is removed?
- What is combustion?
- What is the difference between smoldering and flaming combustion?
- Compare the three types of heat transfer – conduction, convection, and radiation.
- What are some possible causes of an accidental fire?

- What burns in a fire?
- What are the methods to determine flash point? What are the limiting factors?
- What is spontaneous ignition and how does it occur? What types of debris materials are commonly encountered when spontaneous ignition occurs?
- What are some considerations that should be made prior to the collection of evidence?
- What are recommended areas to collect fire debris evidence from at a fire scene? Is carpet or tile flooring a better sample when collecting evidence for ignitable liquid testing? Why?
- What are the advantages and disadvantages to packaging evidence in; metal cans, standard plastic bags, plastic jars, PET cans, nylon bags, paper and glass jars?
- What are the advantages and disadvantages of packaging evidence in unlined metal cans, gray epoxy lined metal cans, and gold epoxy lined metal cans?
- What is the difference between a comparison sample and a control sample and what advantages do each of these samples provide to the laboratory analyst?
- When should comparison and control samples each be collected?
- What is the purpose of a control can?
- What packaging materials are preferred by DFS and why?
- What is the recommended maximum capacity for filling a can with fire debris evidence? Why? What are the disadvantages to overpacking a can?
- How should liquids be packaged?
- What is contamination and how can it occur at the fire scene? What can be done to avoid contamination of evidence at a fire scene?

8.2.4 Evaluation

- 8.2.4.1 The trainer will review the written answers to the questions with the trainee.
- 8.2.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 8.2.4.3 The trainee will be quizzed on the subject matter.

8.3 Initiating Devices

8.3.1 Objectives

Through completion of this module the trainee will develop the theoretical knowledge to be conversant in:

- Pyrotechnic/incendiary devices and initiating reactions (IID's – Improvised Incendiary Devices); and,
- General (very basic) knowledge of explosives and their possible relationships to fire and arson investigations.

8.3.2 Required Readings

- 8.3.2.1 Dehaan, J. D., Kirk's Fire Investigation, 4th Ed., Upper Saddle River, NJ, Prentice-Hall, Inc., 1997, pp. 285-335.

8.3.3 Questions

The trainee will provide written answers to the following questions:

- What are some common devices used for starting fires?
- Where can the materials for the devices be obtained?
- What is a Molotov cocktail?
- How should evidence from a Molotov cocktail be packaged?

- What other exams should be considered when examining Molotov cocktail evidence?
- What is napalm and how is it made?
- What is a hypergolic reaction?
- What are some examples of hypergolic reactions?
- Define incendiary device.
- Define explosive device.
- Define deflagration.
- Define detonation.
- Which metals are highly reactive (flammable)?
- What are the components of matches?
- What is the most widely used initiating device in arson?

8.3.4 Evaluation

- 8.3.4.1 The trainer will review the written answers to the questions with the trainee.
- 8.3.4.2 The trainer and trainee will review and discuss the pertinent points of each of the required readings.
- 8.3.4.3 The trainee will be quizzed on the subject matter.

8.4 Instrumental Methods: Gas Chromatography – Mass Spectrometry

8.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Understand and describe the historical use of gas chromatography for fire debris analysis;
- Understand and describe gas chromatography-mass spectrometry (GC-MS);
- Describe and demonstrate the application of GC-MS to the identification of petroleum products; and,
- Understand and explain ion-profiling and its application to fire debris analysis.

8.4.2 Required Readings

- 8.4.2.1 Bertch, W., “Analysis of Accelerants in Fire Debris – Data Interpretation,” *Forensic Science Review*, Vol. 9, No. 1, June 1997, pp. 1-22.
- 8.4.2.2 Fultz, M. L. and Dehaan, J. D., “Gas Chromatography in arson and explosives analysis”, Gas Chromatography in Forensic Science, Tebbett, Ian, ed., Chapter 5, Ellis Horwood Ltd., Chichester, UK, 1992, pp. 117-145.
- 8.4.2.3 Rood, D., *A Practical Guide to the Care, Maintenance, and Troubleshooting of Capillary Gas Chromatography Systems*, New York, NY, Wiley-VCH, 1999.
- 8.4.2.4 Stauffer, E., Dolan, J., and Newman, R., Fire Debris Analysis, Burlington, MA, Elsevier, Inc., 2008, pp. 235-376.
- 8.4.2.5 ASTM E1618-149 “Standard Test Method for Ignitable Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography-Mass Spectrometry”.
- 8.4.2.6 Dolan, J. A., “Analytical Methods for the Detection and Characterization of Ignitable Liquid Residues from Fire Debris,” *Analysis and Interpretation of Fire Scene Evidence*, Almirall, J., and Furton, K., eds., CRC Press, Florida, 2004, pp. 142-157.

- 8.4.2.7 Koussiafes, P. M., "The Interpretation of Data Generated from Fire Debris Examination: Report Writing and Testimony," *Analysis and Interpretation of Fire Scene Evidence*, Almirall, J., and Furton, K., eds., CRC Press, Florida, 2004, pp. 193-227.
- 8.4.2.8 Nowicki, J., "An Accelerant Classification Scheme Based on Analysis by Gas Chromatography/Mass Spectrometry (GC-MS)," *Journal of Forensic Sciences*, Vol. 35, No. 5, Sept. 1990, pp. 1064-1086.
- 8.4.2.9 Wallace, J. R., "GC/MS Data from Fire Debris Samples: Interpretation and Applications" *Journal of Forensic Sciences*, Vol. 44, No. 5, 1999, pp. 996-1012.
- 8.4.2.10 Smith, R.M., "Mass Chromatographic Analysis of Arson Accelerants", *Journal of Forensic Sciences*, Vol. 28, No. 2, April 1983, pp. 318-329.

8.4.3 Questions

The trainee will provide written answers to the following questions:

- What are the GC-MS chromatographic conditions that are used by DFS for the analysis of fire debris?
- Why does the GC-FID have different chromatographic conditions?
- Why is the selected stationary phase a good choice for petroleum products?
- Describe how to determine if the septum has been cored during a headspace injection and the effect this could have on the analysis.
- Why are the headspace conditions different from the fire debris conditions?
- In what order do nonpolar compounds separate on a nonpolar column?
- Would you expect polar compounds to be retained on a nonpolar column?
- What is a TIC and why is it useful in fire debris analysis?
- What is ion profiling?
- How is ion profiling useful in the identification of ignitable liquids and classes of ignitable liquids? What ions are used by DFS and why? Include their structures.
- Describe the difference between ion profiling and selected ion monitoring.
- What are the ion profiles used for ignitable liquids? Why are they chosen?
- What are the predominant ion profiles for each class of ignitable liquids?
- Can mixtures of different ignitable liquids be resolved using ion profiles? Explain.
- Define weathered/reduced/evaporated.

8.4.4 Practical Exercises

- 8.4.4.1 The trainee will successfully complete the Gas Chromatography and Mass Spectrometry Sections of the Trace Evidence Training Manual.
- 8.4.4.2 The trainee will inject known ignitable liquids; one from each class as a minimum. The data will be displayed using the standard ion profiling macros. The trainee will evaluate the overall patterns of each class, to include carbon ranges, and the expected ion profiles.

8.4.5 Evaluation

- 8.4.5.1 The trainer will review written answers to the questions with the trainee.
- 8.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 8.4.5.3 Review of practical exercises to include discussion regarding major pattern differences and overlap.

8.4.5.4 The trainee will be quizzed on the subject matter.

8.5 Evaluation and Characterization of Debris

8.5.1 Objective

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to understand the effect that the substrate/debris can have on the identification of petroleum products.

8.5.2 Required Readings

- 8.5.2.1 Akmeemana, A., Williams, M.R., and Sigman, M., “Major chemical compounds in the Ignitable Liquids Reference Collection and Substrate Databases,” *Forensic Chemistry*, Vol 5, 2012, pp. 91-108.
- 8.5.2.2 Almirall, Jose and Furton, Kenneth, “Characterization of background and pyrolysis products that may interfere with the forensic analysis of fire debris,” *Journal of Analytical and Applied Pyrolysis*, Vol. 71, Issue 1, March 2004, pp. 51-67.
- 8.5.2.3 Baernocopf, J., “Prevalence of ignitable liquids in clothing with printing,” *Forensic Science International*, 312, (2020).
- 8.5.2.4 Cherry, C., “Arsonist’s Shoes: Clue or Confusion?,” Illinois State Police, copy of presentation.
- 8.5.2.5 Furton, K. G., and Harper, R. J., “Detection of Ignitable Liquid Residues in Fire Scenes: Accelerant Detection Canine (ADC) Teams and Other Field Tests,” Analysis and Interpretation of Fire Scene Evidence, Almirall, J., and Furton, K., eds., CRC Press, Florida, 2004, pp. 75-94.
- 8.5.2.6 Kurz, M. E., et al., “Effect of Background Interference on Accelerant Detection by Canines,” *Journal of Forensic Sciences*, Vol. 41, No. 5, 1996, pp. 868-873.
- 8.5.2.7 Lentini, J. J, et al., “The Petroleum-Laced Background,” *Journal of Forensic Sciences*, Vol. 45, No. 5, 2000, pp. 968-989.
- 8.5.2.8 Stauffer, E., Dolan, J., and Newman, R., Fire Debris Analysis, Burlington, MA, Elsevier, Inc., 2008, pp. 138-151, 295-354, 441-467.
- 8.5.2.9 Tranthim-Fryer, D. J. and DeHaan, J.D., “Canine accelerant detectors and problems with carpet pyrolysis products,” *Science & Justice*, Vol. 37, 1997, pp. 39-46.

8.5.3 Questions

The trainee will provide written answers to the following questions:

- What are some types of material that can give a “petroleum laced background”?
- Why can soil be problematic? What steps can be taken to minimize these effects?
- Why should the soles of shoes be avoided as samples, if possible?
- What types of petroleum products may be encountered in inked paper products?
- What types of petroleum products may be encountered in leather goods?
- What are some pyrolysis products that may be encountered when extracting plastic and/or synthetic materials?
- What are some pyrolysis products that may be encountered when extracting wood and/or organic materials?

- What are some pyrolysis products that may be encountered when extracting clothing?
- Does a positive reaction by an accelerant detection canine or a hydrocarbon detector indicate that a petroleum product is present? Explain.

8.5.4 Practical Exercises

- 8.5.4.1 The trainee will review the NCFS Ignitable Liquid Reference Collection Substrate Database and write a summary detailing what they have learned.
- 8.5.4.2 Extraction and evaluation of various unburned and burned debris samples is to be done in conjunction with the practical exercises in Section 8.6.

8.5.5 Evaluation

- 8.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 8.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 8.5.5.3 The trainee will be quizzed on the subject matter.

8.6 Extraction Methods and Data Evaluation

8.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Perform current extraction techniques to include headspace, solvent, and passive adsorption/elution;
- Determine which extraction procedure to use under varying sample conditions; and
- Identify volatile compounds in headspace samples.

8.6.2 Required Readings

- 8.6.2.1 ASTM E 1388-12 “Standard Practice for Sampling of Headspace Vapors from Fire Debris Samples”.
- 8.6.2.2 ASTM E 1386-10 “Standard Practice for Separation of Ignitable Liquid Residues from Fire Debris Samples by Solvent Extraction”.
- 8.6.2.3 ASTM E 1412-12 “Standard Practice for Separation and Concentration of Ignitable Liquid Residues from Fire Debris Samples by Passive Headspace Concentration with Activated Charcoal”.
- 8.6.2.4 ASTM E 1413-13 “Standard Practice for Separation and Concentration of Ignitable Liquid Residues in extracts from Fire Debris Samples by Dynamic Headspace Concentration”.
- 8.6.2.5 Bertsch, W., and Holzer, G., “Analysis of Accelerants in Fire Debris by Gas Chromatography/Mass Spectrometry,” Forensic Applications of Mass Spectrometry, Yinon, Jehuda, ed., Boca Raton, FL, CRC Press, Inc., 1995, pp. 129-167.
- 8.6.2.6 Buckleton, J. S., Bettany, B. L. and Walsh, K. A. J., “A Problem of Hydrocarbon Profile Modification by Charcoal,” *Journal of Forensic Sciences*, Vol. 34, No. 2, March 1989, pp. 449-453.
- 8.6.2.7 Demers-Kohls, J. F., et al., “Evaluation of the DFLEX Device for Fire Debris Analysis,” *Canadian Society of Forensic Science Journal*, Vol. 27, No. 3, 1994, pp. 99-123.

- 8.6.2.8 Dietz, W. R., "Improved Charcoal Packaging for Accelerant Recovery by Passive Diffusion," *Journal of Forensic Sciences*, Vol. 36, No. 1, January 1991, pp. 111-121.
- 8.6.2.9 Lentini, J. J. and Armstrong, A. T., "Comparison of the Eluting Efficiency of Carbon Disulfide with Diethyl Ether: The Case for Laboratory Safety," *Journal of Forensic Sciences*, Vol. 42, No. 2, 1997, pp. 307-311.
- 8.6.2.10 Newman, R. T., Dietz, W. R. and Lothridge, K., "The Use of Activated Charcoal Strips for Fire Debris Extractions by Passive Diffusion, Part I: The Effects of Time, Temperature, Strip Size, and Sample Concentration," *Journal of Forensic Sciences*, Vol. 41, No. 3, May 1996, pp. 167-176.
- 8.6.2.11 Phelps, J. L., Chasteen, C. E., and Render, M. M., "Extraction and Analysis of Low Molecular Weight Alcohols and Acetone from Fire Debris Using Passive Headspace Concentration," *Journal of Forensic Sciences*, Vol. 39, No. 1, January 1994, pp. 194-206.
- 8.6.2.12 Sandercock, P. M. L., "Comparison of Passive Charcoal Adsorption with a Dynamic Charcoal Adsorption Technique," *Canadian Society of Forensic Science Journal*, Vol. 27, No. 3, 1994, pp. 179-201.
- 8.6.2.13 Sandercock, P. M. L., "Retention of Gasoline and Diesel Fuel Samples on Charcoal: Evaluation of Long Term Preservation of Petroleum Residues," *Canadian Society of Forensic Science Journal*, Vol. 30, No. 4, 1997, pp. 219-224.
- 8.6.2.14 Smith, C. B. and Macy, J., "Methods of Fire Debris Preparation for Detection of Accelerants," *Forensic Science Review*, Vol. 3, No. 1, June 1991, pp. 58-69.
- 8.6.2.15 Stauffer, E., Dolan, J., and Newman, R., *Fire Debris Analysis*, Burlington, MA, Elsevier, Inc., 2008, pp. 377-437.
- 8.6.2.16 Waters, L. V. and Palmer, L. A., "Multiple Analysis of Fire Debris Samples Using Passive Headspace Concentration," *Journal of Forensic Sciences*, Vol. 38, No. 1, January 1993, pp. 165-183.
- 8.6.2.17 Chasteen, C., "Essential Tools for the Analytical Laboratory: Facilities, Equipment, and Standard Operating Procedures," *Analysis and Interpretation of Fire Scene Evidence*, Almirall, J. and Furton, K., eds., CRC Press, Florida, 2004, pp. 112-118.

8.6.3 Questions

The trainee will provide written answers to the following questions:

- Define adsorption, absorption, adsorbent, adsorbate, adsorbed phase.
- What are the two basic types of adsorption that occur? Which occurs with the use of active carbon?
- What are the two basic types of desorption? Which is used for active charcoal, and why?
- Define displacement and breakthrough.
- What problems in recovery can occur if ambient temperatures are used for the extraction process?
- What problems in recovery can occur if extraction temperatures are too high?
- Discuss the factors that can lead to distorted recovery (discuss both skewing toward the light ends as well as toward the heavy ends) and how these factors can be minimized.
- Explain the distortions that can occur among classes of compounds when strong samples are extracted.
- Can kerosene and diesel fuel-type products be differentiated when passive adsorption/elution is the method of extraction? Explain.
- Define and give examples of competitive adsorption.

- Suggest a flow chart for fire debris analysis.
- Why is carbon disulfide used for the elution of ignitable liquids from activated charcoal? What are the advantages and disadvantages of using carbon disulfide?
- Describe the use of steam distillation and vacuum distillation for the extraction of petroleum products from debris. Why are these no longer preferred methods?
- Why is ambient headspace analysis not a preferred method for the identification of petroleum products?
- Describe solvent extraction.
- Why is pentane used for solvent extraction at DFS?
- Under what conditions is solvent extraction preferred over, or in addition to, adsorption/elution extractions?
- How can you determine if a whole sample liquid is aqueous or nonaqueous?
- List some possible reasons for a report of no ignitable liquids identified.

8.6.4 Practical Exercises

- 8.6.4.1 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets, and what abbreviations are in standard use for fire debris analysis.
- 8.6.4.2 The trainee will extract samples containing known ignitable liquids using ambient headspace, passive adsorption/elution and solvent extraction. The trainee will perform each type of extraction on each ignitable liquid provided. The trainee will compare the data from all three extractions for each of the ignitable liquids and for each set of extractions. The ignitable liquids used will include at a minimum:
- Ethanol
 - Whole gasoline
 - Whole kerosene
 - Whole diesel fuel
 - Pennzoil 10W30 motor oil
 - Rislone Engine Treatment
- 8.6.4.3 The trainee will evaluate data from an evaporation series from two different classes. At least one of the series should be prepared by the trainee.
- 8.6.4.4 The trainee will be given a group of 10 liquids, each composed of 4mL of pentane and 1 drop of an ignitable liquid. The trainee will treat these unknowns as if they are separate case extracts. The trainee will run appropriate references and write the results as they would appear on a report.
- 8.6.4.5 The trainee will receive a set of unknown samples consisting of various types of spiked debris. These samples will be passive adsorption/elution (charcoal strip) extracted and analyzed by GC-MS. Appropriate references are to be run and the results written as they would appear on a report.
- 8.6.4.6 The trainee will receive a set of unknown samples consisting of various types of spiked debris. These samples will be solvent (pentane) extracted and analyzed by GC-MS. The headspace of these samples may also be sampled prior to the solvent extraction in order to follow the trace evidence procedures. Appropriate references are to be run and the results written as they would appear on a report.
- 8.6.4.7 The trainee will set up experiments using 50R gasoline and whole kerosene to review how charcoal strip extractions are affected by extraction temperature, extraction time, and sample concentration. The following experiments should be conducted:

- 8.6.4.7.1 Use temperatures of ambient, 65 °C, and 95 °C.

8.6.4.7.2 Use extraction times of 30 minutes, 4 hours, and 16 hours.

8.6.4.7.3 Use sample concentrations of 1 drop, 5 drops, and 1 mL.

8.6.5 Evaluation

8.6.5.1 The trainer will review written answers to the questions with the trainee.

8.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

8.6.5.3 Review of practical exercises to include a comparison of the extraction techniques and the appropriateness of each.

8.6.5.4 The trainee will be quizzed on the subject matter.

8.7 Turpentine and Terpenes

8.7.1 Objectives

Through completion of this module the trainee will develop the theoretical knowledge to be conversant in:

- Manufacturing processes of turpentine
- Composition of soft woods vs. turpentines

8.7.2 Required Readings

8.7.2.1 Trimpe, M. A., "Turpentine in Arson Analysis," *Journal of Forensic Sciences*, Vol. 36, No. 4, July 1991, pp. 1059-1073.

8.7.2.2 Zinkel, D. F., "Turpentine, Rosin and Fatty Acids from Conifers," Organic Chemicals from Biomass, Chapter 9, I.S. Goldstein, ed., CRC Press, Inc., Boca Raton, FL, 1981, pp. 163-187.

8.7.3 Questions

The trainee will provide written answers to the following questions:

- What is turpentine?
- How is turpentine made?
- Under what circumstances could turpentine be identified?
- List the most common terpenes seen in soft wood extracts.

8.7.4 Evaluation

8.7.4.1 The trainer will review the written answers to the questions with the trainee.

8.7.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

8.7.4.3 The trainee will complete a written examination or be quizzed upon the subject matter.

8.8 Vegetable Oils

8.8.1 Objectives

Through the completion of the module, the trainee will develop the theoretical knowledge to be conversant in:

- The chemistry of vegetable oils
- The analysis of fire debris presumed to contain vegetable oils and why it differs from traditional analysis techniques

8.8.2 Required Readings

- 8.8.2.1 ASTM E2881-18: Standard Test Method for Extraction and Derivatization of Vegetable Oils from Fats from Fire Debris and Liquid Samples with Analysis by Gas Chromatography-Mass Spectrometry.
- 8.8.2.2 ASTM E2997-16 Standard Test Method for Analysis of Biodiesel Products by Gas Chromatography-Mass Spectrometry.
- 8.8.2.3 Gambrel, A.K. and Reardon, M.R. "Extraction, Derivatization, and Analysis of Vegetable Oils from Fire Debris," *Journal of Forensic Sciences*, Vol. 53, No. 5, 2008, pp. 1372-1380.
- 8.8.2.4 Kuk, R.J. and Spagnola, M.V., "Extraction of Alternative Fuels from Fire Debris Samples," *Journal of Forensic Sciences*, Vol. 53, No. 5, 2008, pp. 1123-1129.
- 8.8.2.5 Pitts, S.J. and Thomson, C.I. "Analysis and Classification of Common Vegetable Oils," *Journal of Forensic Sciences*, Vol. 48, No. 6, 2003, pp. 1293-1297.
- 8.8.2.6 Schwenk, L.M. and Reardon, M.R. "Practical Aspects of Analyzing Vegetable Oils in Fire Debris," *Journal of Forensic Sciences*, Vol. 54, No. 4, 2009, pp. 874-880.

8.8.3 Questions

The trainee will provide written answers to the following questions:

- Describe the general composition of vegetable oils. Which fatty acids are most commonly encountered in vegetable oils?
- Why are vegetable oils prone to self-heating? What makes some vegetable oils more likely to self-heat than others?
- What is the difference between autoignition and spontaneous ignition?
- Why is the typical ignitable liquid analysis procedure not suitable for vegetable oil analysis?
- Describe the different ways that fatty acids can be derivatized and explain the chemical reactions that occur in each derivatization process.
- What derivatization process is used by DFS? How is the reagent made?
- Describe the analysis procedure for the examination of a vegetable oil:
 - As a whole liquid
 - In fire debris
- Once a vegetable oil undergoes derivatization, what are the compounds of interest during data interpretation?
- What samples, in addition to the case samples, must be analyzed during a vegetable oil analysis?
- Can ignitable liquid analysis and vegetable oil analysis be performed on the same sample?
- What are examples of manufactured and naturally occurring products that contain fatty acid methyl esters?
- What is biodiesel? Are there different blends? Does biodiesel require derivatization?

8.8.4 Practical Exercises

- 8.8.4.1 The trainer will demonstrate how to extract and derivatize a vegetable oil sample and how to interpret the data.

- 8.8.4.2 The trainee will extract and derivatize a known vegetable oil and interpret the data.
- 8.8.4.3 The trainee will receive a set of three unknown samples consisting of various types of debris spiked with a vegetable oil. These samples will be solvent extracted, derivatized, and analyzed by GC-MS. Appropriate references are to be run and the results written as they would appear on a report.

8.8.5 Evaluation

- 8.8.5.1 The trainer will review written answers to the questions with the trainee.
- 8.8.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 8.8.5.3 Review of practical exercises.
- 8.8.5.4 The trainee will be quizzed on the subject matter.

8.9 Microbial Degradation

8.9.1 Objectives

Through completion of this module, the trainee will develop the theoretical knowledge to be conversant in:

- The effects of microbial degradation on fire debris analysis
- Prevention and minimization of microbial degradation

8.9.2 Required Readings

- 8.9.2.1 Hutches, K. "Microbial degradation of ignitable liquids on building materials," *Forensic Science International*, Vol. 232, 2013, pp. e38-e41.
- 8.9.2.2 Mann, D. C. and Gresham, W. R., "Microbial Degradation of Gasoline in Soil," *Journal of Forensic Sciences*, Vol. 35, No. 4, July 1990, pp. 913-923.
- 8.9.2.3 Stauffer, E., Dolan, J., and Newman, R., *Fire Debris Analysis*, Burlington, MA, Elsevier, Inc., 2008., Chapter 12, pp. 471-477.
- 8.9.2.4 Turner, D, Goodpaster, J. "The effect of microbial degradation on the chromatographic profiles of tiki torch fuel, lamp oil, and turpentine," *J. Forensic Sci*, Vol. 56, No. 4, 2011, pp. 984-987.
- 8.9.2.5 Turner, D, Goodpaster, J. "Preserving ignitable liquid residues on soil using Triclosan as an anti-microbial agent," *Forensic Science International*, Vol. 239, 2014, pp. 86-91.
- 8.9.2.6 Turner, D., Williams, M., Sigman, M., and Goodpaster, J., "A comprehensive study of the alteration of ignitable liquids by weathering and microbial degradation." *J. Forensic Sci.* Vol. 63, No. 1., 2018, pp. 58-65.

8.9.3 Questions

The trainee will provide answers to the following questions:

- Define microbial degradation.

- What causes microbial degradation?
- What conditions influence the occurrence of microbial degradation?
- How quickly can microbial degradation occur?
- Is microbial degradation a uniform process?
- What types of samples encountered in fire debris analysis are susceptible to microbial degradation?
- What are the different methods that can be employed to minimize microbial degradation from occurring in fire debris samples? List the pros and cons for each method.
- What indicators of microbial degradation might be present during inventory of fire debris evidence?
- When interpreting fire debris data, what microbial degradation indicators might be present in the data?
- Which components of ignitable liquids are more prone to microbial degradation?

8.9.4 Evaluation

8.9.4.1 The trainer will review written answers to the questions with the trainee.

8.9.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

8.9.4.3 The trainee will be quizzed on the subject matter.

8.10 Supervised Work-Along

8.10.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.

8.10.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.

8.10.3 The trainee shall work at least twenty forensic cases as a technician under the direct supervision of a qualified fire debris examiner. The trainer should ensure as much variety in the work-along as is practicable.

8.11 Case File Review

The trainee should document the review of at least ten completed case files using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder. The case files shall be technically reviewed by an authorized examiner pursuant to QM 17 prior to release.

8.12 Forensic Significance of Fire Debris

The trainer and the trainee will discuss the interpretation of fire debris evidence and its relevance and weight in reports and in testimony. Discussions will include identifying a class of products versus individual identification of a commercial product.

8.13 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

8.14 Fire Debris Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified fire debris examiners, the Chemistry Program Manager, and the Section/Group Supervisor.

The presentation may cover either: the general theory and application of GC-MS in fire debris analysis; the forensic examination of fire debris; or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic fire debris community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee's training program.

8.15 Technical Final

The trainee will field questions related to any/all aspects of their fire debris training.

8.16 Competency Evaluation and Mock Trial

- 8.16.1 As the trainee progresses through fire debris training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these "case" files completed prior to issuance of the final practical test.
- 8.16.2 Using one or all of the "cases" from 8.14.1, the trainee will undergo a series of "mini-mock trial" practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.
- 8.16.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.
- 8.16.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

8.17 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

9 FOURIER TRANSFORM INFRARED SPECTROPHOTOMETRY (FTIR)

9.1 Introduction to Infrared Spectrophotometry

9.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory and applications of electromagnetic radiation;
- Properties of infrared radiation;
- The basic function and design of dispersive IR and FTIR systems;
- The theory and applications of FTIR;
- The advantages and disadvantages of both dispersive and FTIR systems; and,
- The quality assurance/quality control of the FTIR system.

9.1.2 Required Readings

- 9.1.2.1 FBI training course, “Infrared Spectroscopy for Trace Evidence”, September 11-15, 2002.
- 9.1.2.2 Nicolet Corporation, “Theory of FTIR”, internal publication, July 1986.
- 9.1.2.3 Saferstein, Richard, ed., Forensic Science Handbook, Volume 3, Englewood Cliffs, NJ, Prentice-Hall, Inc. 1993, pp.70-248.
- 9.1.2.4 Smith, Brian C., Fundamentals of Fourier Transform Infrared Spectroscopy, CRC Press, Washington, D.C., 1996, pp. 1-53, 56.
- 9.1.2.5 Willard, Hobart H., Merrit, Lynne L. Jr., and Dean, John A., Instrumental Methods of Analysis, 5th edition, D. Van Nostrand Co., New York, New York, 1974, pp. 150-188.

9.1.3 Questions

The trainee will provide written answers to the following questions:

- Describe the electromagnetic spectrum.
- What is infrared spectrophotometry and what is its specificity?
- Define the following terms:
 - Wavelength
 - Amplitude
 - Wavenumber
 - Frequency
 - Dipole moment
 - Harmonic vibration
 - Fundamental vibration
 - Interferometer
 - Overtone
 - Data spacing
 - Interferogram
 - Zero path difference (ZPD)
 - Absorption
 - Transmittance
 - Combination band
 - Monochromator
 - Diatomic
 - Centerburst

- What are the upper and lower limits of the infrared region of the electromagnetic spectrum?
- What region is the most useful analytically?
- What two conditions must be present for infrared absorption to occur?
- What is the intensity of an infrared absorption proportional to?
- What are the two basic categories of molecular vibration?
- What is meant by vibrational coupling?
- Describe the different types of radiation sources for FTIR instruments.
- Describe the different types of detectors available for infrared instruments.
- What is spectral subtraction and how is it useful?
- Describe how an FTIR instrument works.
- What is the relationship between resolution and data spacing?
- Describe reflectance analysis using the microscope attachment.
- Draw a schematic diagram for the dispersive IR and the FTIR.
- What are the advantages of FTIR over dispersive instruments?
- Sketch a Michelson interferometer and describe how it works.
- What is Fourier Transform and how does it apply to IR?
- What is meant by the “fingerprint region” of an IR spectrum? Why is it significant?
- Describe the difference between data presented in transmittance, absorbance, and reflectance. How are they related to each other?
- What are the differences between background subtraction and spectral subtraction?
- Describe the QC procedures and preventative maintenance schedule performed on the FTIR.
- What is polystyrene used to check the function of in the FTIR?
- What model IR does your laboratory use? What radiation source and detectors are used on the FTIR and its attachments in your laboratory?
- At what resolution are samples normally run in your laboratory?
- Describe to a jury how an FTIR operates.
- Discuss the differences between spectra obtained from a solid vs. gas.

9.1.4 Practical Exercise

- 9.1.4.1 The trainer will demonstrate the daily and weekly QC procedures for the bench.
- 9.1.4.2 The trainee will perform the daily and weekly QC procedures for the bench for a minimum of one week.

9.1.5 Evaluation

- 9.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 9.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 9.1.5.3 Review of practical exercise.
- 9.1.5.4 The trainee will be quizzed on the subject matter.

9.2 Sample Preparation and Data Collection

9.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to prepare samples and collect infrared data with the bench using the following sample preparation techniques:

Solids:

KBr pellet
Attenuated Total Reflectance (ATR)

Liquids:
Film on KBr pellet

Gases:
Gas cell

9.2.2 Required Readings

- 9.2.2.1 FBI training course, "Infrared Spectroscopy for Trace Evidence", September 11-15, 2002.
- 9.2.2.2 Miller, R.G.J., Laboratory Methods in Infrared Spectroscopy, Heyden and Sons Ltd., 1965.
- 9.2.2.3 Saferstein, Richard, ed., Forensic Science Handbook, Volume 3, Englewood Cliffs, NJ, Prentice-Hall, Inc. 1993, pp. 70-248.
- 9.2.2.4 Smith, Brian C., Fundamentals of Fourier Transform Infrared Spectroscopy, CRC Press, Washington, D.C., 1996, pp. 1-87-130.
- 9.2.2.5 Thermo Electron Smart Golden Gate MK11 Single Reflection ATR System: Sampling Notes, Specac Ltd., 2006.

9.2.3 Questions

The trainee will provide written answers to the following questions:

- Why are alkali halides used for sample holders?
- What are the differences between diffuse reflectance, reflection-absorption, and attenuated total reflectance?
- What parameters can be changed to improve the quality of a spectra?
- What is the background and why is it collected?

9.2.4 Practical Exercises

- 9.2.4.1 The trainer will demonstrate any of the sample preparation techniques with which the trainee is not familiar.
- 9.2.4.2 Using samples provided by the trainer, the trainee will demonstrate the ability to prepare samples using the listed sample preparation techniques.

9.2.5 Evaluation

- 9.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 9.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 9.2.5.3 Review of practical exercises.

9.3 Infrared Interpretation

9.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Interpret FTIR data;
- Compare data collected with reference samples for identification; and,
- Compare data collected from known and questioned samples to determine whether they may or may not be associated.

9.3.2 Required Readings

- 9.3.2.1 Bellamy, L. J., The Infrared Spectra of Complex Molecules, John Wiley and Sons, New York, 1954.
- 9.3.2.2 Cook, B.W. and Jones, K., A Programmed Introduction to Infrared Spectroscopy, Heyden and Sons Ltd., 1972.
- 9.3.2.3 Syzmanski, Herman A., Interpreted Infrared Spectra, Plenum Press Data Division, New York, 1967.

9.3.3 Questions

The trainee will provide written answers to the following questions:

- State the absorption region for the following functional groups
 - O-H
 - N-H
 - C=O
 - C-O
 - C-H_n
 - C≡N
 - N-O₂
- Explain Beer's Law.
- What is the minimum percent of a compound needed for detection by FTIR?
- What causes a sloped baseline?

9.3.4 Practical Exercises

- 9.3.4.1 The trainee will interpret spectra provided by the trainer.

9.3.5 Evaluation

- 9.3.5.1 The trainer will review the written answers to the questions with the trainee.
- 9.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 9.3.5.3 Review of practical exercises.

9.4 FTIR Microscope Accessory

9.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Align the microscope;
- Perform the day-of-use and weekly QC; and,

- Prepare samples and collect infrared data with the microscope using the microcompression cell with diamond windows.

9.4.2 Required Readings

- 9.4.2.1 Reffner, John A. and Martoglio, Pamela A., “Uniting Microscopy and Spectroscopy” in Practical Guide to Infrared Microspectroscopy, Humecki, Howard J., ed., Marcel Dekker, Inc., New York, 1995, pp. 41-84.
- 9.4.2.2 Saferstein, Richard, ed., Forensic Science Handbook, Volume 3, Englewood Cliffs, NJ, Prentice-Hall, Inc. 1993, pp. 70-248.
- 9.4.2.3 Tungol, Mary, “Analysis of Single Polymer Fibers by Fourier-Transform Infrared Microscopy: The Results of Case Studies,” *Journal of Forensic Sciences*, Vol. 36, No. 4, July 1991, pp. 1027-1043.

9.4.3 Questions

The trainee will provide written answers to the following questions:

- Why is the MCT detector cooled with liquid nitrogen?
- What is the benefit of using the MCT detector with the microscope attachment and not the DTGS detector?
- What is the range of an MCT detector and what is the limiting factor which dictates how low it will detect?
- What are interference fringes? Why do they occur? How can they be avoided?
- How does the amount of pressure applied effect samples in the microcompression cell?
- Why is KBr or AgCl₂ added with samples when using the microcompression cell?
- What is the different between MCT-A and MCT-B detectors? When is one more useful than the other?

9.4.4 Practical Exercises

- 9.4.4.1 The trainer will demonstrate the daily and weekly QC procedures for the microscope.
- 9.4.4.2 The trainee will perform the daily QC procedures for the microscope for a minimum of one week.
- 9.4.4.3 The trainer will demonstrate sample preparation using the microcompression cell if the trainee is not familiar with this technique.
- 9.4.4.4 Using samples provided by the trainer, the trainee will demonstrate the ability to prepare and analyze samples using the microcompression cell.

9.4.5 Evaluation

- 9.4.5.1 The trainer will review the written answers to the questions with the trainee.
- 9.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 9.4.5.3 Review of practical exercises.

9.5 FTIR ATR Accessory

9.5.1 Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Perform the day-of-use QA;
- Understand the use of the ATR correction and,
- Prepare samples and collect infrared data using the ATR.

9.5.2 Required Readings

9.5.2.1 Thermo Electron Smart Golden Gate™ MKII Single Reflection ATR System, Sampling Notes, Specac Ltd., 2I-10560 Issue 4, July 2006.

9.5.3 Questions

The trainee will provide written answers to the following questions:

- Draw a schematic of an ATR sampling unit.
- What is the range of the ATR accessory?
- How large is the sampling area?
- What is the crystal material?
- What compression head anvils are available and what types of samples would they be used for?
- Describe any differences in the spectra obtained using ATR vs. regular transmittance.
- Explain the theory behind the ATR sampling unit including the difference between single-bounce and multi-bounce units.
- What is the ATR correction and when and why is it used?
- What are some pitfalls in sample analysis using the ATR accessory?

9.5.4 Practical Exercises

9.5.4.1 The trainer will demonstrate the operation of the ATR accessory to include the daily QA procedure.

9.5.4.2 The trainee will complete the Smart Golden Gate tutorial.

9.5.4.3 The trainee will complete the ATR Sampling Techniques tutorial.

9.5.4.4 The trainee will read the validation summary and review the associated data.

9.5.4.5 The trainee will analyze a standard sucrose sample and the backing and adhesive surfaces of the reference adhesive tape used for QA. The trainee will compare this data to copies of data on file.

9.5.5 Evaluation

9.5.5.1 The trainer will review the written answers to the questions with the trainee.

9.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

9.5.5.3 Review of practical exercises.

9.6 Competency Evaluation and Mock Trial

The trainee will use FTIR when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

10 FRACTURE MATCH / PHYSICAL FIT

10.1 Introduction to Fracture Match / Physical Fit

10.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the difference between class and individual characteristics;
- Describe how a fracture match / physical fit may be made and why it is considered conclusive that the two objects were at one time a part of the same unit;
- Document a positive fracture match / physical fit; and,
- Write reports for positive associations and negative associations where additional testing has been or will be completed.

10.1.2 Required Readings

- 10.1.2.1 Bradley, Maureen J.; Gauntt, Jennifer M.; Mehlretter, Andria H.; Lowe, Preston C.; Wright, Dana M. "A Validation Study for Vinyl Electrical Tape End Matches", *Journal of Forensic Sciences*, 56(3), May 2011, pp. 606-611.
- 10.1.2.2 Bradley, Maureen J.; Keagy, Roger L.; Lowe, Preston C.; Rickenback, Michael P.; Wright, Dana M.; LeBeau, Marc A. "A Validation Study for Vinyl Duct Tape End Matches", *Journal of Forensic Sciences*, 51(3), May 2006, pp. 504-508.
- 10.1.2.3 Christensen, Angi M.; Sylvester, Adam D. "Physical Matches of Bone, Shell, and Tooth Fragments: A Validation Study", *Journal of Forensic Sciences*, 53(3), May 2008, pp. 694-698.
- 10.1.2.4 Claytor, Lauren K.; Davis, Ann L. "A Validation of Fracture Matching Through the Microscopic Examination of Fractured Surfaces of Hacksaw Blades", *AFTE Journal*, 42(4), 2010, pp. 323-334.
- 10.1.2.5 DeForest, P.; Gaensslen, R.E.; Lee, H.C. Forensic Science: An Introduction to Criminalistics. McGraw-Hill Book Company, New York, 1983, pp. 286-290.
- 10.1.2.6 Dixon, K.C. "Positive Identification of Torn Burned Matches with Emphasis on Cross Cut and Torn Fiber Comparisons", Presentation: American Academy of Questioned Documents Examiners, August, 1982.
- 10.1.2.7 Houck, M.M. "Logical Conclusions from Pattern Analysis: Matches, Non-matches and Exclusions", *Canadian Society Forensic Science Journal*, 25(1), 1992.
- 10.1.2.8 Katterwe, Horst W. "Fracture Matching and Repetitive Experiments: A Contribution of Validation", *AFTE Journal*, 37(3), 2005, pp. 229-241.
- 10.1.2.9 Kirk, P.L., Crime Scene Investigation, 2nd ed. John Wiley and Sons: New York, 1974, pp. 263-265.
- 10.1.2.10 McCabe, Kaitlin R., Tulleners, Frederic A., Braun, Jerome V., Currie, Gilliam, and Gorecho, Esmeraldo N. "A Quantitative Analysis of Torn and Cut Duct Tape Physical End Matching", *Journal of Forensic Sciences*, 58(S1), January 2013, pp. S34-S41.
- 10.1.2.11 Miller, Jerry; Kong, Howard. "Metal Fractures: Matching and Non-Matching Patterns", *AFTE Journal*, 38(2), 2006, pp. 133-165.

- 10.1.2.12 Molchanko, V.S. “Forensic Sciences: The Philosophy of Physical Matching”, *Royal Canadian Mounted Police Gazette*, Vol. 37, 1975.
- 10.1.2.13 Orench, Jose A. “A Validation Study of Fracture Matching Metal Specimens Failed in Tension”, *AFTE Journal*, 37(2), 2005, pp. 142-149.
- 10.1.2.14 Saferstein, R., Ed., Forensic Science Handbook, Prentice-Hall, Inc., New York, NY, 1982, pp. 151, 547.
- 10.1.2.15 Saferstein, R., Criminalistics: An Introduction to Forensic Science, 5th ed., Prentice-Hall, Inc., Englewood Cliffs, NJ, 1977, pp. 61-71.
- 10.1.2.16 Stone, Rocky S. “A Probabilistic Model of Fractures in Brittle Metals”, *AFTE Journal*, 36(4), 2004, pp. 297-301.
- 10.1.2.17 Svensson, A, Wendel, O and Fisher, B.A. Techniques of Crime Scene Investigation, 3rd ed., Elsevier, New York, 1982.
- 10.1.2.18 Tsach, T., Wiesner, S., and S. Yaron. “Empirical Proof of Physical Match: Systematic Research with Tensile Machine”, *Forensic Science International*, Vol. 66, 2007, pp. 77-83.
- 10.1.2.19 Van Hoven, H.A. and H. D. Fraysier, “The Matching of Automotive Paint Chips by Surface Striation Alignment”, *Journal of Forensic Sciences*, 28(2), 1983. pp. 463-67.
- 10.1.2.20 Von Bremen, U. G. and Blunt, L., “Physical Comparison of Plastic Garbage Bags and Sandwich Bags”, *Journal of Forensic Sciences*, 28(3), July 1983, pp. 644-654.
- 10.1.2.21 Zugibe, F. and J. Costello. “The Jigsaw Puzzle Identification of a Hit and Run Automobile”, *Journal of Forensic Sciences*, 31(1), 1986, pp. 329-32.

10.1.3 Questions

The trainee will provide written answers to the following questions:

- What is a class characteristic?
- What is an individual characteristic?
- Is a fracture match considered to be a conclusive identification? Why?
- What is the difference between “fracture match” and “physical fit”? When might one term be more or less appropriate than the other?

10.1.4 Practical Exercises

- 10.1.4.1 The trainer will demonstrate how to use the silicone casting material.
- 10.1.4.2 Using samples provided by the trainer, the trainee will demonstrate the ability to prepare casts of suitable broken edges and compare them.
- 10.1.4.3 The trainer will demonstrate a fracture match / physical fit of a hard, rigid material to include viewing “on edge”.
- 10.1.4.4 The trainee will be given test samples of hard, rigid materials (e.g., plastic automotive lens, test samples of paint fragments) and will be asked to attempt to fracture match / physically fit the pieces, if possible.
- 10.1.4.5 The trainer will demonstrate a fracture match / physical fit of a flexible material that may experience distortion and/or stretching during separation.

- 10.1.4.6 The trainee will be given test samples of a flexible material and will be asked to attempt to fracture match / physically fit the pieces, if possible.

10.1.5 Evaluation

- 10.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 10.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 10.1.5.3 Review of practical exercises.

10.2 Supervised Work-Along

- 10.2.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.
- 10.2.2 The “Training Completion Summary Form” form (222-F201) or MFR shall serve to document the aforementioned authorizations by the Training Coordinator.
- 10.2.3 The trainee shall work as many forensic cases as are available during the training cases as a technician under the direct supervision of a qualified forensic examiner.

10.3 Forensic Significance of Fracture Matches / Physical Fits

The trainer and the trainee will discuss the interpretation of fracture match / physical fit evidence and its relevance and weight in reports and in testimony.

10.4 Report Writing

The trainer will review and discuss with the trainee the standard report wording in the Fracture Match section of the Trace Evidence Procedures Manual.

The trainee should document the review of at least five case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

10.5 Competency Evaluation and Mock Trial

The trainee will successfully complete at least one fracture match as a part of their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

10.6 Certification

There is no individual certification in fracture match.

11 GAS CHROMATOGRAPHY (GC)

11.1 Introduction to Gas Chromatography

11.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory and application of gas chromatography (GC) as it applies to Trace Evidence
- How to properly use the GC instrumentation and software within the Trace Evidence section

11.1.2 Required Readings

- 11.1.2.1 Braithwaite, A., and Smith, F.J., Chromatographic Methods, 4th ed., Chapman and Hall, Ltd., New York, NY, 1985, Chapters 1, 2 & 5.
- 11.1.2.2 Freeman, R. R., ed., et al., High Resolution Gas Chromatography, 2nd edition, Hewlett Packard Co., 1989.
- 11.1.2.3 Rood, Dean, A Practical Guide to the Care, Maintenance, and Troubleshooting of Capillary Gas Chromatographic Systems, 3rd edition, Wiley-VCH, Federal Republic of Germany, 1999.
- 11.1.2.4 Stauffer, E., Dolan, J.A., and Newman, R., Fire Debris Analysis, Elsevier, Massachusetts, 2008, pp.235-264.
- 11.1.2.5 Willard, H. H., Merritt, L.L., and Dean, J.A., Instrumental Methods of Analysis, 5th edition, Van Nostrand, New York, NY, 1974, Chapter 19.
- 11.1.2.6 DFS Trace Evidence Procedures Manual, Gas Chromatography Section.
- 11.1.2.7 Stafford, David T., Ph.D. "Forensic Capillary Gas Chromatography", in Saferstein, Richard, Ph.D., editor. *Forensic Science Handbook, Volume II*. Englewood Cliffs, N. J.: Prentice Hall, 1988, pp. 38-67.
- 11.1.2.8 Hyver, K.J., Sandra, P., editor. *High Resolution Gas Chromatography, Third Edition*. Hewlett Packard Company, 1989.
- 11.1.2.9 Regis Chemical Company. *A User's Guide to Chromatography*. Morton Grove, IL: Regis Chemical Company, 1976, pp. 20-114.
- 11.1.2.10 Hewlett Packard and Agilent Technologies GC instrument manuals.
- 11.1.2.11 ASTM E2881-13 "Standard Test Method for Extraction and Derivatization of Vegetable Oils and Fats from Fire Debris and Liquid Samples with Analysis by Gas Chromatography-Mass Spectrometry".
- 11.1.2.12 Gambrel, A.K. and Rearson, M.R., "Extraction, Derivatization, and Analysis of Vegetable Oils from Fire Debris," *Journal of Forensic Sciences*, Vol. 53, No. 6, 2008, pp. 1372-1380.
- 11.1.2.13 Schwenk, L.M. and Reardon, M.R., "Practical Aspects of Analyzing Vegetable Oils in Fire Debris," *Journal of Forensic Sciences*, Vol. 54, No. 4, 2009, pp. 874-880.
- 11.1.2.14 Stauffer, E., "A Review of the Analysis of Vegetable Oil Residues from Fire Debris Samples: Analytical Scheme, Interpretation of the Results, and Future Needs," *Journal of Forensic Sciences*, Vol. 51, No. 5, 2006, pp. 1016-1129.

11.1.3 Questions

The trainee will provide written answers to the following questions:

- What is chromatography?
- What is gas chromatography?
- What types of information are obtained from GC?
- Draw a schematic diagram for a GC and describe the purpose of each component.
- Define the following terms:
 - o Carrier gas
 - o Mobile phase
 - o Stationary phase
 - o Partition
 - o Volatility
 - o Distribution coefficient
 - o Retention index
 - o Linear velocity
 - o Flow rate
 - o Injection port
 - o Flame ionization detector
 - o Derivatization
 - o Internal standard
- What general criteria should all stationary phases meet?
- What general criteria should all mobile phases meet?
- Besides the stationary phase, what factors influence column selection for a given GC application?
- What determines the appropriate column diameter for a given GC system? The appropriate length? Why are packed column lengths limited to a maximum of 3 meters?
- Describe how the following concepts affect GC separation between components:
 - o Solubility
 - o Boiling point
 - o Intermolecular forces
- Describe the following types of capillary columns:
 - o SCOT
 - o WCOT
 - o Fused Silica
- What factors influence the “inertness” of a column?
- What is the purpose of the polyimide/polyamide coating on a fused silica column?
- What is the difference between a bonded and a cross-linked phase? What advantages does a bonded/cross-linked phase column possess?
- How are liners deactivated after installation? How does it work?
- What is column bleed?
- When and why are columns conditioned? Describe the process.
- What factors govern the operating temperature of a given GC column? What are the upper and lower temperature limits for the following liquid phases? What is the effect of operating above or below these limits?
 - o SE-30
 - o Carbowax (both bonded and non-bonded)
 - o HP-1 (for capillary columns)
 - o HP-5 MS (for capillary columns)
- Define:
 - o retention time (T_R or t_R),
 - o relative retention time (RRT),
 - o retention volume,
 - o unretained retention time (t_m)

- o corrected or adjusted retention time (t'_R or t''_R)
- o phase ratio (β)
- o selectivity (α)
- Define partition coefficient (K)? What is it a function of? How does it relate to equilibrium? What is meant if $K = 1$?
- What is the partition ratio/capacity ratio (k)? How does it relate to retention time?
- Define the following:
 - o theoretical plate (n)?
 - o effective theoretical plate (N)?
 - o theoretical plate height /height equivalent to a theoretical plate (H or HETP)
 - o height equivalent to an effective theoretical plate (H or HEETP)
 - o average linear gas velocity (μ)
 - What is a good value for the HETP? And why?
 - How is the # of N related to column efficiency?
- Define Resolution (R).
 - What is chromatographic resolution a function of?
 - Why is resolution not the best measure of column efficiency and column performance?
- Discuss the effects of column i.d. and stationary phase film thickness with respect to sample capacity, column efficiency, relative retention times and resolution.
- Diagram and explain the Van Deemter plot. Why is Helium a good choice for a carrier gas?
- What two factors influence the relative retention time of two components?
- What is the Kovats retention index (I)? What does it mean if $I = 650$?
- Define Separation Number/Trennzahl Number (TZ). What does it mean if $TZ = 3$?
- What affect do the following have on retention time:
 - o Concentration
 - o Other compounds in the sample
 - o Free base/acid form vs. salt form
- What should be the minimum retention time of the first eluting component in a sample of one or more components to insure the sample has spent enough time in the liquid phase to achieve reasonable separation?
- Discuss the relationship between geometry, pressure drop, column capacity, resolution, sensitivity, speed and column bleed with respect to capillary columns.
- Discuss the sample introduction of gases and vapors, volatile liquids and solids into a GC.
- What is meant by flash vaporization?
- Describe the proper manual injection technique.
- What factors govern the amount of sample to be injected? How much sample/component can the average capillary column hold? What factors influence this?
- What temperature should the injection port be under normal circumstances and why?
- What types of septa are recommended for GC work and why?
- What are the differences and purposes of “split” injection, “splitless” injection and “on-column” injection?
 - Draw a diagram of the injection port and illustrate the carrier gas flow throughout for both split and splitless injections.
 - Explain the use of pulsed split and splitless injections.
- What is an injection port liner? What is it made of? Why is it used? Describe the packing process including the materials used.
- What is a “split ratio” and how is it calculated?
 - What factors govern the use of a particular split ratio (100:1 vs. 50:1)?
 - What is meant by linear split, why is it desirable and how is it achieved?
- What is gas saver and how is it used?
- What is EPC? Explain the difference between constant flow and constant pressure.
- Describe the “solvent effect”?
 - How is it done and why is it important?
 - What factors affect the efficiency of the solvent effect?
 - Define the solvent effect with respect to the equation $K = \square k$.

- What is meant by “cold trapping” and how is it done?
- Why is it necessary to regulate the carrier gas flow?
 - o How is this done?
 - o What factors influence the optimum flow rate for a given carrier gas?
 - o If the carrier gas is too fast or too slow how will it affect the peak shapes of your sample components?
 - o How will it affect the detector?
- Briefly discuss the various detector types (especially Thermal Conductivity, Flame Ionization (FID) and Electron Capture) with respect to the following:
 - o How does each work?
 - o Carrier gas requirements
 - o Sensitivity
 - o Temperature requirements
 - o Stability
 - o Insensitivities
 - o Advantages/disadvantages with respect to trace evidence analysis
- What is “make-up” gas?
 - o How and why is it used?
 - o What determines which gas will be used as a make-up gas?
- Explain the following statement: “response is proportional to the number of carbon atoms in the sample”.
 - o What type(s) of detector is this statement applicable to?
 - o What is meant by “mass-flow” detector?
- What types of compounds should be included in a test mixture used to assess chromatographic performance? Why would these compounds be included and what would each be designed to evaluate?
- What types of GC’s (model, manufacturer, etc.) does the trace evidence laboratory use?
 - o What types of injection ports, carrier gases, flows, columns and detectors does each GC incorporate?
- Outline a logical troubleshooting schematic for isolating the source of a GC system problem.
- What three things can cause insufficient gas flow through a GC system?
- Describe how to change the septum/Microseal on the GC.
 - o What are some of the problems encountered when a septum is too tight or too loose?
- What are some of the common causes and remedies for the following GC system problems:
 - o No peaks
 - o Solvent peak only
 - o Baseline drift or unstable baseline
 - o Ghost peaks
 - o Tailing peaks
 - o Leading peaks
 - o Split peaks
 - o Baseline rise before or after a peak
 - o Baseline drop after a peak
 - o Retention time shift
- Describe the preventative maintenance schedule and QA/QC procedures performed on the GC’s.
- Discuss the operation of an autosampler.
- What is “needle discrimination” and how is it corrected?
- Explain how derivatization is performed, including why it is used sometimes for analysis.
- If two compounds were to co-elute on the GC, what could be done to resolve the peaks?
- Explain as to a jury how a GC operates.
- What is carryover? How can carryover be minimized?
- When carryover is present on the column, how can it be resolved?

11.1.4 Practical Exercises

- 11.1.4.1 The trainer will demonstrate headspace injections.
- 11.1.4.2 The trainer will demonstrate a direct injection of a nonaqueous liquid.
- 11.1.4.3 The trainee will draw up 2.0 microliters of whole gasoline into a reusable Hamilton syringe (or equivalent) and then push the gasoline out of the syringe. The trainee will then draw up 1.0 microliter of pentane into the syringe and inject the pentane on the gas chromatograph. Repeat with one, five, ten and twenty rinses of pentane in between the whole gasoline sample and the injection. Repeat this exercise with diesel fuel. The trainee will give a written description of the results of the exercise.
- 11.1.4.4 The trainer will demonstrate how to set up an auto-sampler sequence.
- 11.1.4.5 Write a method for the GC with carbowax column which creates a program which will perform the following:
 - Inlet and detector temperatures: 240°C
 - Oven temperature: 100°C, 10°C per minute, initial hold of 2 minutes
 - Split ratio: 50:1
 - Column flow rate: 1 mL/min
- 11.1.4.6 Now inject a mixture of dichloromethane and ethanol and see if the two compounds resolve. If not, change the method one parameter at a time until they are resolved. If they are resolved, change the method one parameter at a time in order to improve the resolution.
- 11.1.4.7 Inject the following standards on the GC and describe their peak shapes and retention:
 - Decane in pentane
 - Toluene in pentane
 - Fatty- acids selected by the training coordinator, in pentane
- 11.1.4.8 Perform the derivatization procedure to convert the above selected fatty-acids into FAMES. Inject the derivitized sample onto the GC. Describe the differences noted for the fatty-acids before derivitization and after.
- 11.1.5 Evaluation
 - 11.1.5.1 The trainer will review the written answers to the questions with the trainee.
 - 11.1.5.2 The trainer and the trainee will review and discuss the pertinent points of the required readings.
 - 11.1.5.3 The trainee will be quizzed on the subject matter.

11.2 Quality Assurance and Quality Control

11.2.1 Objective

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Discuss and perform the quality assurance/quality control requirements for the Trace Evidence gas chromatographs.

11.2.2 Required Reading

11.2.2.1 Trace Evidence Section Procedures Manual for Gas Chromatography.

11.2.3 Questions

The trainee will provide written answers to the following questions:

- Describe the day-of-use QC checks for all of the gas chromatographs. Include discussion as to why each check is performed.
- What are the components of the resolution test mixture and polar check samples, which columns are they run on as quality control checks and why were these components included in the check samples?

11.2.4 Practical Exercises

11.2.4.1 The trainer will demonstrate the day-of-use QC procedures for the gas chromatographs.

11.2.4.2 The trainee will perform the daily QC procedure on the gas chromatograph(s) for the duration of one week.

11.2.5 Evaluation

11.2.5.1 The trainer will review the written answers to the questions with the trainee.

11.2.5.2 The trainer and the trainee will review and discuss the pertinent points of the required readings.

11.2.5.3 The trainee will be quizzed on the subject matter.

12 MASS SPECTROMETRY (MS)

12.1 Introduction to Mass Spectrometry

12.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory and application of mass spectrometry (MS) in Trace Evidence analysis
- How to properly use the MS instrumentation and software used in the laboratory

12.1.2 Required Readings

- 12.1.2.1 Agilent Technologies, MSD reference collection, computer software, 1999.
- 12.1.2.2 American Society for Mass Spectrometry, “What is Mass Spectrometry,” Handout, ASMS, www.asms.org, 2001.
- 12.1.2.3 McLafferty, Fred W. and Turecek, Frantisek, Interpretation of Mass Spectra, 4th edition, University Science Books, 1993, Chapters 1-4.
- 12.1.2.4 Watson, J. Throck, Introduction to Mass Spectrometry, 3rd edition, Lippincott-Raven, New York, 1997.
- 12.1.2.5 Virginia Department of Forensic Science Trace Evidence Procedures Manual, Mass Spectrometry Section.
- 12.1.2.6 Saferstein, Richard, Ph.D. “Forensic Applications of Mass Spectrometry”, in Saferstein, Richard, Ph.D., editor. *Forensic Science Handbook, Volume I*. Englewood Cliffs, N. J.: Prentice Hall, 1982, pp. 92-138.
- 12.1.2.7 Yinon, Jehuda. *Forensic Mass Spectrometry*. Boca Raton: CRC Press, Inc., 1987.
- 12.1.2.8 McLafferty, Fred W. and Venkataraghavan, Rengachari. *Mass Spectral Correlations, Second Edition*. Washington, D. C.: American Chemical Society, 1982.
- 12.1.2.9 McLafferty, F. W. *Interpretation of Mass Spectra, Second Edition*. Reading, MA: W. A. Benjamin, Inc., 1973.
- 12.1.2.10 Message, Gordon M. *Practical Aspects of Gas Chromatography/Mass Spectrometry*. New York: John Wiley & Sons, 1984.
- 12.1.2.11 Computer-based NIST library of organic compounds (NIST98.l or higher)
- 12.1.2.12 Agilent Technologies GC/MS instrument manuals
- 12.1.2.13 Agilent Technologies computer-based tutorials
- 12.1.2.14 Silverstein, R. M. et al., *Spectrometric Identification of Organic Compounds* New York: John Wiley & Sons, 1991, pp. 3-41.
- 12.1.2.15 Steiner, R. “Mass Spectrometry Lecture”, Virginia Department of Forensic Science, April 2000.

12.1.2.16 McFadden, W. *Techniques of Combined Gas Chromatography/Mass Spectrometry: Applications in Organic Analysis*, New York: Wiley-Interscience Publications, 1973.

12.1.2.17 Beynon, J. et al., *The Mass Spectra of Organic Molecules*, Amsterdam: Elsevier Publishing Co., 1968.

12.1.3 Questions

- What is mass spectrometry?
- Describe the theory behind its use as an identification technique.
- What types of information are obtained from a GC/MS?
- Draw a schematic diagram of a GC/MS. What is the purpose of each component?
- Define the following terms:
 - o Relative abundance
 - o Base peak
 - o Molecular ion
 - o Precursor ion
 - o *Product ion
 - o Mass/charge ratio
 - o Mass spectrum
 - o Unit mass resolution
 - o Normalization
 - o Carbonium ion
 - o Cleavage
 - o Dalton
 - o Isobaric
 - o Radical
 - o Doubly charged ion
 - o Calibration compound
 - o Torr
 - o Atmosphere
 - o Total Ion Current
- What is the sensitivity of a GC/MS?
- What factors determine the sensitivity?
- What is the difference between spectrometry and spectroscopy?
- Why can column bleed cause a problem in GC/MS and how is it corrected? Septum bleed?
- How can non-volatile compounds be introduced into a mass spectrometer?
- What things must an interface between a GC and a MS accomplish?
- Explain and diagram the capillary direct method of sample transfer for the Agilent systems in the laboratory.
- What is the most common mode of ionization?
- Diagram and describe the components of E.I. source for the MS in your lab.
 - o Are the ions formed positive or negative?
 - o Do they have an even or odd number of electrons?
 - o What is the ionization efficiency of this technique?
 - o What governs the relative abundance of the ions formed?
- What governs the number and energy of the electrons emitted by the filaments?
- From what are the filaments made?
- What is an “ionization appearance potential” curve?
- What is the usual electron energy used in an E.I. source for complete ionization and why?
- What effect does variation in this energy have on ion abundance?
- If a molecule is ionized with energy just at its appearance potential, what information may be obtained?
- What vacuum conditions are necessary in the ionization source and the analyzing regions of a MS and why?
- Describe how a rough pump works.

- Describe how a diffusion pump works.
- Describe how a turbomolecular pump works.
- Is it necessary that the vacuum remain constant?
- What temperature conditions must be maintained in the ion source?
- Explain how chemical ionization is performed.
- What are its advantages/disadvantages with respect to electron ionization?
- What is the number of fragment ions produced by this method dependent on?
- Do the ions formed by this process have an even or odd number of electrons?
- Describe how a quadrupole mass analyzer works.
- What factors influence the practical limits of the quadrupole as a mass filter?
- What determines whether an ion will have a stable trajectory through the quadrupoles?
- Draw a graphical representation of ion stability for ramping DC and RF voltages in a quadrupole filter.
- For the following detectors, describe the theory behind them as well as how they work:
 - o Time of flight
 - o Ion trap
- Define mass resolution.
- What does a resolution of 500 mean?
- What is the resolution a function of?
- Describe how an electron multiplier works.
- Why is it referred to as a continuous dynode?
- With what is the inner surface of the electron multiplier coated?
- What is a “high energy dynode” and how does it work?
- Why is the electron multiplier the detector of choice?
- What are the limiting factors as to how well an electron multiplier can detect incoming ions?
- Explain how the PBM library search routines work.
- How does the software decide which peaks to use?
- What makes a peak significant to each of these searches?
- What are the limitations of the computer library?
- What reference spectra collections are available for your use?
- Do they consist of “normalized” data?
- Do they contain verified data?
- If not, are they still viable references for spectral comparisons?
- List what the base peaks and molecular ions are for each of the following:
 - o Dodecane
 - o Toluene
 - o Acetone
 - o 1, 2, 4 Trimethylbenzene
 - o Methylene chloride
- Can o-xylene and p-xylene be distinguished by MS?
- Can enantiomers and diastereomers be differentiated via MS?
- List the isotopic abundances for each of the following elements: H, C, N, O, F, Si, P, S, Cl, Br, I
- What is the nitrogen rule?
- If a molecular formula has been determined, how can the number of rings and double bonds be determined?
- What influences what bond sites will be ruptured to create molecular fragments?
- Describe how fragmentation patterns are influenced by:
 - o Branched carbon atoms
 - o Double bonds
 - o Rings
 - o Hetero-atoms
 - o Carbonyl groups
- What are the M+2 (or A+2) elements?
- What percentage of intensity of a molecular ion is contributed to the M+1 peak by carbon atoms?
- What is the formula for calculating the number of carbon atoms in a molecule?
- How can the M+1 peak be used to determine the molecular weight?

- What requirements are necessary for an ion to be considered a molecular ion?
- Define the term “logical neutral loss” and give examples.
- What mass losses during fragmentation are highly unlikely?
- What is the most desirable characteristic of mass spectra of trimethylsilyl derivatives?
- In what types of compounds is a molecular ion peak frequently not detectable?
- In what types of compounds are molecular ion peaks most likely to occur?
- What do the peaks occurring at higher mass numbers than the molecular ion often represent?
- What ions can be associated with the following m/z ratios?
 - o 43
 - o 58
 - o 77
 - o 91
- Describe the term “rearrangement”.
- Describe a “gamma hydrogen (McLafferty) rearrangement” and show examples.
- Describe an “adjacent hydrogen rearrangement” and show examples.
- Define the following terms and describe how these terms relate mass spectrometry to chromatography?
 - o scan rate
 - o scan cycle time
 - o reset time
 - o a/d conversion rate
 - o spectral tilting
 - o Mass peak detect threshold
 - o GC peak detect threshold
- Explain the terms “sequence file”, “sequence log”, “macro” and “data file”.
- Draw the structure of PFTBA and relate the structure to the ions found in the autotune report.
- What macros are used on the GC/MS in your laboratory and how do they work?
- Explain sequencing and what its utility is.
- Set up a sequence table on MassHunter. Print out the result in “brief” format and describe what each field represents.
- Describe the autotuning procedure, explaining what each part of the program accomplishes.
- Describe how to perform the following techniques:
 - o Headspace analysis
 - o Wet needle injection
- What is SIM and what is it used for?
- Under what conditions can a MS be used for quantitation?
- Describe the preventative maintenance schedule and the QA/QC procedures performed on the GC/MS.
- Describe the use of blanks on the GC/MS.
- Briefly describe the various techniques of “Atmospheric Pressure Ionization” including:
 - o Electrospray (ES)
 - o Atmospheric pressure chemical ionization (APCI).
- Explain as to a jury how a mass spectrometer operates.

12.1.4 Practical Exercises

- 12.1.4.1 The trainer will show the trainee all of the components of the GC-MS system.
- 12.1.4.2 Perform a standard spectra autotune on the GC/MS and describe what each value on the report represents. What types of parameter values may indicate a problem with the instrument?
- 12.1.4.3 The trainer will discuss the criteria for acceptance of the daily autotune.
- 12.1.4.4 The trainee will perform the daily QC procedures for the GC-MS for a minimum of one week.
- 12.1.4.5 Obtain an unknown spectrum from the trainer. Using interpretive methods, give as much

information about the unknown compound as possible.

- 12.1.4.6 Create two methods using the parameters listed below. Run a dodecane standard on each method and compare the results.

12.1.4.6.1 Method 1

- Oven temperature: 220 – 240 °C @ 20 °C / minute
- Scan Range: 400 – 14 amu
- a/d = 4

12.1.4.6.2 Method 2

- Oven temperature: 220 – 240 °C @ 20 °C / minute
- Scan Range: 400 – 14 amu
- a/d = 0

- 12.1.4.7 Change the background method so that the mass detect threshold is set to zero. Run the background and discuss the different possibilities for setting the thresholds in methods for trace evidence.

- 12.1.4.8 Perform a headspace injection of a mixture of volatile solvents.

12.1.5 Evaluation

- 12.1.6 The trainer will review the written answers to the questions with the trainee.

- 12.1.7 Review of practical exercises.

- 12.1.8 The trainee will be quizzed on the subject matter.

12.2 Sample Preparation and Data Collection

12.2.1 Objective

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Prepare and inject samples to include gases, whole liquids and extracts.

12.2.2 Required Reading

Trace Evidence Procedures Manual, GC-MS section.

12.2.3 Question

The trainee will provide written answers to the following question:

- Describe differences in the parameters for the analysis of: gases/liquids; strong/weak; and references/standards versus case samples.

12.2.4 Practical Exercises

- 12.2.4.1 The trainer will demonstrate headspace and liquid injections.

- 12.2.4.2 The trainer will demonstrate how to set-up the instrument for single as well as autosampler injections including daily QC checks.

12.2.4.3 The trainee will inject samples that are relevant to or a part of their subdiscipline training.

12.2.5 Evaluation

12.2.5.1 The trainer will review the written answers to the questions with the trainee.

12.2.5.2 The trainer and the trainee will review and discuss the pertinent points of the readings.

12.2.5.3 Review of practical exercises.

12.2.5.4 The trainee will complete a technical question and answer session on the GC-MS.

12.2.5.5 The trainee will demonstrate the ability to perform routine maintenance on the instrument to include as a minimum; cleaning of the source, GC column replacement and basic troubleshooting.

12.3 Competency Evaluation and Mock Trial

The trainee will use GC-MS when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

13 GENERAL CHEMICAL

13.1 Overview of General Chemical Examinations

- 13.1.1 General Chemical analyses are those that require chemistry-related examinations of evidentiary material that are not believed to be a controlled substance. It should be noted that identification of an unknown may not be possible; however, general classification of a substance is usually achievable.
- 13.1.2 General Chemical exams may be conducted on a variety of evidentiary materials which include, but are not limited to:
- Bank dyes (see ¶ 24)
 - Tear gas and Pepper sprays (see ¶ 25)
 - Sugar/salt
 - Inks
 - Tapes, adhesives and glues (¶ 26)
 - Acids and bases
 - Cosmetics
 - Tars, asphalts, oils and greases
 - Crayons and other waxes
 - Nitrous oxide
 - Condom lubricants
 - Soaps and cleaning products
 - Clandestine laboratory precursors
- 13.1.3 An examiner trainee will only be assigned general chemical cases after certification in another sub-discipline. A separate mock trial exercise is not required.
- 13.1.4 Cases requiring specific instrumentation will only be assigned to examiners who have completed the section in the Training Manual for that instrument.

13.2 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to analyze various types of evidentiary materials as listed in ¶ 13.1.2.

13.3 Required Readings

- 13.3.1 Any appropriate and applicable reading, as determined by the trainer.
- 13.3.2 Virginia Department of Forensic Science, Trace Evidence Procedures Manual, ¶ 6 General Chemical.
- 13.3.3 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide (applicable sections).

13.4 Questions

- 13.4.1 List examples of some common classifications of compounds that are received by the Trace Evidence section as general unknowns.
- 13.4.2 Discuss the use and list examples of non-destructive techniques which can be used to characterize general unknowns.
- 13.4.3 Discuss different approaches for solid and liquid samples.
- 13.4.4 Discuss the use of reference materials in the analysis of general unknowns.

- 13.4.5 Define “class characteristics.”

13.5 Practical Exercises

- 13.5.1 The trainee should document the review of at least three applicable case files previously examined by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.
- 13.5.2 Obtain at least three known applicable samples (Acid/Base, salt, sugar, etc.) from the trainer for analysis, following the applicable protocols in the Trace Evidence Procedures Manual, if available.
- 13.5.3 Obtain at least two applicable unknown samples from the Trainer. Analyze these samples along with the appropriate controls as if mock cases. Submit the case notes, data, and report wording to the Trainer.

13.6 Evaluation

- 13.6.1 The trainer will review the written answers to the questions with the trainee.
- 13.6.2 Review of practical exercises.

14 GLASS

14.1 Introduction to Glass

14.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The history of glass;
- Manufacturing processes and applications of glasses;
- The chemical composition, to include formulations, of glass; and,
- The general aspects of forensic glass examinations.

14.1.2 Required Readings

- 14.1.2.1 Almirall, J., et al., “Examination of Glass”, Forensic Interpretation of Glass Evidence, Curran, J., et al. ed., CRC Press, Florida, 2000, pp. 1-6.
- 14.1.2.2 Copley, Geoffrey J., “The composition and manufacture of glass and its domestic and industrial applications”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 27-46.
- 14.1.2.3 De Forest, Peter, “What is Trace Evidence?”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 17-19.
- 14.1.2.4 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 161-180, pp. 202-209.
- 14.1.2.5 Thornton, J. I., “Interpretation of Physical Aspects of Glass Evidence”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 97-118.

14.1.3 Questions

The trainee will provide written answers to the following questions:

- Define glass.
- Why is glass useful forensic evidence?
- Give a brief summary of the history of glass, from its “invention” to its present day use.
- What is the purpose of Si, Na and Ca in glass in ordinary soda lime glass?
- What elements can be used to provide glass with improved resistance to thermal expansion, alkali and acid?
- What are some of the colorants and discolorants used in the formulation of glass?
- Explain formers, modifiers and intermediates.
- Define cullet.
- Explain the basic manufacturing process for container glass, float glass, tempered glass and laminated glass.
- Describe the benefits of tempering.
- Describe annealing and explain its production process.
- What are the manufacture end uses for tempered, laminated, wire reinforced and low-e glass?

14.1.4 Evaluation

- 14.1.4.1 The trainer will review the written answers to the questions with the trainee.

14.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

14.1.4.3 The trainee will be quizzed on the subject matter.

14.2 Recognition, Collection, Packaging and Controls

14.2.1 Objectives

Through completion of this module, the trainee will have developed and demonstrated theoretical knowledge and/or practical skills relating to:

- Recognize and preserve other evidentiary materials;
- Describe the proper collection of glass evidence; and,
- Make recommendations for proper packaging of glass evidence.

14.2.2 Required Readings

14.2.2.1 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide.

14.2.2.2 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 179.

14.2.3 Questions

The trainee will provide written answers to the following questions:

- Describe how evidence should be collected and packaged for each of the following scenarios as it would be described to an investigator who has made an inquiry:
 - Two suspects, 3 separate businesses
 - One suspect, a single residence B & E, multiple windows broken
- Why should clothing for glass examination and the known glass sample never be packaged in the same container?
- Why should a sample of glass be collected from every broken window at the scene?
- Why should glass evidence be collected from the frame or frames rather than the ground/floor/windowsill?
- Explain the types of packaging used with glass evidence. Include advantages and disadvantages of these types of packaging.
- Is tape a preferred method of glass collection for known or questioned glass samples for submission to the laboratory? Explain.

14.2.4 Practical Exercise

14.2.4.1 Demonstrate an evidence fold to the trainer.

14.2.5 Evaluation

14.2.5.1 The trainer will review the written answers to the questions with the trainee.

14.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

14.2.5.3 Review of practical exercise.

14.3 Physical Properties of Glass

14.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Determine the physical properties of glass to include: color, texture, thickness, temper, float, flat, container, type, and other surface characteristics;
- Demonstrate the use of a micrometer;
- Demonstrate the use of a continuity tester to determine if a glass sample has a low-e surface coating; and,

14.3.2 Required Reading

- 14.3.2.1 Almirall, J., et al., “Examination of Glass”, Forensic Interpretation of Glass Evidence, Curran, J., et al. ed., CRC Press, Florida, 2000, pp. 2-5 and 10-14.
- 14.3.2.2 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 180-186.
- 14.3.2.3 Thornton, J. I., “Interpretation of Physical Aspects of Glass Evidence”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 97-121.

14.3.3 Questions

The trainee will provide written answers to the following questions:

- How is a glass sample determined to be a float or non-float type?
- How is a broken tempered glass source identified?
- How do density and refractive index relate?
- Describe the types of density determination/comparison processes. Why doesn't DFS perform this examination?
- What are some identifiable characteristics of container glass, including surface and physical characteristics that can be determined visually and microscopically?
- How is low-e glass identified?
- How is laminated glass identified?
- What physical properties are normally measured or noted in glass analysis?

14.3.4 Practical Exercises

- 14.3.4.1 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for glass analysis.
- 14.3.4.2 The trainer will demonstrate how each physical property is determined for glass samples.
- 14.3.4.3 The trainer will provide at least twenty different glass samples for the trainee to determine physical properties. Glass samples will include, at a minimum: mirror, wire-reinforced, flat (float, non-float, tempered, non-tempered), laminated, container, decorative, and low-e glass. The trainee will fill out a glass worksheet for each glass sample detailing the observations made.

14.3.5 Evaluation

- 14.3.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.3.5.3 Review of practical exercises.
- 14.3.5.4 The trainee will be quizzed on the subject matter.

14.4 Basic Microscopic Evaluation of Glass and Other Materials

14.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Discuss microscopy theory and applications;
- Properly use a stereomicroscope and polarized light microscope;
- Make microscopic observations of glass, sand and other materials;
- Determine if a material is isotropic or anisotropic;
- Identify microscopic particles as glass; and,
- Perform refractive index estimations using the Becke line technique.

14.4.2 Required Readings

- 14.4.2.1 Almirall, J., et al., “Examination of Glass”, Forensic Interpretation of Glass Evidence, Curran, J., et al. ed., CRC Press, Florida, 2000, pp. 2-5 and 10-14.
- 14.4.2.2 De Forest, P. R., “Foundations of Forensic Microscopy”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 216-319.
- 14.4.2.3 Hamer, P. S., “Microscopic Techniques for Glass Examination”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 47-62.
- 14.4.2.4 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed. Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 186-195.

14.4.3 Questions

The trainee will provide written answers to the following questions:

- Prepare a brief technical explanation of the following types of microscopes:
 - Compound microscope
 - Stereo microscope
 - Phase contrast microscope
 - Polarized light microscope (PLM)
- What characteristics can be observed from the microscopic examination of a glass particle?
- Define and explain the terms isotropic, anisotropic and birefringence.
- What information can be determined from the observed degree of contrast between a particle and the oil medium?
- What information can be determined using the Becke Line technique?
- Describe the procedure for adjusting a microscope to Köhler Illumination.

14.4.4 Practical Exercises

- 14.4.4.1 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.
- 14.4.4.2 The trainee will conduct stereoscopic examinations of glass, sand and other common materials. Record observations to include: color, clarity and shape.
- 14.4.4.3 The trainee will conduct PLM examinations of glass, sand and other common materials in oil mounts. Record if the materials are isotropic or anisotropic and note the Becke line movement.
- 14.4.4.4 The trainee will observe glass samples mounted in Cargille oils with refractive indices below, near and above that of the glass sample. Record the isotropic property, degree of contrast (relief) and refractive index relative to the mounting oil.
- 14.4.4.5 The trainee will be given a set of unknown glass samples. Estimate the refractive index of each sample by Becke line technique using Cargille oils.

14.4.5 Evaluation

- 14.4.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.4.5.3 Review of practical exercises.

14.5 Introduction to GRIM3 Theory and Application

14.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Perform the calibration of the system;
- Perform QA and QC checks and assess proper operation of system;
- Understand the components of system; and,
- Perform routine troubleshooting and maintenance.

14.5.2 Required Readings

- 14.5.2.1 GRIM3 User Manual 08, September 2006.
- 14.5.2.2 Hamer, P. S., "Microscopic Techniques for Glass Examination", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 56-62.
- 14.5.2.3 Manual for Locke Scientific Reference Glasses and Silicone Oils for Refractive Index Determination (Parts 1 through 7).
- 14.5.2.4 Trace Evidence Section Procedures Manual for Glass.

14.5.3 Questions

The trainee will provide written answers to the following questions:

- What are the main components of the GRIM3 system?
- What wavelength is used for routine refractive index measurements?
- How is the wavelength changed on the GRIM3?
- What data is actually measured by the GRIM3 to determine refractive index?
- Explain the QA and QC checks on the GRIM3 system

14.5.4 Practical Exercises

- 14.5.4.1 The trainer will demonstrate the operation of the GRIM3 system.
- 14.5.4.2 The trainee will at a minimum perform a complete calibration of the system for Silicone Oil B using the B series of standards. Additionally, the trainee may perform the calibration for Silicone Oil A using Standards A2 through A5 and Standards B1 and B2.
- 14.5.4.3 The trainee will measure a minimum of five of the B series standards as samples using the calibration generated in 14.5.4.2. Assess the measured values against the certified values for the standards.
- 14.5.4.4 The trainer will demonstrate how the hot stage and slide are cleaned. The trainer will also demonstrate how the interference filter on the microscope is cleaned, and how the microscope lamp is changed.

14.5.5 Evaluation

- 14.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.5.5.3 Review of practical exercises.

14.6 Refractive Index Measurement

14.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Assess a glass sample to determine the appropriate sampling technique and oil selection for refractive index measurement;
- Measure the refractive index of glass samples using the GRIM3 system; and,
- Determine if the refractive index of questioned glass particles and/or samples is consistent with the refractive index of a known glass sample.

14.6.2 Required Readings

- 14.6.2.1 Almirall, J., et al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J. M., et al., ed., CRC Press, Florida, 2000, pp. 17-22 and 26.
- 14.6.2.2 Hamer, P. S., "Microscopic Techniques for Glass Examination", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 56-62.
- 14.6.2.3 Marcouiller, J. M., "A Revised Glass Annealing Method to Distinguish Glass Types," *Journal of Forensic Sciences*, 35(3), May 1990, pp. 554-559.

- 14.6.2.4 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 195-202.
- 14.6.2.5 Newton, A. W. N., et al., “A Study of the Performance and Utility of Annealing in Forensic Glass Analysis,” *Forensic Science International*, Vol. 155, 2005, pp. 119-125.
- 14.6.2.6 Sandercock, P. M. L., “Sample Size Considerations for Control Glass in Casework,” *Canadian Society of Forensic Science Journal*, 33(4), 2000, pp. 173-185.

14.6.3 Questions

The trainee will provide written answers to the following questions:

- Define refractive index.
- Why is the property of refractive index useful for forensic glass examinations?
- What are the limitations of refractive index for forensic glass examinations?
- Explain Snell’s Law.
- Explain dispersion.
- Explain the relationship between refractive index and dispersion.
- Define annealing.
- How does annealing affect refractive index?
- What are N_C , N_D and N_F ?
- Describe the Emmen’s Double Variation Method and GRIM3. Compare and contrast.
- Why are silicone oils used versus other types of oil media for refractive index measurement?

14.6.4 Practical Exercises

- 14.6.4.1 The trainee will measure the refractive index of the glass samples examined in 14.3.4.3 using the GRIM3.
- 14.6.4.2 The trainer will provide the trainee with a set of ten glass samples to be treated as unknowns that are obtained from glass standards with certified refractive index data. The trainee will measure the refractive index of the glass samples using the GRIM3.
- 14.6.4.3 The trainer will give the trainee ten sets of glass samples, each set to include a minimum of one “known” and one “questioned” glass sample. The trainee will examine the physical properties, refractive index and density to determine if the “known” and “questioned” samples can be associated. The testing conducted should be done to the extent necessary to draw a conclusion.

14.6.5 Evaluation

- 14.6.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.6.5.3 Review of practical exercises.

14.7 Glass Particle Recovery and Collection from Clothing, Tools and Other Objects

14.7.1 Objectives

Through completion of this module, the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Work with extremely small samples;
- Recognize and recover glass from debris that has been recovered from clothing, tools and other objects;
- Clean recovered glass particles in preparation for refractive index measurement;
- Prepare a mount and sketch of the recovered glass particles; and,
- Discuss transfer and persistence of glass particles on clothing.

14.7.2 Required Readings

- 14.7.2.1 Almirall, J., et al., “Examination of Glass”, Forensic Interpretation of Glass Evidence, Curran, J. M., et al., ed., CRC Press, Florida, 2000, pp. 6-10 and 14-21.
- 14.7.2.2 Brewster, Fay, et al., “The Retention of Glass Particles on Woven Fabrics,” *Journal of Forensic Sciences*, 30(3), July 1985, pp. 798-805.
- 14.7.2.3 Curran, J. M., et al., ed., “Glass Found at Random and Frequency of Glass”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 87-102.
- 14.7.2.4 Curran, J. M., et al., ed., “Transfer and Persistence Studies”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 103-122.
- 14.7.2.5 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 179.
- 14.7.2.6 Petterd, J.H., et al., “Glass particles in the clothing of members of the public in south-eastern Australia- a survey,” *Forensic Science International*, Vol. 103, 1999, pp. 193-198.
- 14.7.2.7 Thornton, J. I., “Interpretation of Physical Aspects of Glass Evidence”, Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, Brian, ed., Taylor & Francis, New York, 2001, pp. 116-118.

14.7.3 Questions

The trainee will provide written answers to the following questions:

- Describe the overall examination scheme for forensic glass examination.
- Why and how does broken glass transfer occur?
- What are some ways broken glass can be transferred from its source to an object or clothing item?
- How do fabric type and construction affect the retention of glass particles on clothing?
- How does the type of material and time affect the retention of glass particles on clothing?
- Why are shoes not necessarily the best evidence for glass examination?
- Why does the Department of Forensic Science Trace Evidence Section combine clothing items but does not include shoes?
- When is it not appropriate to combine clothing items?
- How should shoes be processed if an impressions examination is requested?
- How should an object or tool be processed? How should it be processed if a latent prints examination is requested?
- Describe how glass particles may be retained on a tool/object.

14.7.4 Practical Exercises

- 14.7.4.1 The trainer will provide several glass samples that are large enough to allow the trainee to familiarize themselves with the manipulation of glass particles using the stereomicroscope.

- 14.7.4.2 The trainer will provide a “debris” sample with a large number of glass particles in it. The trainee will search the debris and recover at least twenty particles. Ten glass particles will be mounted on a slide “as is” for refractive index determination. Another ten glass particles will be cleaned using the procedure described in the Glass section of the Trace Evidence Procedures Manual and mounted on a separate slide for refractive index determination. Refractive index will be determined using the GRIM3 and the data for both slide preparations will be compared.
- 14.7.4.3 The trainer will provide a “debris” sample with a known number of glass particles. The trainee will search the debris and report the number glass particles. A “known” glass sample or samples will also be provided so that the complete examination may be conducted as a practice case. Additional similar exercises may be conducted as appropriate.
- 14.7.4.4 The trainer will provide the trainee with two or three exercises set up with clothing, tools or other objects that contain a known number of glass particles. The trainee will search the debris and report the number glass particles. A “known” glass sample or samples will also be provided so that the complete examination may be conducted as a practice case. Additional similar exercises will be conducted as appropriate.
- 14.7.5 Evaluation
- 14.7.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.7.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.7.5.3 Review of practical exercises.

14.8 Glass Fracture Examinations

14.8.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Assess the characteristics of different types of glass fractures to include those caused by impact, heat, projectiles and glass cutters;
- Perform point of impact and direction of impact examinations;
- Perform sequence of impact examinations; and,
- Perform fracture match examinations.

14.8.2 Required Readings

- 14.8.2.1 Curran, J. M., et al., “Examination of Glass”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 6-10.
- 14.8.2.2 Haag, M.G., “Asymmetrically-Positioned Concentric and Radial Cracks at Shallow-Angle Glass Impact Sites for Determination of Projectile Direction of Travel”, *AFTE Journal*, 48(3), Summer 2016, pp. 173-177.
- 14.8.2.3 Hueske, E.E., “Chapter 13: Bullet Ricochet Phenomena”, Practical Analysis and Reconstruction of Shooting Incidents, CRC Press, Florida, 2016, pp. 259-286.
- 14.8.2.4 Kirk, P. L., “Glass”, Crime Investigation, 2nd Edition, John Wiley & Sons, New York, 1974, pp. 261-267.

- 14.8.2.5 Koons, Robert D., et al., “Forensic Glass Comparisons”, Saferstein, R., ed., Forensic Science Handbook, Vol. 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, p. 179, pp.173-177.
- 14.8.2.6 Thornton, J. I., “Interpretation of Physical Aspects of Glass Evidence”, Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor & Francis, New York, 2001, pp. 98-116.
- 14.8.2.7 Van Arsdale, M., “Determining Bullet Trajectory From a Ricochet off Windshield Glass”, *AFTE Journal*, 30(2), Spring 1998, pp. 309-315.

14.8.3 Questions

The trainee will provide written answers to the following questions:

- What is the 4R rule?
- Explain how direction of impact determinations can be made.
- Explain how sequence of impact determinations can be made.
- Explain hackling.
- Explain each of the following types of glass fracture and list the primary characteristics of each: impact fractures, heat fractures, fractures caused by projectiles, fractures caused by low angle bullet deflection off of laminated windshields, glass cutters.
- Describe the process of glass fracture by impact as it relates to compression and tension forces.
- Describe how the evidence for direction and sequence of impact determinations should be collected and packaged.

14.8.4 Practical Exercises

- 14.8.4.1 The trainee will break glass objects, such as window panes and bottles, by various methods, and examine fracture characteristics. This exercise should include glass breakage by thrown objects, by tools and by projectiles. At least one example of sequence of impact should be conducted. The trainee will write a summary of this exercise to include observations made.
- 14.8.4.2 The trainee will be given at least three broken glass panes with unknown direction of force. The trainee will document observations and determine direction of force. Additional similar exercises will be conducted as appropriate.
- 14.8.4.3 The trainee will successfully complete the Fracture Match Section of the Trace Evidence Training Manual.
- 14.8.4.4 The trainee will be given at least three exercises involving fracture match examinations. The exercises should be designed to include both positive and negative fracture match results.

14.8.5 Evaluation

- 14.8.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.8.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.8.5.3 Review of practical exercises.

14.9 Supervised Work-Along

- 14.9.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope

of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.

- 14.9.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.
- 14.9.3 The trainee shall work at least ten forensic cases as a technician under the direct supervision of a qualified glass examiner. The trainer should ensure as much variety in the work-along as is practicable. At least five of the glass cases must be associative reports.

14.10 Forensic Significance of Glass

The trainer and the trainee will discuss the interpretation of glass evidence and its relevance and weight in reports and in testimony. Discussions will include probabilities versus possibilities.

14.10.1 Objectives

Through completion of this module, the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Knowledge of the capabilities and limitations of analytical instrumentation with reference to comparison of glass
- Knowledge of other examinations used in the forensic community for glass analysis
- Ability to interpret data and draw conclusions
- Application of frequency of occurrence data

14.10.2 Required Readings

- 14.10.2.1 Almirall, Jose R., “Elemental Analysis of Glass Fragments,” Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor & Francis, New York, 2001, pp. 65-81.
- 14.10.2.2 Curran, J. M., et al., “Glass Found at Random and Frequency of Glass”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 87-102.
- 14.10.2.3 Curran, J. M., et al., “Transfer of Persistence Studies”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 103-131.
- 14.10.2.4 Curran, J. M., et al., “Reporting Glass Evidence”, Forensic Interpretation of Glass Evidence, CRC Press, Florida, 2000, pp. 153-163.
- 14.10.2.5 Daeid, Niamh Nic, “Statistical Interpretation of Glass Evidence,” Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor & Francis, New York, 2001, pp. 85-94.
- 14.10.2.6 Evett, I.W., and Lambert, J.A., “The Interpretation of Refractive Index Measurements. IV,” *Forensic Science International*, Vol. 24, 1984, pp. 149-163.
- 14.10.2.7 Koons, R. D. and Buscaglia, M.S., “The Forensic Significance of Glass Composition and Refractive Index Measurements,” *Journal of Forensic Sciences*, 44(3), 1999, pp. 496-503.
- 14.10.2.8 Meyer, R., et al., “Forensic glass analysis and frequency of occurrence,” *Midwestern Association of Forensic Scientists*, 17(4), 1998, pp. 19-38.
- 14.10.2.9 Miller, Elmer T., “Forensic Glass Comparisons”, Forensic Science Handbook, Saferstein, R., ed., Prentice-Hall, New Jersey, 1982, pp. 165-168.

- 14.10.2.10 Newton, A. W. N., et al., “The Consequences of potentially differing distributions of the refractive indices of glass fragments from control and recovered sources,” *Forensic Science International*, Vol. 140, 2004, pp. 185-193.

14.10.3 Questions

The trainee will provide written answers to the following questions:

- What criteria must be met to report an association of glass evidence?
- What are the limitations of the frequency of occurrence data?
- How is frequency of occurrence data obtained?
- What frequency of occurrence data is used to obtain conclusion strength?
- What factors affect the strength of the conclusion in glass comparisons?
- Describe other criteria used in the forensic community for determining associations and the conclusion strength.
- Describe other examinations and instruments used in the forensic community for glass analysis, with emphasis on elemental analysis.

14.10.4 Practical Exercises

- 14.10.4.1 The trainee will draw conclusions and write a report for the examinations completed in 14.7.4.3 and 14.7.4.4.

14.10.5 Evaluation

- 14.10.5.1 The trainer will review the written answers to the questions with the trainee.
- 14.10.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 14.10.5.3 Review of practical exercises.

14.11 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

14.12 Glass Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified glass examiners, the Chemistry Program Manager, and the Section/Group Supervisor.

The presentation may cover either: the general theory and application of the instrumentation used in glass analysis and the forensic examination of glass or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic glass community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee's training program.

14.13 Technical Final

The trainee will field questions related to any/all aspects of their glass training.

14.14 Competency Evaluation and Mock Trial

14.14.1 As the trainee progresses through glass training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these "case" files completed prior to issuance of the final practical test.

14.14.2 Using one or all of the "cases" from 14.14.1, the trainee will undergo a series of "mini-mock trial" practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.

14.14.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

14.14.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

14.15 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

15 HAIR**15.1 Introduction to Hair****15.1.1 Objectives**

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The history and use of hair examinations; and,
- Hair terminology.

15.1.2 Required Readings

- 15.1.2.1 Introduction to Hairs and Fibers Training Course Materials, F.B.I., March 2007 (only hair sections).
- 15.1.2.2 Bisbing, Richard E., “The Forensic Identification and Association of Human Hair”, Saferstein, Richard, ed., Forensic Science Handbook, Volume 1, 2nd ed., Pearson Education, Inc., Upper Saddle River, NJ, 2002, pp. 389-428.
- 15.1.2.3 Deedrick, Douglas W. and Koch, Sandra L., “Microscopy of Hair Part I: A Practical Guide and Manual for Human Hairs”, *Forensic Science Communications*, 6(1), January 2004.
- 15.1.2.4 Deedrick, Douglas W. and Koch, Sandra L., “Microscopy of Hair Part II: A Practical Guide and Manual for Animal Hairs”, *Forensic Science Communications*, 6(3), July 2004.
- 15.1.2.5 Petraco, N. and Frass, C., “Morphology and Evidential Significance of Human Hair Roots”, *Journal of Forensic Sciences*, Vol. 33, 1988, pp. 68-76.
- 15.1.2.6 Tridico, S., “Examination, Analysis, and Application of Hair in Forensic Science-Animal Hair.” *Forensic Science Review*, 17(1), 2005, pp. 17-28.

15.1.3 Questions

The trainee will provide written answers to the following questions:

- Define the following:
 - Anagen
 - Body hair
 - Catagen
 - Cortex
 - Cortical fusi
 - Follicle
 - Fur hairs
 - Guard hairs
 - Keratin
 - Limb hair
 - Medulla
 - Melanin
 - Ovoid bodies
 - Papilla
 - Pigment granules
 - Putrid root
 - Scales
 - Tactile hairs
 - Telogen

- Transitional hair
- Vellus hair

15.1.4 Evaluation

- 15.1.4.1 The trainer will review the written answers to the questions with the trainee.
- 15.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

15.2 Recognition, Collection, Packaging and Controls

15.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Collect hair and fiber evidence;
- Describe to an investigator the proper way to collect hair evidence;
- Recommend proper packaging for hair evidence;
- Detail the proper controls that are to be taken and why; and,
- Describe the contents of a Virginia DFS PERK kit.

15.2.2 Required Readings

- 15.2.2.1 Palenik, Skip, “Microscopy and Microchemistry of Physical Evidence”, Saferstein, R., Volume II, Prentice Hall, Englewood Cliffs, NJ, 1988, pp. 161-168.
- 15.2.2.2 Robertson, J. and Roux, C., “From the Crime Scene to the Laboratory– Transfer, Persistence and Recovery of Fibres.” In: Robertson, J. and Grieve, M. (editors). Forensic Examination of Fibres, 2nd edition, 89-100 (chapter. 5.1). London: Taylor and Francis. 1999.
- 15.2.2.3 Springer F., “From the Crime Scene to the Laboratory – Collection of Fibre Evidence from Crime Scenes.” In: Robertson, J. and Grieve, M. (editors). Forensic Examination of Fibres, 2nd edition, 101-115 (chapter. 5.2). London: Taylor and Francis. 1999.
- 15.2.2.4 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide.

15.2.3 Questions

The trainee will provide written answers to the following questions:

- What knowns are to be collected?
- How are the knowns to be collected?
- Describe three ways of collecting hairs from clothing.
- Describe the advantages and disadvantages of each the three techniques.
- What type of textile material has good hair/fiber retention properties?

15.2.4 Practical Exercises

- 15.2.4.1 Demonstrate the druggist or paper fold to the trainer.
- 15.2.4.2 Describe proper measures to avoid body fluid and hair/fiber contamination of evidence.

15.2.4.3 Explain to the trainer the information you would give an officer for recognition, collection and packaging of hair evidence.

15.2.4.4 Demonstrate and discuss how you would use post-it-notes in hair examinations.

15.2.4.5 Practice collecting hair from a variety of items (e.g., clothing, brush, tape, items of various sizes and surface textures).

15.2.5 Evaluation

15.2.5.1 The trainer will review the written answers to the questions with the trainee.

15.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

15.2.5.3 Review of practical exercises.

15.2.5.4 The trainee will be quizzed on the subject matter.

15.3 Stereomicroscopic Evaluation and Microscopic Examination

15.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Distinguish animal hairs from human hairs;
- Prepare temporary and permanent microscopic slides of hairs;
- Evaluate hairs for nDNA and mtDNA analysis;
- Determine the physical properties of hairs to include: color, texture, thickness, and other characteristics;
- Use a stereomicroscope properly; and,
- Use a comparison microscope properly.

15.3.2 Required Readings

15.3.2.1 Collins, T. "Mounting Media and Antifade reagents." *Microscopy Today*, 14(1), 2006, pp. 34-39.

15.3.2.2 Hicks, John, Microscopy of Hairs: A Practical Guide and Manual, Federal Bureau of Investigation, U.S. Government Printing Office, Washington, D.C., January 1977.

15.3.2.3 Henson, C.R. and Rowe, W.F. "The Effect of Elevated Temperature on the Microscopic Morphology of Human Head Hair." *Microscope*, Vol. 50, 2002, pp. 21-24.

15.3.2.4 Houck, M. M. and Budowle, B., "Correlation of Microscopic and Mitochondrial DNA Hair Comparisons", *Journal of Forensic Sciences*, 47(5), 2002, pp. 964-967.

15.3.2.5 Linch, C.A., Smith, S.L. and Prahlow, J.A., "Evaluation of the Human Hair for DNA Typing Subsequent to Microscopic Comparison", *Journal of Forensic Sciences*, 43(2), 1998, pp. 305-314.

15.3.2.6 Linch, C.A. and Prahlow, J.A., "Postmortem Microscopic Changes Observed at the Human Head Hair Proximal End", *Journal of Forensic Sciences*, 46(1), 2001, pp. 15-20.

- 15.3.2.7 Long B., Walbridge-Jones S., Lundgren K., et al., "Synthetic Wig Fibers: Analysis & Differentiation from Human Hairs." *Journal of the American Society of Trace Evidence Examiners*, 5(1), 2014, pp. 2-21.
- 15.3.2.8 Moenssens, Andre A., Ray E. Mosses and Fred E. Inbau, Scientific Evidence in Criminal Cases, 3rd ed., The Foundation Press Inc., Mineola, New York, 1986, pp. 475-495.
- 15.3.2.9 Shamala R. and Surekha, R. "Mounting media: An overview." *Journal of Dr. NTR University of Health Sciences*, 3(5), 2014, pp.1-8.
- 15.3.2.10 Wildman, A.B., "The Identification of Animal Fibers", *J. Forensic Science Society*, 1(2), 1961, pp. 1-8.

15.3.3 Questions

The trainee will provide written answers to the following questions:

- List some of the obvious differences between human hairs, animal hairs and fibers.
- Sketch and label a human head hair to include shaft and root portion.
- Sketch the human growth cycles indicating which root forms are suitable for referral for nDNA analysis.

15.3.4 Practical Exercises

- 15.3.4.1 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.
- 15.3.4.2 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for hair analysis.
- 15.3.4.3 The trainer will demonstrate the recovery of hairs and/or fibers from a variety of textile materials or other objects.
- 15.3.4.4 The trainer will demonstrate/discuss color, texture, thickness and other hair characteristics using the stereomicroscope. Synthetic and natural fibers will also be included.
- 15.3.4.5 The trainer will demonstrate and the trainee will practice preparing scale casts of hairs.
- 15.3.4.6 The trainer will demonstrate/discuss microscopic characteristics using the comparison microscope. Synthetic and natural fibers will also be included.
 - 15.3.4.6.1 The microscopic hair characteristics will include, but not be limited to, color, texture, thickness, medullation, pigment, cross-section, growth stage, damage and artifacts.
- 15.3.4.7 The trainer will provide reference samples for the trainee to examine using the stereomicroscope and the comparison microscope. Synthetic and natural fibers will also be included. The trainee will record their observations.
- 15.3.4.8 The trainee will be provided with a series of training sets to assist in determining their ability to correctly assess:
 - Hairs versus fibers
 - Hairs of human versus animal origin
 - Suitability of human hairs for nuclear DNA (PCR) typing

- 15.3.4.9 The trainer will discuss with the trainee how to use microscopic hair characteristics to group hairs for mtDNA analysis.
- 15.3.4.10 Mount several hairs using different temporary and semi-permanent mounting media. Discuss utility, precautions, and limitations in choosing a mounting medium.
- 15.3.4.11 The trainer will issue the trainee with a set of hairs/fibers with different cross-sectional shapes. The trainee will attempt to identify the cross-sectional shape of each fiber prior to making cross sections and then compare results.
- 15.3.4.12 The trainee will practice photographing the root area for documentation purposes and practice demounting hairs from slides.
- 15.3.5 Evaluation
 - 15.3.5.1 The trainer will review written questions with the trainee.
 - 15.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
 - 15.3.5.3 Review of practical exercises.

15.4 Supervised Work-Along

- 15.4.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.
- 15.4.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.
- 15.4.3 The trainee shall work at least ten forensic cases as a technician under the direct supervision of a qualified hair examiner. The trainer should ensure as much variety in the work-along as is practicable.

15.5 Forensic Significance of Hair

- 15.5.1 Required Readings
 - 15.5.1.1 Houck, M., Bisbing, R., Watkins, T. and Harmon, R. “Locard Exchange: The Science of Forensic Hair Comparisons and the Admissibility of Hair Comparison Evidence: Frye and Daubert Considered.” *Modern Microscopy Journal*, 2004, pp. 1-10.
 - 15.5.1.2 Houck M. and Bisbing R., “Forensic Human Hair Examination in the 21st Century.” *Forensic Science Review*, 17(1), 2005, pp. 51-66.
 - 15.5.1.3 Houck, M., “Is Microscopic Hair Comparison a Legitimate Science?” In: Koen, W. and Bowers, C., eds., Forensic Science Reform, London: Academic Press Ltd., 2017, pp. 34-53.
 - 15.5.1.4 Kaye, David H. “Ultracrepidarianism in Forensic Science: The Hair Evidence Debacle.” *Washington & Lee Law Review Online*, 72(2), 2015.
 - 15.5.1.5 Lanning, K.A., Michaud, A.L., Bisbing, R.E., Springer, F.A., and Tridico, S.R., “Scientific Working Group on Materials Analysis Position on Hair Evidence.” *Journal of Forensic Sciences*, 54(5), 2009, pp. 1198-1202.

15.5.1.6 Taupin, J. M. “Forensic hair morphology comparison—a dying art or junk science?” *Science & Justice*, 44(2), 2004, pp. 95-100.

15.5.1.7 Trejos, T., Koch, S., and Mehlretter, A., “Scientific foundations and current state of trace evidence – A review,” *Forensic Chemistry*, 18(100223), May 2020. [May limit to hair portions]

15.5.2 Evaluation

15.5.2.1 The trainer and the trainee will discuss the interpretation of hair evidence and its relevance and weight in reports and in testimony.

15.6 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least five case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft wording for both internal and external reporting as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

15.7 Hair Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified trace evidence examiners, the Chemistry Program Manager, and the Section/Group Supervisor.

The presentation may cover either: the forensic examination of hairs or a current topic from the forensic literature that has been approved by the Chemistry Program Manager that is of interest to the forensic community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee’s training program.

15.8 Technical Final

The trainee will field questions related to any/all aspects of their hair training.

15.9 Competency Evaluation and Mock Trial

15.9.1 As the trainee progresses through hair training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis, as appropriate. There will be a minimum of three of these “case” files completed prior to issuance of the final practical test.

15.9.2 Using one or all of the “cases” from 15.9.1, the trainee will undergo a series of “mini-mock trial” practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.

- 15.9.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

- 15.9.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

15.10 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

16 ION CHROMATOGRAPHY (IC)**16.1 Introduction to Ion Chromatography (IC)****16.1.1 Objectives**

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- Basic IC terminology;
- The theory and basic design of the instrument;
- Sample preparation techniques;
- The interpretation of results;
- The capabilities and limitations of the instrument;
- QA/QC procedures; and,
- Basic troubleshooting.

16.1.2 Required Readings

- 16.1.2.1 Conlon, R. D., Ettre, L. S., and Yost, R. W., Practical Liquid Chromatography – An Introduction, Perkin-Elmer Corporation: Norwalk, CT, 1980.
- 16.1.2.2 Glajch, J. L., Kirkland, J. J., and Snyder, L. R., Practical HPLC Method Development, John Wiley and Sons, Inc., New York, NY, 1988.
- 16.1.2.3 Kirkland, J. J., and Snyder, L. R., Introduction to Modern Liquid Chromatography, John Wiley and Sons, Inc., New York, NY, 1974.
- 16.1.2.4 Shipgun, O. A., and Zolotov, Yu A., Ion Chromatography in Water Analysis, Ellis Horwood Limited, Chitcester, England, 1988.
- 16.1.2.5 Smith, Robert E., Ion Chromatography Applications, 2nd ed., CRC Press, Inc, Boca Raton, FL, 1988.
- 16.1.2.6 Weiss, Joachim, Handbook of Ion Chromatography, Dionex Corporation, Sunnyvale, CA, 1986.
- 16.1.2.7 Dionex ICS-5000⁺ Operator's Manual
- 16.1.2.8 Appropriate manuals for the Eluent Generator Cartridges, Suppressors, and Continuously Regenerated Trap Columns

16.1.3 Questions

The trainee will provide written answers to the following questions:

- What is ion chromatography and what information can be obtained from this technique?
- Diagram a typical IC. Explain the purpose of each component.
- Explain how separation occurs in the column and what factors affect separation.
- What column and mobile phase is used when analyzing for anions/perchlorate? Cations?
- Diagram the suppressor and explain how it works.
- How do absorbance, electrochemical, and conductivity detectors work?
- Compare HPLC with IC.
- What are the IC's limitations?
- Why do we use deionized water in conjunction with the IC? Why is it important to rinse glassware and sample vials with deionized water prior to sample analysis on the IC?

- What can be said about the presence of carbonate ion in case samples?

16.1.4 Practical Exercises

- 16.1.4.1 The trainer will demonstrate the operation of the instrument, anion and cation, to the trainee. The trainee will observe at least one complete set-up and analysis of IC samples.
- 16.1.4.2 The trainer will provide to the trainee a set of 10 anion solutions and a set of 10 cation solutions. The trainee will analyze these solutions which will be properly diluted for comparison with the anion and cation standards.
- 16.1.4.3 The trainee will explain/demonstrate to the trainer how to change an IC column.
- 16.1.4.4 The trainee will be given a minimum of five samples to analyze by IC. These samples will include both anions and cations.

16.1.5 Evaluation

- 16.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 16.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 16.1.5.3 Review of practical exercises.
- 16.1.5.4 The trainee will be quizzed on the subject matter.

16.2 Competency Evaluation and Mock Trial

The trainee will use ion chromatography when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

17 LIGHT MICROSCOPY

17.1 Introduction to Microscopy

17.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The general history of microscopy;
- The theory of light (including dispersion, refraction, diffraction, etc.);
- Optics and image formation;
- Lens aberrations;
- The theory and /or proper use of various types of microscopy (stereoscopic, phase contrast, polarizing, other);
- The construction of various types of microscopes, including the purposes of their various components;
- Proper microscope care and maintenance techniques ;
- Proper microscope illumination techniques;
- Micrometry; and
- Photomicrography.

17.1.2 Required Readings

- 17.1.2.1 DeForest, P.R., “Foundations of Forensic Microscopy”, Saferstein, R., ed., Forensic Science Handbook, Volume 1, 2nd edition, Pearson Education, Inc., New Jersey, 2002, pp. 215-319.
- 17.1.2.2 Delly, J. G., “Photography Through the Microscope,” Kodak Publication P-2, 9th ed., 1988, pp. 1-38.
- 17.1.2.3 McCrone, et al., Polarized Light Microscopy, McCrone Research Institute, Chicago, IL, 1984.
- 17.1.2.4 McCrone & Delly, “The Particle Atlas”, edition II, Vol. I, McCrone Research Institute, IL, 1973, pp. 3–56.
- 17.1.2.5 Needham, H.H., “The Microscope, a practical guide”, Charles Thomas Publishers, 1968.

17.1.3 Questions

The trainee will provide written answers to the following questions:

- Describe the operation of the stereomicroscope in layman’s terms.
- Describe two different stereomicroscope designs.
- What is the difference in the image produced by a stereomicroscope versus a compound microscope?
- What is polarized light?
- Explain chromatic and spherical aberration. Use diagrams in explanations.
- Define dispersion, refraction and, diffraction as related to lenses.
- Name two ways that the contrast of an image can be increased.
- Where is the “intermediate image plane” located?
- Name three ways to observe the objective back focal plane.
- Explain what the numerical aperture of an objective is.
- What is an infinity corrected objective?
- What is the total magnification of a microscope?
- What is a diffuser filter?
- What are the functions of the sub-stage condenser?

- Explain retardation as it applies to a birefringent material.
- Define extinction, sign of elongation and pleochroism.
- What is an immersion objective?
- What regular maintenance is necessary to maintain the microscope?
- Define “empty magnification.”
- What is meant when it is stated that two objectives are parfocal?
- What is the typical measuring unit used when measuring length or width using a compound microscope?

17.1.4 Practical Exercises

- 17.1.4.1 The trainer will demonstrate the proper use of the stereomicroscope.
- 17.1.4.2 The trainer will demonstrate the proper achievement of Köhler illumination to the extent possible.
- 17.1.4.3 The trainer will demonstrate techniques for utilizing bright field, polarized light and phase contrast microscopy.
- 17.1.4.4 The trainer will demonstrate refractive index determinations utilizing the Becke line method.
- 17.1.4.5 The trainer will demonstrate photomicrography with the digital camera.
- 17.1.4.6 The trainee will demonstrate their ability to perform all of the above-listed practical exercises to the trainer.
- 17.1.4.7 The trainee will demonstrate proficiency in taking measurements using the stage micrometer and the ocular reticule.
- 17.1.4.8 The trainer will demonstrate proper cleaning of the microscope body and optics.

17.1.5 Evaluation

- 17.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 17.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 17.1.5.3 Review of practical exercises.
- 17.1.5.4 The trainee will be quizzed on the subject matter.

17.2 Competency Evaluation and Mock Trial

The trainee will use microscopy when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

18 MICROSPECTROPHOTOMETRY (MSP)

18.1 Microspectrophotometry

18.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the history and use of MSP;
- Define and explain MSP terminology;
- Apply techniques for obtaining reproducible MSP data using the S.E.E. instrument; and,
- Interpret MSP data and articulate the significance of an MSP association.

18.1.2 Required Readings

- 18.1.2.1 Biermann, Thomas W. and Wiggins, Kenneth G., “Color Analysis of Fibres”, Robertson J., Roux C, and Wiggins, K.G, eds., Forensic Examination of Fibres, 3rd ed, Taylor and Francis, Inc., 2017, pp 174-244.
- 18.1.2.2 Berns, Roy S., Principles of Color Technology, John Wiley and Sons, NY, 2000, pp. 3, 7-14, 27-29, 82-83, 88-91, 199-200.
- 18.1.2.3 CRAIC 2030 PV User Manual (as found on instrument).
- 18.1.2.4 CRAIC Technologies, “UV-Visible-NIR Microspectroscopy: A Primer and A Review,” Training Materials, 2007.
- 18.1.2.5 Gaudette, Barry D., “The Forensic Aspects of Textile Fiber Examination”, Saferstein, R., Forensic Science Handbook, Vol. 2, Prentice Hall, Englewood Cliffs, NJ, 1988, pp. 245-248.
- 18.1.2.6 Grieve M., Dunlop J., Haddock P., “An Investigation of Known Blue, Red, and Black Dyes Used in the Coloration of Cotton Fibers”, *Journal of Forensic Sciences*, 35(2), March 1990, pp. 301-315.
- 18.1.2.7 Houck, M., FBI Laboratory, Handout, “Color Analysis of Textile Fibers”.
- 18.1.2.8 Martin, P., “Instrumental Color Analysis in Forensic Science”, S.E.E. Incorporated, American Academy of Forensic Science, Feb. 2000 Meeting, Reno, NV.
- 18.1.2.9 Menold, R., FBI Laboratory, Handout, “Color Analysis and Spectrophotometry”, American Academy of Forensic Science, Feb. 2000 Meeting, Reno, NV.
- 18.1.2.10 S.E.E. Incorporated, Handout, “Microspectrometers: Theory, Design, and Use”. (~Paul Martin, 11/5/98)

18.1.3 Questions

The trainee will provide written answers to the following questions:

- Define the following:
 - Charge coupled device array detector (CCD)
 - Color, visible spectrum
 - Dark scan
 - Diode array spectrophotometer (DAD)
 - Didymium
 - Dysprosium oxide

- Holmium oxide
- Interference filter wheel spectrophotometer
- Metameric pair
- MSP
- Reference scan
- Reflectance MSP
- Sample scan
- Spectrophotometer
- Transmission MSP
- uv MSP
- vis MSP
- What are the components of a microspectrophotometer?
- Can MSP be used to identify dyes? Why or why not?
- What colors are poor candidates for analysis by MSP?
- Discuss light absorption versus light transmission.
- What is required prior to casework using MSP?
- What spectral characteristics are meaningful differences?

18.1.4 Practical Exercises

- 18.1.4.1 The trainer will demonstrate the QC checks and how to obtain MSP spectra.
- 18.1.4.2 The trainee will perform the QC checks and obtain MSP spectra while being observed/assisted by the trainer.
- 18.1.4.3 The trainee will be provided with a set of fifteen (15) microscope slides that contain homogeneously colored fibers. These microscope slides are stored in the Central Laboratory MSP work area. The trainee will obtain and print at least one spectrum from at least one fiber on each slide.

18.1.5 Evaluation

- 18.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 18.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 18.1.5.3 Review of practical exercises.

18.2 Competency Evaluation and Mock Trial

The fiber trainee will use MSP when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

All other users will receive an e-mail from the Chemistry Program Manager stating that they may independently perform analysis using the MSP.

19 PAINT

19.1 Introduction to Paint, Coatings and Polymers

19.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- History and use of protective/decorative coatings and polymers;
- Paint, coatings and polymer terminology;
- Manufacturing processes and applications of paints and polymers; and
- Chemical formulations and compositions of various paints, coatings and polymers.

19.1.2 Required Readings

- 19.1.2.1 Bentley, John, "Composition, manufacture and use of paint", Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 7, pp. 123-141.
- 19.1.2.2 Crown, David A., The Forensic Examination of Paints and Pigments, Springfield, IL., Charles C. Thomas, 1968.
- 19.1.2.3 Deaken, Donna, "Automotive Body Primers: Their Application in Vehicle Identification," Journal of Forensic Sciences, Vol. 20, No. 2, April 1975, pp. 283-287.
- 19.1.2.4 Hare, Clive H., "Anatomy of Paint", Materials Technology, November 1989.
- 19.1.2.5 Lear, James B., "Analysis of Paints", Journal of Coatings Technology, Vol. 53, No. 674, March 1981, pp. 51-57.
- 19.1.2.6 McBane, Bruce N., "Automotive Coatings", Federation Series on Coatings Technology, 1987.
- 19.1.2.7 Moenssens, Andre A., and Inbau, Fred E., Scientific Evidence in Criminal Cases, 3rd ed., Mineola, NY, Foundation Press, 1986. Chapter 8 I. Introduction pp. 466-469; II. Instrumentation and Methods of Analysis pp. 469-504; V. Paint pp.417-421.
- 19.1.2.8 Morgans, W.M., Outlines of Paint Technology, Volume 1: Materials, New York, NY, John Wiley & Sons, 1982.
- 19.1.2.9 Morgans, W.M., Outlines of Paint Technology, Volume 2: Finished Products, New York, NY, John Wiley & Sons, 1984.
- 19.1.2.10 Prane, Joseph A., "Introduction to Polymers and Resins", Federation Series on Coatings Technology, 1986.
- 19.1.2.11 Sullivan, D. A., "Water and Solvent Evaporation from Latex and Latex Paint Films," Journal of Paint Technology, Vol. 47, No. 610, November 1975, pp. 60-67.
- 19.1.2.12 Thornton, John I., "Forensic Paint Examination", Saferstein, Richard, ed., Forensic Science Handbook, Volume 1, 2nd edition, 2002, Chapter 8, pp. 429-452.

Also, appropriate units from the Federation Series of Coatings, Technology and referral to the Paint and Coatings Dictionary, as necessary.

19.1.3 Questions

The trainee will provide written answers to the following questions:

- Define the following terms referring to paint terminology:
 - Cross-linker
 - Drying oils
 - Enamel
 - Lacquer
 - Latex
 - Plasticizer
 - Solvent
 - Stain
 - Varnish
- Briefly describe the differences among the following types of paint:
 - Automotive Paint
 - Structural (architectural) Paint
 - Bicycle Paint
 - Maintenance Paint
 - Marine Paint
 - Aircraft Paint
- What is a polymer?
- What is a paint?
- What is the difference between a paint and a coating?
- What are the two primary purposes of paint?
- What makes a paint unique?
- What is a paint vehicle?
- What is a paint binder?
- What is a pigment?
- What is an extender pigment? List 5 of the more common extenders.
- What is a paint additive? List at least 3.
- What is a paint drier? List at least 5.
- What is the difference between a thermosetting resin and a thermoplastic resin?
- What is the most widely used white paint pigment? Name the two forms of this white pigment. How can these two forms of white paint pigment be distinguished from each other?
- What metal pigment is used in metallic motor vehicle paint?
- What is pearlescent paint?
- How does a pearlescent pigment/particle impart color? Draw and explain.
- What is iridescent paint?
- What role do mica flakes play in paint?
- What is a primer?
- What is a primer surfacer used for in automotive paints?
- What is a substrate?
- Name three types of latex polymers.
- What are some common types of lacquer paints?
- What is meant by the term “Let Down” in the paint industry?
- Is a wetting agent a vehicle or a binder?
- Name several other synthetic binders (other than alkyds) that are used in paints.
- Which white pigment is used as a mildew inhibitor? In flame or fire retardant paints?
- What is the primary function of the solvent in paint?
- Describe how the paint films are formed for latex, thermoplastic, and thermosetting paints.
- Describe the difference between a liquid paint and a dried paint film in terms of oils, solvents, plasticizers, resinous vehicles, extenders, and pigments.
- Describe additives used in latex paints.
- What are the three common forms of alkyd paint? How are they different from one another?
- What is an epoxy? When is it often used?
- What are some common cross-linking agents? Under what conditions does cross-linking occur?

- What is polyurethane? What types of applications commonly use polyurethane?
- Describe the electrodeposition of paint.
- What is the general composition of an electrodeposition paint?
- When, why, and how was lead used in paint?

Answer the following questions regarding the manufacturing processes for paint.

- How are raw materials acquired and mixed?
- What variations may exist in binders from different companies?
- What is a batch of paint and typically how large is it?
- Describe the quality control measures used in the manufacturing of paint.
- How is paint packaged and distributed?
- Describe the application processes of brush, spray, powder coating, and coil-coating.
- Describe the application process of an OEM finish on motor vehicles.
- What does OEM mean?
- Describe the multiple methods for repainting and repairing vehicles.
- What is the purpose of each OEM layer of paint?
- What are some differences between OEM and repainted motor vehicle finishes?
- What is anti-chip paint? When is it used? How can it be recognized?
- What factors affect the color of the primer surfacer layer?

19.1.4 Evaluation

19.1.4.1 The trainer will review the written answers to the questions with the trainee.

19.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

19.1.4.3 The trainee will be quizzed on the subject matter.

19.2 Recognition, Collection, Packaging and Controls

19.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe to an investigator the proper way to collect paint evidence;
- Recommend proper packaging for paint evidence; and
- Detail the proper controls that are to be taken and why.

19.2.2 Required Readings

19.2.2.1 Saferstein, Richard, Ed., Forensic Science Handbook, Volume II, Englewood Cliffs, NJ, Prentice-Hall, Inc. 1988. Chapter 4, pp. 161-208.

19.2.2.2 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide.

19.2.3 Questions

The trainee will provide written answers to the following questions:

- How would you describe to an investigator the proper way to collect paint evidence?
- What is the recommended packaging for paint evidence?
- What controls should be taken during the collection of paint?

19.2.4 Practical Exercises

- 19.2.4.1 Demonstrate the druggist or paper fold to the trainer.
- 19.2.4.2 Explain to the trainer the information given to an officer over the phone if asked what evidence should be collected in an automotive hit and run involving two vehicles. Involving a vehicle and a pedestrian.
- 19.2.4.3 Explain to the trainer the information given to an officer for a breaking and entering with a painted door and tools?

19.2.5 Evaluation

- 19.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.2.5.3 Review of practical exercises.

19.3 Stereomicroscopic Evaluation of Paint

19.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Determine the physical properties of paints and/or polymers to include: color, texture, thickness, layer sequence, presence of decorative flake, other surface characteristics;
- Take appropriate notes;
- Use a stereomicroscope properly;
- Work with extremely small samples;
- Discern colors accurately, including pastels;
- Distinguish OEM finishes from repaints; and
- Recognize and recover paint from debris, from a smear on clothing and from a tool.

19.3.2 Required Readings

- 19.3.2.1 Thornton, John I., "Forensic Paint Examination", Saferstein, Richard, ed., Forensic Science Handbook, Volume 1, 2nd edition, 2002, Chapter 8, pp. 452-472, 473-478.

19.3.3 Questions

The trainee will provide written answers to the following questions:

- What different methods could be used to determine the layer structure of a paint chip when viewing the chip microscopically?
- What characteristics can be observed from a microscopic examination of a paint chip?
- What is a good method to observe a clear coating in the layer of a paint?
- What are some noticeable differences between primers and the finish coats in motor vehicle paints?
- How many primers would generally be expected in the original finish of a motor vehicle paint?
- Describe the differences between an original finish paint particle and a paint particle from a repainted vehicle.
- What does overspray look like and when might it be encountered?

19.3.4 Practical Exercises

- 19.3.4.1 At the stereomicroscope, the trainer will demonstrate/discuss color, texture and layer structure. Included in this discussion will be different light sources (e.g., UV/VIS; ALS), different lighting angles (e.g., oblique, 90 degrees) and different color background (black/white; complementary color). Demonstration by the trainer will include manipulation of paint particles to expose the layer structure in a variety of ways.
- 19.3.4.2 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for paint analysis.
- 19.3.4.3 The trainer will provide several paint samples that are large enough to allow the trainee to familiarize themselves with the manipulation of paint particles using the stereomicroscope.
- 19.3.4.4 The trainer will provide ten different paint samples for the trainee to examine using the stereomicroscope. A summary chart(s) will be prepared which will include the number, color and descriptions of texture for each layer(s) in the samples as well as a pictorial representation. Additionally, an assessment as to whether the sample is an OEM or a refinish will be included. The paint worksheet may be used but is not required.
- 19.3.4.5 The trainer will provide a number of different types of paints and/or coatings for the trainee to examine using the stereomicroscope which the trainee will describe in notes and drawings. These will include, but are not limited to, body filler (body putty), bicycle paint, marine paint, “house” paint, Virginia license plate paint, and a sample of a stop sign or additional reflective material.
- 19.3.4.6 The trainer will provide a “debris” sample with a known number of paint particles. The trainee will search the debris and report the number and color of the particles recovered and whether they appear to be automotive in origin or not. The trainer may also include other materials that might typically be encountered in a debris sample and request that the trainee recover and list these as well.
- 19.3.4.7 The trainer will provide the trainee with a paint smear(s) on clothing and paint transferred to a tool for recovery of the paint. This may be accomplished through simulated case samples or by having the trainee work closely with the trainer using actual evidentiary material.

19.3.5 Evaluation

- 19.3.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.3.5.3 Review of practical exercises.

19.4 Microchemical Testing

19.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Safely prepare microchemical reagents;
- Correctly classify a paint layer in terms of its solubility;
- Determine the microchemical properties of paints and/or polymers; and
- Discuss the applicability of solvent testing to the classification of paints as OEM or refinish.

19.4.2 Required Readings

- 19.4.2.1 Thornton, J., et al., “Solubility Characterization of Automobile Paints”, Journal of Forensic Sciences, Vol. 28, No. 4., 1983, pp. 1004-1007.

19.4.3 Questions

The trainee will provide written answers to the following questions:

- What microchemical reactions are expected from an acrylic lacquer? A nitrocellulose lacquer? An acrylic enamel and an alkyd enamel? A latex paint?
- What paint pigment gives a “false positive” diphenylamine reaction?
- What does a nitrocellulose primer in an automotive paint indicate?
- What white pigment bubbles in HCl?
- Cite the reference for the LeRosen test?

19.4.4 Practical Exercises

- 19.4.4.1 The trainee will assemble the necessary solvents and acids and prepare the necessary reagents. The trainee will become familiar with the requirements and will perform appropriate QC checks.
- 19.4.4.2 The trainer will provide the trainee with known samples of paint as follows: an enamel, a solution lacquer, a dispersion lacquer, and a nitrocellulose lacquer. These knowns will be tested using chloroform, acetone, toluene and diphenylamine. A table correlating general paint type with solubilities and reaction in diphenylamine will be prepared.
- 19.4.4.3 The trainer will provide the trainee with a variety of known paint samples to be tested in LeRosen.
- 19.4.4.4 The trainer will provide the trainee with at least ten different paint samples which the trainee will characterize as to colors, textures, types, layer sequence, OEM/refinish, solubility and microchemical reactions. Record results on a paint worksheet.
- 19.4.4.5 The trainer will provide the trainee with at least three different sets of “K” and a “Q” paint samples. The trainee will examine the paints and characterize as to colors, textures, types, layer sequence, OEM/refinish, solubility and microchemical reactions to determine if there are meaningful differences. Record results on paint worksheets.

19.4.5 Evaluation

- 19.4.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.4.5.3 Review of practical exercises.

19.5 Fracture Match / Physical Fit

19.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the difference between class and individual characteristics;

- Describe how a fracture match may be made and why it is considered conclusive that the two objects were at one time a part of the same unit;
- Document a positive fracture match; and
- Write reports for positive fracture matches, negative fracture matches and negative fracture matches where additional testing has been or will be completed.

19.5.2 Required Readings

- 19.5.2.1 VanHoven, Harvey A., and Fraysier, Harry D., “The Matching of Automotive Paint Chips by Surface Striation Alignment”, Journal of Forensic Sciences, Vol. 28, No. 2, 1983, pp. 463-467.

19.5.3 Questions

The trainee will provide written answers to the following questions:

- Is a fracture match considered to be a conclusive identification? Why?

19.5.4 Practical Exercises

- 19.5.4.1 The trainee will successfully complete the Fracture Match Section of the Trace Evidence Training Manual.
- 19.5.4.2 The trainee will be given test samples of plastic automotive lens and test samples of paint fragments and they will be asked to fracture match the pieces, if possible.

19.5.5 Evaluation

- 19.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.5.5.3 Review of practical exercises.

19.6 Fluorescence

19.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the theory and operation of fluorescence microscopy; and
- Successfully assess and document known and questioned paint samples.

19.6.2 Required Readings

- 19.6.2.1 Rost, F.W.D., Fluorescence Microscopy, Vol. 1, Cambridge University Press, Great Britain, 1996, pp. 1-63 and 104-128.

19.6.3 Questions

The trainee will provide written answers to the following questions:

- Is fluorescence a physical, chemical or optical property? Explain.

- Explain when a Q sample would or would not be excluded from being associated with a K sample when observing differences in fluorescence.

19.6.4 Practical Exercises

- 19.6.4.1 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.
- 19.6.4.2 The trainer will demonstrate the examination of a K and Q paint sample using fluorescence microscopy. This demonstration will include the use of the Fluorescence worksheet.
- 19.6.4.3 The trainee will analyze the three K and Q paint sets from Section 19.4.4.5.

19.6.5 Evaluation

- 19.6.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.6.5.3 Review of practical exercises.

19.7 Fourier Transform Infrared Spectrophotometry (FTIR)

19.7.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the theory and operation of the FTIR; and
- Successfully analyze a variety of paint samples from intact layers to smears.

19.7.2 Required Readings

- 19.7.2.1 Beverage, Alexander, Fung, Tony and MacDougall, Donald, "Use of infrared spectroscopy for the characterisation of paint fragments", Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 10, pp. 183-225, 233-241.
- 19.7.2.2 Ryland, Scott G., "Infrared Microspectroscopy of Forensic Paint Evidence" in Practical Guide to Infrared Microspectroscopy, Humecki, Howard J., ed., Marcel Dekker, Inc., New York, 1995, pp. 163-243.
- 19.7.2.3 Smalldon, K. W., "The Identification of Paint Resins and Other Polymeric Materials from the Infra Red Spectra of their Pyrolysis Products," Journal of the Forensic Science Society, Vol. 9, (no date given), pp. 135-140.

19.7.3 Questions

The trainee will provide written answers to the following questions:

- A component present in approximately what concentration will generally not be seen in an FTIR spectrum?
- What are the advantages and disadvantages of the FTIR analysis of paint?

19.7.4 Practical Exercises

- 19.7.4.1 The trainee will successfully complete the FTIR Section of the Trace Evidence Training Manual.
- 19.7.4.2 The trainee will be given three Virginia PDQ samples that are in the database which they will analyze via FTIR. The spectra will be interpreted and compared against the database spectra.
- 19.7.4.3 The trainee will sample and obtain FTIR spectral data for at least three paint smears.
- 19.7.4.4 The trainee will analyze samples from a previous paint proficiency.
- 19.7.5 Evaluation
 - 19.7.5.1 The trainer will review the written answers to the questions with the trainee.
 - 19.7.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
 - 19.7.5.3 Review of practical exercises.

19.8 Pyrolysis Gas Chromatography (PGC)

19.8.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to understand the application of PGC for the analysis of paint.

19.8.2 Required Readings

- 19.8.2.1 Cardosi, P.J., "Pyrolysis-Gas Chromatographic Examination of Paints," Journal of Forensic Sciences, Vol. 27, No. 3, 1982, pp. 695-703.
- 19.8.2.2 CDS Technical Paper 091373, "Application of Pyrolysis-GC to the Identification of Automobile Paint," Chemical Data Systems, Oxford, PA.
- 19.8.2.3 Challinor, John M., "Pyrolysis techniques for the characterisation and discrimination of paint fragments", Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 9, pp. 165-182.
- 19.8.2.4 Jain, N. C., et al., "Identification of Paints by Pyrolysis-GC," Journal of Forensic Science Society, Vol. 5, 1965, pp. 102-109.
- 19.8.2.5 Levy, E. J., "The Analysis of Automobile Paints by Pyrolysis-GC," Analytical Pyrolysis, 1977.
- 19.8.2.6 Tsgue, Shin, "Characterization of Polymers by Pyrolysis/High Resolution Gas Chromatography with Fused-Silica Capillary Columns," Chromatography Forum, November-December 1986, pp. 44-50.
- 19.8.2.7 Wolf, Clarence J., et al., "Pyrolysis Gas Chromatography of Polymers," Analytical Chemistry, Vol. 52, No. 3, March 1980, pp. 348A-358A.

19.8.3 Questions

The trainee will provide written answers to the following questions:

- Discuss briefly the theory of PGC.
- Describe the type of data provided by PGC and illustrate with examples.

- Describe the strengths and limitations of PGC as an analytical tool for the analysis of paint.

19.8.4 Evaluation

- 19.8.4.1 The trainer will review the written answers to the questions with the trainee.

19.9 Scanning Electron Microscopy-Energy Dispersive X-Ray (SEM-EDS)

19.9.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the theory and operation of the SEM-EDS system and its application to paint analysis;
- Explain how to prepare samples for analysis via the SEM-EDS system; and
- Explain the appropriate approach and common pitfalls to data interpretation.

19.9.2 Required Readings

- 19.9.2.1 Henson, M. Lynn and Jergovich, Tammy A., "Scanning electron microscopy and energy dispersive X-ray spectrometry (SEM-EDS) for the forensic examination of paints and coatings", Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 11, pp. 243-272.
- 19.9.2.2 Ward, Dennis C., and Carlson, Timothy L., "Paint Analysis Using the Scanning Electron Microscope," Crime Laboratory Digest, F.B.I. Laboratory, Washington, DC, 1983, pp.2-6.

19.9.3 Questions

The trainee will provide written answers to the following questions:

- How does sample preparation affect resulting data? Include sample size and orientation in your answer.
- How small a percentage of an element can generally be detected by this instrumental technique?
- Are paint samples generally carbon coated? Why or why not?

19.9.4 Practical Exercises

- 19.9.4.1 The trainee will successfully complete designated sections of the SEM-EDS Section of the Trace Evidence Training Manual.
- 19.9.4.2 The trainee will work with an examiner qualified to use the SEM-EDS for an orientation to the instrument and hands-on training.
- 19.9.4.3 The trainee will analyze one of the three K and Q paint sets from Section 19.4.4.5. Alternatively, items from an actual case may be analyzed in lieu of samples from the previous paint sets.

19.9.5 Evaluation

- 19.9.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.9.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.9.5.3 Review of practical exercises.

19.10 Microspectrophotometry (MSP)

19.10.1 Objective

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge to:

- Understand the limited capability of MSP for paint analysis.

19.10.2 Required Readings

- 19.10.2.1 Eyring, Michael B., “Visible Microscopical Spectrophotometry in the Forensic Sciences”, Saferstein, Richard, ed., Forensic Science Handbook, Volume 1, 2nd edition, 2002, Chapter 6, pp. 354-364, 367-376.
- 19.10.2.2 Stoecklein, Wilfried, “The role of colour and microscopic techniques for the characterisation of paint fragments”, Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 8, pp. 156-161.

19.10.3 Questions

The trainee will provide written answers to the following questions:

- Briefly explain MSP and how it works.
- When/how is MSP useful in paint examinations?
- Explain why MSP is not routinely used for paint analysis in the Virginia Department of Forensic Science.

19.10.4 Practical Exercises

- 19.10.4.1 The trainee will successfully complete the Color Analysis Section of the Trace Evidence Training Manual.

19.10.5 Evaluation

- 19.10.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.10.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

19.11 Paint Data Query (PDQ)

19.11.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the history and development of the PDQ;
- Describe how samples are collected and what information is necessary for a paint sample's submission to the PDQ database;
- Successfully demonstrate a layer system query and a fill-in-the-blank query; and
- Search a paint sample and report results of that search.

19.11.2 Required Readings

- 19.11.2.1 Beverage, Alexander, Fung, Tony and MacDougall, Donald, “Use of infrared spectroscopy for the characterisation of paint fragments”, Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 10, pp. 225-233.
- 19.11.2.2 Bishea, Gregory A., Buckle, J.L., and Ryland, Scott G., “International Forensic Automotive Paint Database”, TWGMAT communication, obtained from the FBI Chemistry Unit, Oct. 1998.
- 19.11.2.3 Buckle, J.L., MacDougall, D.A., and Grant, R.R., “PDQ – Paint Data Queries: The History and Technology Behind the Development of the Royal Canadian Mounted Police Forensic Laboratory Services Automotive Paint Database”, *Canadian Society of Forensic Science Journal*, Vol. 30, No. 4, (1997), pp. 199-212.
- 19.11.2.4 PDQ User’s Manual.

19.11.3 Questions

The trainee will provide written answers to the following questions:

- What are the requirements for a paint sample for submission to the paint database?
- What are the requirements for a forensic paint case sample in order to be searched via the PDQ?
- What information may be derived from a successful PDQ search?
- How is the information from a successful PDQ search reported in a Certificate of Analysis?
- What are the three major uses of the PDQ?

19.11.4 Practical Exercises

- 19.11.4.1 The trainee will use the three samples previously analyzed in 19.7.4.2 to search the database and report their results.

19.11.5 Evaluation

- 19.11.5.1 The trainer will review the written answers to the questions with the trainee.
- 19.11.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 19.11.5.3 Review of practical exercises.

19.12 Supervised Work-Along

- 19.12.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.
- 19.12.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.
- 19.12.3 The trainee shall work at least ten forensic cases as a technician under the direct supervision of a qualified paint examiner. The trainer should ensure as much variety in the work-along as is practicable.

19.13 Forensic Significance of Paint

The trainer and the trainee will discuss the interpretation of paint evidence and its relevance and weight in reports and in testimony. Discussions will include probabilities versus possibilities.

19.13.1 Required Readings

19.13.1.1 Thornton, John I., “Forensic Paint Examination”, Saferstein, Richard, ed., Forensic Science Handbook, Volume 1, 2nd edition, 2002, Chapter 8, pp. 472-473.

19.13.1.2 Willis, Sheila, McCullough, John and McDermott, Sean, “The interpretation of paint evidence”, Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 12, pp. 273-287.

19.14 Report Writing

The trainer will review and discuss with the trainee the standard report wording of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

19.15 Paint Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified paint examiners, the Chemistry Program Manager, and Section/Group Supervisor.

The presentation may cover either: the general theory and application of the instrumentation used in paint analysis; the forensic examination of paints and polymers; or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic paint community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee’s training program.

19.16 Technical Final

The trainee will field questions related to any/all aspects of their paint training.

19.17 Competency Evaluation and Mock Trial

19.17.1 As the trainee progresses through paint training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these “case” files completed prior to issuance of the final practical test.

19.17.2 Using one or all of the “cases” from 19.12.1, the trainee will undergo a series of “mini-mock trial” practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.

- 19.17.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

- 19.17.4 The trainer and the trainee will review the mock trial recording in a timely fashion.

19.18 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

20 PRIMER RESIDUE

20.1 Introduction to Formation, Collection and Analysis

20.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory of Gunshot Residue (GSR) formation;
- Methods of Primer Residue collection;
- The history of Primer Residue detection methods; and,
- Bulk elemental analysis versus SEM-EDS analysis.

20.1.2 Required Readings

- 20.1.2.1 Aerospace Corporation, "Final Report on Particle Analysis for Gunshot Residue Detection" LEA, 1977.
- 20.1.2.2 ASTM E 1588 – 20 Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive Spectroscopy.
- 20.1.2.3 Basu, S., "Formation of Gunshot Residues," *Journal of Forensic Sciences*, Vol. 27, 1982, pp. 72-91.
- 20.1.2.4 Basu, S. and Ferriss, S., "A Refined Collection Technique for Rapid Search of Gunshot Residue Particles in the SEM," *Scanning Electron Microscopy*, Vol. 1, 1980, pp.375-384 and 392.
- 20.1.2.5 Basu, S. Ferriss, S., and Horn, R., "Suicide Reconstruction by Glue-Lift of Gunshot Residue," *Journal of Forensic Sciences*, Vol. 29, 1984, pp. 843-864.
- 20.1.2.6 Cowan, M. E. and Purdon, P. L., "A Study of the Paraffin Test" *Journal of Forensic Sciences*, Vol. 12, 1967, pp. 19-36.
- 20.1.2.7 DeGaetano, D. H., and Siegel, J. A., "Survey of Gunshot Residue Analysis in Forensic Science Laboratories," *Journal of Forensic Sciences*, Vol. 35, 1990, pp. 1087-1095.
- 20.1.2.8 DeGaetano, D. H., Siegel, J. A., and Klomparens, K. L., "A Comparison of Three Techniques Developed for Sampling and Analysis of Gunshot Residue by Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis," *Journal of Forensic Sciences*, Vol. 37, 1992, pp. 281-300.
- 20.1.2.9 F.B.I. Law Enforcement Bulletin, 4, 5, "The Dermal Nitrate Test", 1935.
- 20.1.2.10 Meng, H. H., and Caddy, B., "Gunshot Residue Analysis – A Review", *Journal of Forensic Sciences*, Vol. 42, 1997, pp. 553-570.
- 20.1.2.11 Romolo, F. S., and Margot, P., "Identification of Gunshot Residue: A Critical Review, *Forensic Science International*", Vol. 119, 2001, pp. 195-211.
- 20.1.2.12 Singer, R. L., et al., "A Survey of Gunshot Residue Analysis Methods," *Journal of Forensic Sciences*, Vol. 41, 1996, pp. 195-198.
- 20.1.2.13 Schwoeble, A. J. and Exline, D., Current Methods in Forensic Gunshot Residue Analysis, c. 2000.

20.1.2.14 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide.

20.1.3 Questions

The trainee will provide written answers to the following questions:

- Briefly describe the difference between GSR and Primer Residue.
- What is the significance in morphology of Primer Residue?
- Describe various Primer Residue collection techniques and their pros and cons.
- Compare and contrast microchemical vs. elemental analysis.
- Compare and contrast bulk elemental analysis vs. SEM-EDS analysis.
- Describe the pitfalls in “suicide reconstruction by Primer Residue analysis”.

20.1.4 Practical Exercises

20.1.4.1 The trainee will update the Trace Evidence Section’s bibliography of Primer Residue publications.

20.1.4.2 The trainee will successfully complete the SEM-EDS Section of the Trace Evidence Training Manual.

20.1.5 Evaluation

20.1.5.1 The trainer will review the written answers to the questions with the trainee.

20.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

20.1.5.3 Review of practical exercises.

20.1.5.4 The trainee will be quizzed on the subject matter.

20.2 Ammunition

20.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe ammunition components and their contributions in SEM-EDS analysis;
- Recognize differences between conventional primer composition and “lead free” primers; and,
- Understand how manufacturer, caliber and age of ammunition can affect the amount and type of Primer Residue deposited on the hands of a shooter.

20.2.2 Required Readings

20.2.2.1 Brozek-Mucha, Z., and Jankowicz, A., “Evaluation of the Possibility of Differentiation Between Various Types of Ammunition by Means of GSR Examination with SEM-EDX Method,” *Forensic Science International*, Vol. 123, 2001, pp. 39-47.

20.2.2.2 Bydal, B., “Percussion Primer Mixes,” *AFTE Journal*, 22(1), January 1990, pp. 1-25.

- 20.2.2.3 Coumbaros, J., et al., “Distribution of Lead and Barium in Gunshot Residue Particles Derived from .22 Caliber Rimfire Ammunition,” *Journal of Forensic Sciences*, 46(6), November 2001, pp. 1352-1357.
- 20.2.2.4 Haag, L.C., “Federal’s New Syntech Ammunition: Properties of Forensic Interest”. *AFTE Journal*, 50(4), Fall 2018, pp. 212-220.
- 20.2.2.5 Harris, A., “Analysis of Primer Residue from CCI Blazer Lead Free Ammunition by Scanning Electron Microscopy/Energy Dispersive X-Ray,” *Journal of Forensic Sciences*, 40(1), January 1995, pp. 27-30.
- 20.2.2.6 Gunaratnam, L. and Himberg, K., “The Identification of Gunshot Residue from Lead – Free Sintox Ammunition,” *Journal of Forensic Sciences*, 39(2), March 1994, pp. 532-536.
- 20.2.2.7 Midkiff, C. R., “The Changing Face of Firearms Residue Testing. Then and Now,” Parts 1, 2, 3 and 4; MAAFS Newsletter, Vol. 25, No. 2, 3, and 4, 1997 and Vol. 28, No. 3, 2000.
- 20.2.2.8 Oommen, Z. and Pierce, S., “Lead-Free Primer Residues: A Qualitative Characterization of Winchester Winclean, Remington/UMC Leadless, Federal Ballisticlean, and Speer Lawman Cleanfire Handgun Ammunition,” *Journal of Forensic Sciences*, 51(3), May 2006, pp. 509-519.
- 20.2.2.9 Wallace, J. S. and McQuillan, J. “Discharge Residues from Cartridge-operated Industrial Tools,” *Journal of Forensic Science Society*, Vol. 24, 1984, pp. 495-508.
- 20.2.2.10 Wallace, J. S., “Chemical Aspects of Firearms Ammunition,” *AFTE Journal*, 22(4), October 1990, pp. 364-389.
- 20.2.2.11 Wallace, J.S. “Discharge Residue Particles from Blank Cartridges,” *AFTE Journal*, 18(4), October 1989, pp. 33-39.
- 20.2.2.12 Zeichner, Arie, et al., “Antimony Enrichment on the Bullets’ Surfaces and the Possibility of Finding It in Gunshot Residue (GSR) of Ammunition Having Antimony-Free Primers,” *Journal of Forensic Science Society*, 43(3), 1998, pp. 493-501.
- 20.2.2.13 Zeichner, A., et al., “Gunshot Residue Particles Formed by Using Ammunitions That Have Mercury Fulminate Based Primers,” *JFSCA*, 37(4), Nov. 1992, pp. 1567-1573.
- 20.2.2.14 Zeichner, A., et al., “Gunshot Residue Particles Formed by Using Different Types of Ammunition in the Same Firearms,” *JFSCA*, 36(4), July 1991, pp. 1020-1026.
- 20.2.2.15 Zeichner, A. and Levin, N., “More on the Uniqueness of Gunshot Residue (GSR) Particles,” *Journal of Forensic Sciences*, 42(6), 1997, pp. 1027-1028.
- 20.2.2.16 Zona, C. A., “The Analysis of Nyclud Ammunition Discharge Residues Using Transmission Electron Microscopy and Polarized Light Microscopy,” *Microscope*, 44(1), 1996, pp. 11-14.

20.2.3 Questions

The trainee will provide written answers to the following questions:

- How do the elements encountered in components of ammunition, including the various types of primers compare to the list of “permissible” elements in Primer Residue as suggested by the Aerospace Corp?
- What differences might be expected between classic Primer Residue and residue from “roofing guns” or starting pistols?

- Describe the difference between Boxer and Berdan primed ammunition and its corresponding Primer Residue.
- Describe typical chemical compounds used as oxidizers, fuels, sensitizers and frictionators in primer mixes.
- What elements might be found in residue from “lead free” primers and why is this problematic for automated SEM-EDS analysis?
- What is the most common type of primer residue produced by .22 cal ammunition?
- What is the danger of using “headstamp” information to draw conclusions about primer residue composition?
- What is Co in Primer Residue a potential indicator of?
- What steps are taken during the manual review process to recognize particles from non-standard primer residue formulations?

20.2.4 Practical Exercises

20.2.4.1 The trainer will arrange for the trainee to work in conjunction with a Firearms examiner to complete the following exercises. Prepared SEM stubs shall be analyzed and findings summarized.

20.2.4.1.1 Test fire (downrange not into a water tank) the following cartridges and determine the elemental composition in the primer cup area of the cartridge case. Use a wooden applicator stick to scrape the appropriate area of the case and touch the end of the stick to a prepared SEM stub. Also sample the hand of the shooter after each firing. Use a revolver for the .22, a semi auto for the 9mm and a revolver for the .38. Clean the weapon between each firing and wash the hand between each firing.

- Federal .22 LR power-flite with lead bullet
- Remington .22 LR yellow jacket
- CCI Blazer .22 LR with lead bullet
- W-W .22 LR with copper wash bullet
- 9mm Luger W-W with 115 gr. FMJ bullet
- 9mm Luger Wolf with 115 gr. FMJ bullet
- 9mm Luger Winchester Ranger with a 85 gr Frangible bullet
- 9mm Luger PMC with a 124 gr FMJ bullet
- .38 Spl. CCI Speer with a 110 gr. Jacketed HP
- .38 Spl. CCI Blazer with 158 gr RN bullet
- .38 Spl. PMC with a 158 gr. Lead RN bullet
- .38 Spl. Remington Golden Saber

20.2.4.1.2 Test fire (downrange not into a water tank) the following cartridges and determine the elemental composition in the primer cup area of the cartridge case. Use a wooden applicator stick to scrape the appropriate area of the case and touch the end of the stick to a prepared SEM stub. Also sample the hand of the shooter after each firing. Use a semi auto except for the .38 spl. Clean the weapon between each firing and wash the hand between each firing. Retain the samples for future analysis.

- Winclean .38 spl
- Remington Leadless 9mm
- Winchester Ranger frangible 9mm
- Federal Balisticlean .40
- CCI Blazer lead free .45
- Federal Syntech 9mm

20.2.5 Evaluation

- 20.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 20.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 20.2.5.3 Review of practical exercises.

20.3 Collection of Primer Residue

20.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Instruct law enforcement officers in the proper collection of Primer Residue;
- Understand the limitations of sampling various surfaces; and,
- Discuss sampling location issues with regard to suicide cases.

20.3.2 Required Readings

- 20.3.2.1 Schwartz, R., and Zona, C., "A Recovery Method for Airborne Gunshot Residue Retained in Human Nasal Mucus," *Journal of Forensic Sciences*, 40(4), 1995, pp. 659-661.
- 20.3.2.2 Stone, I. C. and Petty, C. S., "Examination of Gunshot Residues," *Journal of Forensic Sciences*, 19(4), 1974, pp. 784-788.
- 20.3.2.3 Wrobel, H., et al., "Comparison of Properties of Adhesive Tapes, Tabs, and Liquids Used for the Collection of Gunshot Residue and Other Trace Materials for SEM Analysis *Journal of Forensic Sciences*, 43(1), 1998, pp.178-181.
- 20.3.2.4 Zeichner, A. and Levin, N., "Collection Efficiency of Gunshot Residue (GSR) Particles from Hair and Hands Using Double-Side Adhesive Tape," *Journal of Forensic Sciences*, 38(3), 1993, pp. 571-584.

20.3.3 Questions

The trainee will provide written answers to the following questions:

- Who prepares Primer Residue kits for DFS and how are they QC'd?
- Why is clothing not typically sampled for Primer Residue analysis by SEM-EDS and what are the exceptions to this general rule?
- If a vehicle is sampled where are the best places to find Primer Residue?
- Which is a better place for collection of Primer Residue in a suicide, at the scene or at the morgue?
- How can blood on the hands affect Primer Residue collection?
- Under what circumstances would test firing a weapon in an alleged suicide case be considered?

20.3.4 Practical Exercises

- 20.3.4.1 Explain to the trainer how to properly use a Primer Residue kit to include filling out all of the paperwork.

20.3.5 Evaluation

- 20.3.5.1 The trainer will review the written answers to the questions with the trainee.

20.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

20.3.5.3 Review of practical exercises.

20.4 Analysis of Primer Residue

20.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Determine if a Primer Residue sample requires carbon coating;
- Conduct automated SEM-EDS analysis of Primer Residue particles;
- Understand the potential X-ray overlaps with regard to Primer Residue;
- Classify particles as being characteristic of or consistent with Primer Residue; and,
- Explain all QA/QC, negative and positive controls involved in Primer Residue analysis.

20.4.2 Required Readings

20.4.2.1 Andrasko, J. and Maehly, A., “Detection of Gunshot Residue on Hands by Scanning Electron Microscopy,” *Journal of Forensic Sciences*, 22(4), 1977, pp. 279-287.

20.4.2.2 Collins, P., et al., “Glass-Containing Gunshot Residue Particles: A New Type of Highly Characteristic Particle?” *Journal of Forensic Sciences*, 48(3), 2003, pp. 538-553.

20.4.2.3 Kee, T. and Beck, C., “Casework Assessment of an Automated Scanning Electron Microscope/Microanalysis System for the Detection of Firearms Discharge Particles,” *Journal of Forensic Science Society*, Vol. 27, 1987, pp. 321-330.

20.4.2.4 Kerrick, D.M., et al., “The Role of Carbon Thickness in Electron Microprobe Analysis,” *American Mineralogist*, Vol. 25, 1973, pp. 920-925.

20.4.2.5 Lebieczik, J. and Johnson, D. “Rapid Search and quantitative Analysis of Gunshot Residue Particles in SEM,” *Journal of Forensic Sciences*, 45(1), 1999, pp. 83-92.

20.4.2.6 Meng, H. and Caddy, B., “Gunshot Residue Analysis – A Review,” *Journal of Forensic Sciences*, 42(4), 1997, pp. 553-570.

20.4.2.7 Operator’s manual for Carbon evaporator.

20.4.3 Questions

The trainee will provide written answers to the following questions:

- What is “charging” and how can it be avoided?
- Why is the negative control placed into the microscope before the samples to be analyzed?
- If the same field is being analyzed on the positive control sample why can the number of primer residue particles detected potentially change during the run?
- Describe the steps to be taken if a primer residue particle was found on a negative control sample.
- What is the significance of large amounts of sulfur detected in a potential primer residue particle?

20.4.4 Practical Exercises

20.4.4.1 The trainer will discuss with the trainee how to take appropriate notes, how to properly use worksheets and what abbreviations are in standard use for Primer Residue analysis.

20.4.4.2 The trainee will conduct automated Primer Residue analysis on the hand samples from the “lead free” ammunition collected and retained from 20.2.4.1.2.

20.4.5 Evaluation

20.4.5.1 The trainer will review the written answers to the questions with the trainee.

20.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

20.4.5.3 Review of practical exercises.

20.5 Retention of Primer Residue

20.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Discuss how long Primer Residue would be expected to be found on the hands of a shooter; and,
- Describe the methods of Primer Residue deposition on the hands and how this material can be lost including environmental factors.

20.5.2 Required Readings

20.5.2.1 Berk, R., et al., “GSR in Chicago Police Vehicles and Facilities: An Empirical Study,” *Journal of Forensic Sciences*, 52(4), 2007, pp. 838-841.

20.5.2.2 Fojtasek, L., et al., “Time Periods of GSR Particles Deposition After Discharge-Final Results,” *Forensic Science International*, Vol. 153, 2005, pp. 132-135.

20.5.2.3 Gerard, R., et al., “Observations of Gunshot Residue Associated with Police Officers, Their Equipment, and Their Vehicles,” *Canadian Society of Forensic Science Journal*, 45(2), 2012, pp. 57-63.

20.5.2.4 Jalanti, T., et al., “The persistence of Gunshot Residue on Shooters’ Hands,” *Science & Justice*, 39(1), 1999, pp. 48-52.

20.5.2.5 Kilty, J.W., “Activity after Shooting and its Effect on the Retention of Primer Residue,” *Journal of Forensic Sciences*, 20(2), 1975, pp. 219-230.

20.5.2.6 Luten, R., Neimke, D., Barth, M., and Niewoehner, L. “Investigating airborne GSR particles by the application of impactor technology”, *Forensic Chemistry*, Vol. 8, May 2018, pp. 72-81.

20.5.2.7 Mann, M. and Espinoza, E. O., “The Incidence of Transient Particulate Gunshot Residue in Oregon and Washington Bow Hunters,” *Journal of Forensic Sciences*, 38(1), 1993, pp. 23-27.

20.5.2.8 Reed, G. E., et al., “Analysis of Gunshot Residue Test Results in 112 Suicides,” *Journal of Forensic Sciences*, 35(1), 1990, pp. 62-68.

20.5.3 Questions

The trainee will provide written answers to the following questions:

- How many particles does it take to determine whether a person fired, touched or was in close proximity to the discharge of a weapon?
- Can it be determined whether someone fired a weapon with the right hand or left hand by Primer Residue results?
- What size Primer Residue particle would be expected to be found in the air after a weapon is discharged and what significance does this have with regard to Primer Residue in suicide cases?
- How long does Primer Residue remain on clothing?
- How long might primer residue particles be found in the air after a weapon is discharged and what factors affect the length of time?

20.5.4 Practical Exercises

- 20.5.4.1 The trainer will arrange for the trainee to work in conjunction with a Firearms examiner to test fire a .38 special revolver using PMC with a 158 gr. Lead RN bullet for all of the following exercises. All test firings will be downrange. The weapon will be cleaned and hands will be washed before each exercise. Each recovered sample will be analyzed with respect to amount and type of residue found and the trainee will plot the number of particles versus time.
- 20.5.4.2 Fire one shot and collect one sample from the back of the shooting hand and one sample from the back of the non shooting hand immediately after the shooting.
- 20.5.4.3 Fire one shot and collect one sample from the back of the shooting hand and one sample from the back of the non shooting hand 1 hour later after normal clerical activity.
- 20.5.4.4 Fire one shot and collect one sample from the back of the shooting hand and one sample from the back of the non shooting hand 3 hours later after normal clerical activity.
- 20.5.4.5 Fire one shot and collect one sample from the back of the shooting hand and one sample from the back of the non shooting hand 6 hours later after normal clerical activity.

20.5.5 Evaluation

- 20.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 20.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 20.5.5.3 Review of practical exercises.

20.6 Interpretation of Primer Residue

20.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to list potential sources of indicative particles.

20.6.2 Required Readings

- 20.6.2.1 Berk, R., "Automated SEM/EDS Analysis of Airbag Residue I: Particle Identification," *Journal of Forensic Science*, 54 (1), 2009, pp. 60 – 68.
- 20.6.2.2 Berk, R., "Automated SEM/EDS Analysis of Airbag Residue II: Airbag Residue as a Source of Percussion Primer Residue Particles," *Journal of Forensic Science*, 54 (1), 2009, pp. 69 – 76.

- 20.6.2.3 Cardinetti, B., et al., “X-ray Mapping Technique: A Preliminary Study in Discriminating Gunshot Residue Particles from Aggregates of Environmental Origin,” *Forensic Science International*, Vol. 143, 2004, pp. 1–19.
- 20.6.2.4 Garofano, L., et al., “Gunshot Residue Further Studies on Particles of Environmental and Occupational Origin,” *Forensic Science International*, Vol. 103, 1999, pp. 1–21.
- 20.6.2.5 Gauriot, R., “Statistical Challenges in the Quantification of GSR Evidence,” *Journal of Forensic Sciences*, 58(5), 2013, pp. 1149-1155.
- 20.6.2.6 Gerard, R., et al., “A Survey of Primer Residues Produced by Contemporary Powder-Actuated Tool Rounds and Their Relation to Gunshot Residue,” *Canadian Society of Forensic Science Journal*, 44(3), 2011, pp. 81-88.
- 20.6.2.7 Gerard, R., et al., “The Long Range Deposition of Gunshot Residue and the Mechanism of its Transportation,” *Canadian Society of Forensic Science Journal*, 44(3), 2011, pp. 97-104.
- 20.6.2.8 Ingo, G., et al., “Thermal and Microchemical Investigation of Automotive Brake Pad Wear Residues,” *Thermochemica Acta* Vol. 418, 2004, pp. 61-68.
- 20.6.2.9 Lindsay, E., et al., “Passive Exposure and Persistence of Gunshot Residue (GSR) on Bystanders to a Shooting: Comparison of Shooter and Bystander Exposure to GSR,” *Canadian Society of Forensic Science Journal*, 44(3), 2011, pp. 89-96.
- 20.6.2.10 Mosher, P.V., et al., “Gunshot Residue – Similar Particles Produced by Fireworks,” *Canadian Society of Forensic Science Journal*, 31(2), 1998, pp. 157-168.
- 20.6.2.11 Torre, C., et al., “Brake Linings: A Source of Non-GSR Particles Containing Lead, Barium, and Antimony,” *Journal of Forensic Sciences*, Vol. 47, 2002, pp. 494-504.
- 20.6.2.12 Tucker, W., et al., “Gunshot residue and brakepads: Compositional and morphological considerations for forensic casework,” *Forensic Science International*, Vol. 270, 2017, pp. 76-82.
- 20.6.2.13 Wolten, G. M., et al., “Particle Analysis for the Detection of Gunshot Residue II: Occupational and Environmental Particles,” *Journal of Forensic Sciences*, 1979, pp. 423-430.
- 20.6.2.14 Wright, D., and Trimpe, M., “Summary of the FBI Laboratory’s Gunshot Residue Symposium May 31-June 3, 2005,” *Forensic Science Communications*, 8(3), 2006.

20.6.3 Questions

The trainee will provide written answers to the following questions:

- Where do spherical particles containing Ce and La come from?
- How is brake dust typically distinguished from Primer Residue?
- What elements are expected in fireworks residue including sparklers?
- Where might Sr residue be found and why is it significant?
- What types of particles are expected to be found in large numbers when dealing with “hybrid-type” passenger side airbags?
- What elements are expected in a child’s “cap” pistol?

20.6.4 Practical Exercises

- 20.6.4.1 The trainee will collect 28 samples of brake dust from vehicles. Record the make, model and year of the vehicle and whether the dust is from a disc or drum brake. The trainee will analyze

these samples by automated Primer Residue analysis and will record particles that have the potential to be problematic.

20.6.4.2 The trainee will collect 14 samples of fireworks residue to include sparklers. The trainee will analyze these samples by automated Primer Residue analysis and will record particles that have the potential to be problematic.

20.6.4.3 The trainee will review the findings and associated data from the Hilti nail gun study conducted by Scott Maye in September of 2008.

20.6.5 Evaluation

20.6.5.1 The trainer will review the written answers to the questions with the trainee.

20.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

20.6.5.3 Review of practical exercises.

20.7 Supervised Work-Along

20.7.1 Prior to handling evidence/performing supervised work-alongs on casework, the trainee shall demonstrate competence through the successful completion of practical exercises or completion of a competency test. The trainee shall be authorized to perform supervised casework tasks within the scope of the associated practical exercise(s), or competency test, following successful completion of the practical exercise(s) or competency test.

20.7.2 The “Training Completion Summary Form” form (222-F201) or a MFR shall serve to document the aforementioned authorizations by the Training Coordinator.

20.7.3 The trainee shall work at least thirty forensic cases as a technician under the direct supervision of a qualified primer residue examiner. The trainer should ensure as much variety in the work-along as is practicable.

20.8 Case File Review

20.8.1 The trainee should document the review of at least ten completed case files using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder. The case files shall be technically reviewed by an authorized examiner pursuant to QM 17 prior to release.

20.9 Report Writing

The trainer will review and discuss with the trainee the standard report wording in the Primer Residue section of the Trace Evidence Procedures Manual.

The trainee should document the review of at least ten case files previously reviewed by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.

The trainee will draft report wording as a part of the analysis of their training sets as well as when performing supervised work-along.

Report writing will be evaluated throughout the training period by the trainer.

20.10 Primer Residue Presentation

The trainee may be asked to prepare a presentation of approximately 20-30 minutes in length which they will present to a group consisting of qualified primer residue examiners, the Chemistry Program Manager, and Section/Group Supervisor.

The presentation may cover either: the general theory and application of the instrumentation used in primer residue analysis; the forensic examination of primer residue; or a current topic that has been approved by the Chemistry Program Manager that is of interest to the forensic primer residue analysis community.

The purpose of the presentation is to provide the trainee with the opportunity to practice speaking in front of and fielding technical questions from a group of their peers.

The presentation would generally occur about halfway through the trainee's training program.

20.11 Technical Final

The trainee will field questions related to any/all aspects of their primer residue training.

20.12 Competency Evaluation and Mock Trial

20.12.1 As the trainee progresses through primer residue training, they will begin to process training sets as they would for casework to include drafting a Certificate of Analysis. There will be a minimum of three of these "case" files completed prior to issuance of the final practical test.

20.12.2 Using one or all of the "cases" from 20.11.1, the trainee will undergo a series of "mini-mock trial" practice sessions with qualified examiners from the Trace Evidence Section. It may be useful to include practice sessions with examiners from Sections other than Trace Evidence.

20.12.3 The trainee will be provided with a final practical test for analysis. This test will mimic actual casework to the maximum extent possible.

20.12.4 The trainee will analyze the final practical test samples and issue a Certificate of Analysis based upon their findings. The trainee will be called upon to defend their results via testimony in a formal mock trial setting.

20.12.5 The trainer and the trainee will review the mock trial recording in a timely fashion.

20.13 Certification

Upon successful completion of the training program, following the Department of Forensic Science, Quality Manual, the trainee will be issued a written certification memorandum.

21 SCANNING ELECTRON MICROSCOPY AND ENERGY DISPERSIVE SPECTROMETRY (SEM-EDS)

21.1 Introduction to Scanning Electron Microscopy (SEM)

21.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory of SEM design and operation;
- The history and development of advances in SEM;
- The capabilities and limitations of the instrument; and,
- The QA/QC of the instrument.

21.1.2 Required Readings

21.1.2.1 Flegler, S. L., Heckman, J. W. and Klomparens, K. L., Scanning and Transmission Electron Microscopy An Introduction, Oxford University Press, 1993, pp. 65-76; 82-90; 173-195.

21.1.2.2 Gabriel, Barbara L., SEM: A User's Manual for Material Science, American Society for Metals, 1985, pp. 3-31; 53-71.

21.1.2.3 Postek, Michael T., et al., Scanning Electron Microscopy: A Student's Handbook, Ladd Research Industries, Inc. 1980, pp. 1-38; 47-96.

21.1.2.4 Ritchie, N.W.M., DeGaetano, D., Edwards, D., Niewoehner, L., Plateke, F., and Wyatt. M.. "Proposed practices for validating the performance of instruments used for automated inorganic gunshot residue analysis", *Forensic Chemistry*, Vol. 20, August 2020, 100252.

21.1.3 Questions

The trainee will provide written answers to the following questions:

- Give definitions for the following: depth of field; working distance; resolution.
- Describe the relationship to the items listed above with changes in accelerating voltage; objective aperture size and backscatter electron image.
- Describe how magnification is achieved in the SEM.
- What is lens hysteresis and why is it important?
- Compare and contrast electron gun sources.
- Describe the various signals produced in the SEM, how they are detected and what they are used for.
- Describe electron beam specimen interactions.
- Describe the vacuum systems used in the SEM.

21.1.4 Practical Exercises

21.1.4.1 The trainer will demonstrate the operation of the instrument to which the trainee will initially/primarily be assigned.

21.1.4.2 The trainee will correct an astigmatic image.

21.1.4.3 The trainee will demonstrate filament replacement, saturation and column liner replacement.

21.1.4.4 The trainee will demonstrate image capture and storage procedures.

21.1.4.5 The trainee will perform the monthly QC for the instrument to which they are assigned.

21.1.5 Evaluation

- 21.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 21.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 21.1.5.3 Review of practical exercises.
- 21.1.5.4 The trainee will be quizzed upon the subject matter.

21.2 Introduction to Energy Dispersive Spectrometry (EDS)

21.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The theory of EDS design and operation;
- The history and development of advances in EDS;
- The capabilities and limitations of the instrument; and,
- The QA/QC of the instrument.

21.2.2 Required Readings

- 21.2.2.1 Jenkins, R. and Snyder, R.L., An Introduction to X-Ray Powder Diffractometry, Wiley-Interscience, New York, NY, 1996, pp. 140-142.
- 21.2.2.2 Multimedia Tutorial, The Principles and Practice of X-ray Microanalysis, Vols. 1 and 2, Oxford Instruments plc, 1997.

21.2.3 Questions

The trainee will provide written answers to the following questions:

- Describe the Bohr atomic model and how characteristic X-rays are named.
- Define escape peak, sum peak and system peak; what causes them and how you minimize them.
- Describe the components of the energy dispersive X-ray system.
- What is bremsstrahlung?
- What would an EDS spectrum be expected to look like if steric hindrance was a problem?
- How does “process time” affect spectral resolution? What are the advantages of increasing or decreasing process time?
- What is “dead time”? What happens if it becomes excessive?
- Define critical excitation energy. When is it appropriate to use low vs. high KV?
- What is meant by EDS resolution? Why does the element, peak and count rate need to be specified when describing EDS resolution?
- Describe peak overlaps and specifically how to deal with Pb/S/Mo; Ti/Ba; Ca/Sb; P/Zr?
- What is zero offset and gain?
- What is the approximate detection limit for an EDS system?
- What is the difference between quantitative analysis and qualitative analysis?
- What is ZAF?
- Why is N more difficult to detect with a light element detector than C or O?

21.2.4 Practical Exercises

- 21.2.4.1 The trainee will successfully complete an exercise demonstrating effects of condenser lens setting on image resolution and working distance changes on depth of field.

21.2.5 Evaluation

- 21.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 21.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 21.2.5.3 Review of practical exercises.
- 21.2.5.4 The trainee will calibrate the instrument and demonstrate proper QA/QC, laboratory safety and equipment maintenance and operation techniques.

21.3 Instrument Support Specimen Preparation and Analysis

21.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Prepare instrument support samples for SEM-EDS analysis;
- Determine if a sample requires carbon coating;
- Understand how to prepare samples by freeze drying;
- Explain the appropriate approach and common pitfalls to data interpretation and,
- Become familiar with variable pressure and 25KV operating conditions.

21.3.2 Required Readings

- 21.3.2.1 Henson, M. Lynn and Jergovich, Tammy A., "Scanning electron microscopy and energy dispersive X-ray spectrometry (SEM-EDS) for the forensic examination of paints and coatings", Forensic Examination of Glass and Paint Analysis and Interpretation, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 11, pp. 243-272.
- 21.3.2.2 Operator's manual for Carbon evaporator.
- 21.3.2.3 Stromberg, Maehly, Chemical Criminalistics, O. Brandstetter: Wiesbaden, Germany, 1981, pp. 185-200.
- 21.3.2.4 Ward, Dennis C., and Carlson, Timothy L., "Paint Analysis Using the Scanning Electron Microscope," Crime Laboratory Digest, F.B.I. Laboratory, Washington, DC, 1983, pp. 2-6.

21.3.3 Questions

The trainee will provide written answers to the following questions:

- What is "charging" and how can it be avoided?
- What are the advantages and disadvantages of variable pressure?
- Is the secondary image or backscatter image more useful when analyzing multilayered paint samples?
- How do homogeneity and heterogeneity in instrument support samples affect the data?
- How does the size of the area sampled affect the data?
- What is composite sampling and when might it be appropriate?
- What are the advantages and disadvantages of operating at 25KV compared to 20KV?

21.3.4 Practical Exercises

- 21.3.4.1 The trainer will demonstrate the complete operational cycle, to include proper clean up, of the carbon evaporator.
- 21.3.4.2 The trainer will observe the trainee complete a complete operational cycle, to include proper clean up, of the carbon evaporator.
- 21.3.4.3 The trainer and the trainee will discuss spectrum labeling techniques including all visible peaks to be labeled in an auto-scaled spectrum and the appropriate use of manual labels for escape peaks, sum peaks and peaks that would otherwise be illegible if computer labeling was used.
- 21.3.4.4 The trainer and the trainee will prepare and analyze paint instrument support samples to include as a minimum: multilayered samples, two-layered samples in cross-section and top/bottom, and smears using variable pressure at 25 KV.
- 21.3.4.5 The trainer and the trainee will prepare and analyze explosives and general chemical instrument support samples to include as a minimum whole powders and dried extracts.
- 21.3.4.6 The trainer and the trainee will prepare and analyze a tissue sample from an electrocution case, if available.

21.3.5 Evaluation

- 21.3.5.1 The trainer will review the written answers to the questions with the trainee.
- 21.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 21.3.5.3 Review of practical exercises.

21.4 Competency Evaluation and Mock Trial

The trainee will use SEM-EDS when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

22 X-RAY DIFFRACTION (XRD)

22.1 Introduction to X-radiation, Diffraction and the X-ray Diffractometer

22.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- The characteristics and properties of x-rays;
- The general understanding of crystalline states;
- Principles of diffraction;
- The theory and basic design of the instrument;
- The capabilities and limitations of the instrument;
- Sample preparation techniques;
- The interpretation of results;
- QA/QC procedures; and,
- Safety issues.

22.1.2 Required Readings

- 22.1.2.1 Gobel, H. E., "Identification of Crystalline Phases and Phase Kinetics of Solid Body Reactions Through Powder X-Ray Diffraction," Siemens Analytical Systems, Vol. 4, 1985, pp. 167-176.
- 22.1.2.2 Jenkins, R., ed., "Sample Preparation Methods in X-Ray Powder Diffraction," *Powder Diffraction*, Vol. 1, 1986, pp. 51-63.
- 22.1.2.3 Jenkins, R., and deVries, J. L., An Introduction to X-Ray Diffractometry, N. V. Philips, Gloeilampenfabrieken, Eindhoven, Germany.
- 22.1.2.4 McCarthy, Gregory J., Hubbard, Camden R., and Foris, Catherine M., PDF Workbook - Use of the X-Ray Powder Diffraction File, JCPDS, International Centre For Diffraction Data.
- 22.1.2.5 Skoog, Douglas A., and West, Donald M., Principles of Instrumental Analysis, 2nd edition, Saunders College, Philadelphia, PA, 1980, pp. 427-457.
- 22.1.2.6 Thacher, P. J. and Briner, G. P., "The Application of X-Ray Powder Diffraction to Forensic Science," *Powder Diffraction*, Vol. 1, 1986, pp. 320-324.
- 22.1.2.7 Willard, H. H., Merritt, L. L., and Dean, J. A., Instrumental Methods of Analysis, 5th edition, D. Van Norstrand Company, New York, NY, 1974, pp. 258-301.

22.1.3 Questions

The trainee will provide written answers to the following questions:

- What are x-rays and how are they formed?
- What determines the wavelength and intensity of an x-ray?
- What is a crystalline compound?
- Define Bragg's Law and how it relates to x-ray diffraction.
- What is the wavelength of Copper K_{α} radiation?
- How does the wavelength of Cu K_{α} radiation relate to (typical) intermolecular distances in crystals.
- Name the basic components of the XRD and their function.
- What detector do we use? Explain how it works.
- How can K_{β} radiation be removed from the pattern?

- In a simple mixture, what approximate minimum percentage of a compound must be present for detection?
- How are samples prepared for analysis by XRD?
- What are the advantages/disadvantages of the XRD?

22.1.4 Practical Exercises

- 22.1.4.1 The trainer will demonstrate the operation of the instrument to the trainee.
- 22.1.4.2 The trainee will prepare, examine, and perform database searches on 10 different known powders provided by the trainer. The results will be compared with library standards.
- 22.1.4.3 The trainee will prepare, examine, and perform database searches on 10 different known powder mixtures provided by the trainer. The exercise will include using a variety of sample holders, including the zero background plate.
- 22.1.4.4 The trainee will be given 10 unknown samples to analyze by XRD.

22.1.5 Evaluation

- 22.1.5.1 The trainer will review the written answers to the questions with the trainee.
- 22.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 22.1.5.3 Review of practical exercises.
- 22.1.5.4 The trainee will be quizzed on the subject matter.

22.2 Competency Evaluation and Mock Trial

The trainee will use x-ray powder diffraction when completing their subdiscipline competency test and will defend their results as a part of their mock trial in that subdiscipline.

23 LAMP FILAMENTS

23.1 Overview

The primary purpose of a lamp filament analysis is to determine whether the lamp was lighted or unlighted at the moment of impact. Fortunately, the filaments of incandescent lamps often give the key to answering the question. The stresses generated on a filament by the accelerations and sudden stops of a collision produce deformation and fracture phenomena with characteristic differences between hot and cold filaments. Further evidence may arise if the glass bulb is broken during the accident. If the filament is hot, it will be oxidized and it may melt any broken glass that comes in contact with it.

The examiner conducting a lamp analysis should make every effort to obtain all lamps that are located in the damaged area of the vehicle, as well as an accident report. In addition, the socket position on the vehicle from which the lamp is removed and the function of the lamp should also be obtained from the investigator. Lamps should be identified with a unique item number and described as to type of lamp and specific location on the vehicle from which it was obtained. The terms “passenger” and “driver” side rather than “right” and “left” side of the vehicle should be used so that position from which the lamp is removed is totally clear.

Example: #1 head lamp – passenger side, outside lamp
 #2 parking lamp – driver side

23.2 Objectives

- 23.2.1 To familiarize the trainee with the theoretical and practical aspects of filament examination
- 23.2.2 To provide the trainee with the knowledge, skills and abilities to examine, document through photography and case notes and interpret the characteristics of a lamp as to the "on" or "off" condition at the time of vehicle impact
- 23.2.3 To familiarize the trainee with proper preservation and packaging techniques for vehicle lamp samples
- 23.2.4 To prepare the trainee for testimony

23.3 Required Readings

- 23.3.1 Baker, J.S., Fricke, L.B., Baker, K.S., and T.L. Aycock *Traffic Collision Investigation*, "Chapter 7: Lamp Examination for 'On' or 'Off' in Vehicle Collisions," Northwestern University Center for Public Safety, 2001, pp. 301 - 366.
- 23.3.2 Coldwell, B.B. and T.B. Melski, "Motor Vehicle Lights as Evidence in Traffic Accident Investigations," *R.C.M.P. Gazette*, May 1961, pp. 2-8.
- 23.3.3 Moseley, Alfred L., "Use of Lamp Filaments in Collision Analysis," in *Research on Fatal Highway Collisions*, Papers 1962 – 1963, Harvard Medical School, pp. 187-195.
- 23.3.4 Murphy, K.J., Rioux, J.M., Stone, H.S. Stone, and A.W. Stuart, "Determination of the Temperature of the Filament Adjacent to the Incandescent Filament in a Double Beam Headlight," *Can. Soc. Forensic Sci. J.*, 24(2), 1991, pp. 91-96.
- 23.3.5 Rivers, R.W. and P.E. Hochgraf, Traffic Accident Investigators' Lamp Analysis Manual, Charles C. Thomas Publisher, Ltd. (Springfield), 2001
- 23.3.6 Slavin, James M., "Weaknesses in Traffic Accident Investigation," *FBI Law Enforcement Bulletin*, Feb. 1968, pp. 2-6, pp. 17-20.
- 23.3.7 Stauffer, Eric., "Interpretation of Automotive Light Bulb Examination Results: An Intriguing Case," *J. Forensic Sci.*, January 2007, 52(1), pp. 119-124.

- 23.3.8 Thompson, J.W., "Switched On?", *Journal of Forensic Science Society*, Vol. II, No. 3, July, 1971, pp. 151-152.
- 23.3.9 Tobin, William A., "Noninvasive Evaluation of Vehicular Lamp Bulbs," *Crime Laboratory Digest*, 21(1), January 1994, pp. 5-7.
- 23.3.10 Virginia Department of Forensic Science Trace Evidence Procedures Manual, ¶ 11 - Lamp Filaments.
- 23.3.11 Osram Sylvania: Sylvania Automotive Lighting Catalog - <http://www.sylvaniaautocatalog.com/ProductCatalogs>
- 23.3.12 GE Lighting - <http://www.gelighting.com/> (many excellent resources at this site)
- 23.3.13 Badger, Joseph E., "Casting New Light On Lamp Investigation," *Law Enforcement Technology*, September 1989, 53, pp. 38-39.
- 23.3.14 Bleyl, Robert L., "Who Had the Green Signal?", *Journal of Police Science and Administration*, 8(4), Dec. 1980, pp. 437-439.
- 23.3.15 Biglio, L., Kubicki, B., and Codella P., FTIR Diagnostics of Tungsten-Halogen Lamps: Role of Halogen Concentration, Phosphorus, Wall Material, and Burning Environment," *Applied Spectroscopy*, 45(5), 1991, pp. 819 –833.
- 23.3.16 Saferstein, R., Forensic Science Handbook, Chapter 4, "Forensic Glass Comparisons", pp. 139-182, 1982.

23.4 Questions

23.4.1 Define the following terms as they apply to lamp analysis. Draw sketches where applicable.

- glass envelope
- filament
- filament support
- base
- base arrangement
- bulb shape
- lugs
- normal lamp
- sealed beam lamp
- halogen lamp
- incandescent
- trade number
- age sag
- burnout
- cold fracture
- oxidation
- blackened filament
- bright filament
- tinted (rainbow) filament
- hot shock
- fused glass
- molten glass
- voltage
- watts

- PAR
- dual purpose lamp

- 23.4.2 What is the significance of the trade number?
- 23.4.3 How are lamps classified? (four ways)
- 23.4.4 Describe the standard base arrangements used in lamps.
- 23.4.5 Describe what is meant by filament configuration.
- 23.4.6 What is an index on a lamp? What types of lamps is an index designed for?
- 23.4.7 Sketch an indexed dual filament, dual purpose tail lamp. Which filament is the brake/turn filament? Taillight? Which contact is associated with each filament?
- 23.4.8 What is the difference between a sealed beam lamp and a halogen lamp?
- 23.4.9 What are the advantages of halogen lamps over sealed beam (non-halogen) lamps?
- 23.4.10 What is the environment in a sealed beam lamp?
- 23.4.11 What is shielding and how is it applied in lamps?
- 23.4.12 How are filaments manufactured? What are the characteristics of a new filament?
- 23.4.13 How do you determine the high beam filament from the low beam filament in a sealed beam lamp?
- 23.4.14 What is a quartz-iodide lamp?
- 23.4.15 Explain the principle of operation of a halogen lamp.
- 23.4.16 What kind of glass is used for a halogen lamp? Why?
- 23.4.17 Why are halogen lamps less likely to show signs of an "on" or "off" condition after an impact?
- 23.4.18 What are the normal signs of aging in lamps?
- 23.4.19 What is pitting (notching)?
- 23.4.20 What occurs when a lamp has a normal burnout?
- 23.4.21 What are the basic principles of lamp filament examinations?
- 23.4.22 Can an "on" or "off" determination be made for a lamp containing an LED?
- 23.4.23 What is brittle fracture? Why is it important in determining the "on" or "off" condition of a lamp?
- 23.4.24 Discuss the significance of the presence or absence of fused glass on a filament.
- 23.4.25 Discuss the significance of the presence of molten glass on a filament.
- 23.4.26 What does an etching on the glass indicate?
- 23.4.27 In a dual filament headlamp with oxidation present, how can you determine which filament was lighted?

- 23.4.28 What can be determined about a normal lamp? Does the absence of hot shock indicate that a filament was not lighted at the time of an impact? Why or why not?
- 23.4.29 Why is tungsten used for lamp filaments? What is its melting point?
- 23.4.30 At what temperature do tungsten filaments become incandescent?
- 23.4.31 How long does it take for a filament to become incandescent after the light switch is turned on? How long to cool off such that no indications of hot shock will be observed?
- 23.4.32 Will a flashing lamp (such as a turn signal) have time to cool off in the dark phase of the flash sequence to affect the observation of hot shock? Explain.
- 23.4.33 What effect will turning on the lights after an impact have on the lamp filaments?
- 23.4.34 What is the effect of a fire on a vehicle lamp?
- 23.4.35 How does headlamp glass differ from other automotive glass?
- 23.4.36 How forceful does an impact have to be to show significant abnormalities in a filament?
- 23.4.37 What factors affect how much distortion is produced in an incandescent filament?
- 23.4.38 How close to an impacted area on a vehicle would a lamp need to be in order to show signs of cold fracture or cold shock?
- 23.4.39 Does it take more force to produce cold fracture or hot shock? Explain.
- 23.4.40 Does it take more force to deform an old filament or a new filament?
- 23.4.41 What can be the effects on lamp filaments with respect to secondary vehicle impacts?
- 23.4.42 Is it possible to determine direction of force of the impact based on the direction of filament distortion?
- 23.4.43 Why are filaments enclosed in a glass bulb or envelope?
- 23.4.44 What effect does weather have on exposed lamps?
- 23.4.45 What circumstances could be the reason for a slight bend in a filament?
- 23.4.46 After an accident, a lamp with the glass intact was found to have a distorted filament? What conclusions can be made about this lamp?
- 23.4.47 How can a short circuit affect the examiner's ability to determine the "on" or "off" condition of a filament/lamp?
- 23.4.48 Explain how oxidation can occur. Does the presence of white or yellow oxidation always indicate that a lamp was lighted when the glass was broken? Explain.
- 23.4.49 What considerations should be made when examining lamps from the rear of pick-up trucks?
- 23.4.50 What steps should be taken during examination to explain confusing indications such as age sag, irregularities, curvature in a filament, possible deformation due to cold shock?
- 23.4.51 Why is it important to obtain all lamps from the region of the vehicle that was impacted (i.e., all lamps from the front of a vehicle if the front was impacted or from the rear if the rear was impacted)?

- 23.4.52 Can lamps from the front of a vehicle be of assistance to the examiner when the collision was limited to the rear of a vehicle?

23.5 Practical Exercises

- 23.5.1 The Training Coordinator (TC) or designee will demonstrate and discuss the following with the trainee:
- Documenting and photographing lamp specimens
 - Various lamp normalities and abnormalities
 - Proper preservation and packaging techniques
 - Opening a sealed beam lamp
 - Review resources available on the internet, such as the Osram Sylvania site and the GE Lighting site to assist with lamp classification/automotive replacement guides
 - Lamp interpretations, case documentation, and report writing.
- 23.5.2 The trainee should document the review of at least ten case files previously examined by qualified examiners using the appropriate Technical Review Form. The trainer should ensure as much variety in the case files as is practicable, including being generated by multiple examiners, if possible. The potential findings of the reviews shall be discussed with the trainer. Technical Review forms generated in this capacity shall be marked as Training and retained in their Training Binder.
- 23.5.3 The trainee will perform experiments using various types of lamps. The methods of impact and the notation of which filament(s) are lighted will be noted. The experimental lamps will be photographed and evaluated.
- 23.5.4 The TC will discuss testimony preparation, including *voir dire*, with the trainee for presenting and defending results of examinations.
- 23.5.5 The trainee will be provided at least five lamps for examination, each as a mock case. Case documentation and report formats will be consistent with the Procedures Manual.
- 23.5.6 The trainee will successfully complete a Northwestern University Traffic Institute "Motor Vehicle Lamp Examination" course, the California Criminalistics Institute "M115 Headlamp Examination" course, or an equivalent.

23.6 Evaluation

- 23.6.1 The trainer will review the written answers to the questions with the trainee.
- 23.6.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 23.6.3 Review of practical exercises.
- 23.6.4 Successful completion of competency test (practical test, technical final, mock trial).

24 BANK DYE

24.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The use and operation of bank security devices;
- Chemical composition and analysis;
- Sample preparation techniques;
- The interpretation of results;
- QA/QC procedures; and,
- Safety issues.

24.2 Reference

- 24.2.1 Virginia Department of Forensic Science, Trace Evidence Procedures Manual, ¶ 6.4 Bank Dye.
- 24.2.2 Martz, R.M., Reutter, D.J., and Lasswell, L.D. III. "A Comparison of Ionization Techniques for Gas Chromatography/Mass Spectroscopy Analysis of Dye And Lachrymator Residues from Exploding Bank Security Devices", *Journal of Forensic Sciences*, 1983, 28, pp. 200-207.
- 24.2.3 Reynolds, P.C., "Analysis of Bank Dye Evidence and the Challenges of Daubert Hearings," *Forensic Science Communications*, Jan. 2008, 10(1).
- 24.2.4 Kataoka, M., Seto, Y., Tsuge, K., and M. Noami. "Stability and Detectability of Lachrymators and their Degradation Products in Evidence Samples", *Journal of Forensic Sciences*, 2002, 47, pp. 44-51.
- 24.2.5 Egan, James M.; Rickenbach, Michael; et al., "Bank Security Dye Packs: Synthesis, Isolation and Characterization of Chlorinated Products of Bleached 1-(Methylamino)anthraquinone", *Journal of Forensic Sciences*, 2006, 51, pp. 1276-1283.
- 24.2.6 Jagardeo, Eschwar; et al.; "Analysis of Trace Amounts of Bank Dye and Lachrymators from Exploding Bank Devices by Solid Phase Microextraction and Gas Chromatography-Mass Spectrometry", *Journal of Chromatographic Science*, 2006, 44, pp. 86-90.
- 24.2.7 Seiden, H. "Removal of Dye-Pack Stains on U.S. Currency: A Reconstruction", *International Journal of Forensic Document Examiners*, 1996, 2, pp. 220-225.
- 24.2.8 MacBay, Michelle, "Money Packs as a Security Measure in Financial Institutions", In-house from CRJ 571.
- 24.2.9 MSDS of SECURITY PAC Pyrotechnic Unit, from ICI Americas, 1992.
- 24.2.10 MSDS of SECURITY PAC Electronic Protection System, 3SI Security Systems, 2004.

24.3 Assignments

Completion of required readings

24.3.1 Completion of study questions

24.3.2 Completion of practical exercises

24.4 Questions

24.4.1 Name both past and present manufacturers of dye packs.

- 24.4.2 What chemicals are used in dye packs? Draw their structure. Describe their relative abundance in the dye pack and their function.
- 24.4.3 Explain the possible presence of chlorinated derivatives of MAAQ.
- 24.4.4 Describe any known uses of MAAQ.
- 24.4.5 Describe how a dye pack functions.
- 24.4.6 Describe how items such as currency and clothing may appear after contacting an expended dye pack.
- 24.4.7 Describe the use of positive and negative controls in the analysis of bank dye.

24.5 Practical Exercises

- 24.5.1 Prepare solutions of CS and MAAQ at varying concentrations and describe how the concentration affects the chromatography. Save solutions for ¶ 24.5.2.
- 24.5.2 Separately, apply solutions of varying concentrations from the exercise above to paper towels or fabric. Allow to dry. Extract and compare the results to those obtained in the previous exercise to assess recovery. Run appropriate negative controls.
- 24.5.3 Obtain five unknowns from the Training Coordinator for analysis. Analyze these unknown items along with the appropriate controls as if mock cases. Submit the case notes, data and report wording to the Training Coordinator.

24.6 Evaluation

- 24.6.1 The trainer will review the written answers to the questions with the trainee.
- 24.6.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 24.6.3 Review of practical exercises.

25 TEAR GAS AND PEPPER SPRAYS

25.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- Types of sprays/products available;
- Chemical composition and analysis;
- Sample preparation techniques;
- The interpretation of results;
- QA/QC procedures; and,
- Safety issues.

25.2 Reference

- 25.2.1 Virginia Department of Forensic Science, Trace Evidence Procedures Manual, ¶ 6.10 Tear Gas and Pepper Sprays.
- 25.2.2 Nowicki, J. "Analysis of Chemical Protection Sprays by GC/MS"; *Journal of Forensic Sciences*, 1982, 27(3), pp. 704-709.
- 25.2.3 Fung, T., Jeffrey, W., and A.D. Beveridge. "The Identification of Capsaicinoids in Tear Gas Sprays"; *Journal of Forensic Sciences*, 1982, 27(4), pp. 812-821.
- 25.2.4 Martz R., Reutter, D., and L. Lasswell. "A Comparison of Ionization Techniques for Gas Chromatography/Mass Spectroscopy Analysis of Dye and Lachrymator Residues from Exploding Bank Security Devices"; *Journal of Forensic Sciences*, 1983, 28(1), pp. 200-208.
- 25.2.5 Ferslew K.E., Orcutt, R.H. and A.N. Hagardorn. "Spectral Differentiation and Gas Chromatographic/Mass Spectrometric Analysis of the Lachrimators 2-chloroacetophenone and O-Chlorobenzylidene Malononitrile"; *Journal of Forensic Sciences*, 1986, 31(2), pp. 658-665.
- 25.2.6 Mongan, A.L. and E. Buel. "Identification of Dog Repellent in the Clothes of an Assault Suspect Using Gas Chromatography/Mass Spectrometry"; *Journal of Forensic Sciences*, 1995, 40(3), pp. 513-514.
- 25.2.7 Kataoka, Mieko, et al.; "Stability and Detectability of Lachrymators and their Degradation Products in Evidence Samples," *Journal of Forensic Sciences*, 47(1), 2002, pp. 44-51.
- 25.2.8 Lewis, Karla and Robert J. Lewis, "An Assessment of Four Solvents for the Recovery of 2-Chlorobenzylidenemalononitrile and Capsaicins from "CS" and "Pepper" Type Lachrymator Sprays, and an Examination of Their Persistence on Cotton Fabric," *Journal of Forensic Sciences*, 46(2), 2001, pp. 352-355.

25.3 Assignments

- 25.3.1 Completion of required readings
- 25.3.2 Completion of study questions
- 25.3.3 Completion of practical exercises

25.4 Questions

- 25.4.1 Describe the safety considerations and precautions required relating to samples containing suspected tear gas or pepper spray. What symptoms indicate exposure to these chemicals?

25.4.2 Define the following acronyms and provide their chemical structure and molecular weight:

- CN
- CS
- OC

25.4.3 Describe the types of OC sprays/products on the market including spray (aerosol), stream, fog and pepperball (powder).

25.4.4 Describe/define the following components of spray products:

- Active ingredient
- Carrier
- Propellant
- UV dye
- CS tear gas

25.4.5 What are the three main capsaicinoids, including their chemical structure and molecular weight?

25.4.6 Discuss the use of positive and negative controls in the identification of tear gas and pepper spray.

25.5 Practical Exercises

25.5.1 Prepare solutions of capsaicin and dihydrocapsaicin at varying concentrations and describe how the concentration affects the chromatography. Save solutions for ¶ 25.5.2.

25.5.2 Separately, apply solutions of varying concentrations from the exercise above to paper towels or fabric. Allow to dry. Extract and compare the results to those obtained in the previous exercise to assess recovery. Run appropriate negative controls.

25.5.3 Obtain at least two unknowns from the Training Coordinator for analysis. Analyze these unknown items along with the appropriate controls as if mock cases. Submit the case notes, data and report wording to the Training Coordinator.

25.6 Evaluation

25.6.1 The trainer will review the written answers to the questions with the trainee.

25.6.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

25.6.3 Review of practical exercises.

26 TAPES

26.1 Introduction to Tapes and Adhesives

26.1.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills in:

- The history and use of tapes and adhesives;
- Tapes and adhesives terminology;
- Manufacturing processes for tapes and adhesives; and
- Chemical formulations and compositions of various tapes and adhesives.

26.1.2 Required Readings

- 26.1.2.1 Johnston, John, Pressure Sensitive Adhesive Tapes: A Guide to their Function, Design, Manufacture, and Use, Pressure Sensitive Tape Council, 2000, Chapters 1, 2, 6, 7, and 8.
- 26.1.2.2 Shurtape, “Duct Tape Fundamentals”, 25 July, 2008.
- 26.1.2.3 Smith, Jenny M., “Forensic Examination of Pressure Sensitive Tape”, Blackledge, Robert D., ed., Forensic Analysis on the Cutting Edge, John Wiley & Sons, 2007, pp. 291-317.
- 26.1.2.4 SWGMAT, “Guideline for the Forensic Examination of Pressure-Sensitive Tapes,” Forensic Science *Communications*, Vol. 10, No. 4, 2008.

26.1.3 Questions

The trainee will provide written answers to the following questions:

- What is a polymer?
- What is a pressure sensitive adhesive?
- What is a pressure sensitive tape?
- Briefly describe the differences between warp, weft, machine, and fill. When are these terms used?
- Briefly describe the differences among the following types of tape:
 - Duct tape
 - Vinyl tape
 - Packaging tape
 - Paper tape
 - Filament/Strapping tape
- Discuss, in general, pressure sensitive tape manufacturing processes.
- What are the differences between laminated and coextruded construction?
- What is a tape additive? List at least 3.
- What role does scrim fabric play in tape?
- Name the two most common scrim patterns. Draw them.
- What is plasticizer? When might this be found?
- What is a pigment? When might they be found?
- What is an elastomer? List at least 5.
- Describe why and how a variety of analyses are typically conducted on tape which requires the coordination amongst laboratory sections.

26.1.4 Evaluation

- 26.1.4.1 The trainer will review the written answers to the questions with the trainee.

26.1.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

26.1.4.3 The trainee will be quizzed on the subject matter.

26.2 Recognition, Collection, Packaging and Handling

26.2.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe to an investigator the proper way to collect tape evidence;
- Recommend proper packaging for tape evidence; and
- Detail the proper handling techniques that are possible and when to use each.

26.2.2 Required Readings

26.2.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see Misc. Tapes and FBI Tape Protocol sections only).

26.2.2.2 Lightning Powder Company, “Un-Du® for Tape Separation”, *Minutiae*, Sep-Oct 2000, Issue 62, pp. 3.

26.2.2.3 Smith, Jenny M., “Forensic Examination of Pressure Sensitive Tape”, Blackledge, Robert D., ed., *Forensic Analysis on the Cutting Edge*, John Wiley & Sons, 2007, pp. 318-319.

26.2.2.4 Virginia Department of Forensic Science Evidence Handling and Laboratory Capabilities Guide, see adhesive tape section pp. XI-13.

26.2.3 Questions

The trainee will provide written answers to the following questions:

- Describe how to package tape evidence.
- What might cause phthalate contamination in tape components?
- Describe three ways of unraveling a wad of tape or removing it from a surface.
- Describe the advantages and disadvantages of each of the three techniques.
- How is evidence handled in terms of contamination prevention?

26.2.4 Practical Exercises

26.2.4.1 Explain to the trainer the information given to an officer over the phone if asked how tape evidence should be collected and packaged in a home invasion case where the victim’s hands and feet were bound with tape.

26.2.4.2 Explain to the trainer the information given to an officer over the phone if asked how tape evidence should be collected from the home invasion suspect’s residence.

26.2.4.3 The trainee will practice using various methods (i.e., methanol, chloroform, heptane, hexane, toluene, inverted Dust-Off, liquid nitrogen, a heat gun, freezer) on different classes of tapes (i.e., duct tape, electrical tape, packaging tape, masking tape, office tape) that have been stuck together. Record observations and results.

26.2.5 Evaluation

- 26.2.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.2.5.3 Review of practical exercises.

26.3 Stereomicroscopic Evaluation of Tapes (and Adhesive)

26.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Work with extremely small samples;
- Identify tape classes;
- Discern unique features and/or surface characteristics;
- Recognize and recover other trace evidence from tape;
- Describe the weave and knit patterns of duct tape scrim fabric;
- Make cross-sections of tape backings; and
- Describe how a fracture match / physical fit may be made.

26.3.2 Required Readings

- 26.3.2.1 Bradley, M.J., Keagy, R.L., Lowe, P.C., Rickenbach, M.P., Wright, D.M., and LeBeau, M.A., "A Validation Study for Duct Tape End Matches", *Journal of Forensic Sciences*, 2006, Vol. 51, No. 3, pp. 504-508.
- 26.3.2.2 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see FBI Tape Protocol section only).
- 26.3.2.3 Hobbs, A.L., Gauntt, J., Keagy, R., Lowe, P.C., Ward, D., "A New Approach for the Analysis of Duct Tape Backings", *Forensic Science Communications*, Vol. 9, No. 1, 2007.
- 26.3.2.4 Keto, R.O., "Forensic Characterization of Black Polyvinyl Chloride Electrical Tape", *Proceedings of the International Symposium on the Analysis and Identification of Polymers*, FBI Academy, Quantico VA, 1984, pp. 137-143.
- 26.3.2.5 Pribush, Robert A., "Forensic Analysis of Duct Tape", Addendum to *Proceedings of SCANNING 2004*, April 2004, pp. 147.
- 26.3.2.6 Smith, Jenny, "The Forensic Value of Duct Tape Comparisons", *Midwestern Association of Forensic Scientists Newsletter*, 1998, Vol. 27, No. 1, pp. 28-33.
- 26.3.2.7 Teetsov, A.S. and Stellmack, M.L., "Hand-Sectioning and Identification of Pressure-Sensitive Tapes", *Modern Microscopy Journal*, June 30, 2004.
- 26.3.2.8 Virginia Department of Forensic Science, *Trace Evidence Procedures Manual*, General Chemical – Tapes and Adhesives section.

26.3.3 Questions

The trainee will provide written answers to the following questions:

- What are calendaring marks?

- What are manufacturing marks? What influence do manufacturing marks have at this point in the examination?
- What characteristics can be observed from a microscopic examination of tapes and adhesives?
- How does one compare the colors of known and questioned tapes or adhesives under the stereomicroscope?
- What influence does width have at this point in the examination?
- How does one ensure that tape or adhesive samples will not be contaminated?
- What characteristics cause tapes or adhesives to be eliminated at this stage?

26.3.4 Practical Exercises

- 26.3.4.1 At the stereomicroscope, the trainer will demonstrate/discuss color, width, thickness, and any other applicable observed characteristics of different tape samples. Demonstration by the trainer will include manipulation of tapes to make cross-sections.
- 26.3.4.2 The trainer will provide several tape samples to allow the trainee to familiarize themselves with the manipulation of tapes using the stereomicroscope. The trainee will use these tapes to record physical observations and measurements.
- 26.3.4.3 The trainee will practice making cross-sections of several tape backings.
- 26.3.4.4 The trainee will practice removing adhesive from tape.
- 26.3.4.5 The trainer will discuss removal/recovery of trace evidence from tape or adhesive.
- 26.3.4.6 The trainee will successfully complete the Fracture Match Section of the Trace Evidence Training Manual.
- 26.3.4.7 The trainee will be given tape test samples and they will be asked to fracture match the pieces, if possible.

26.3.5 Evaluation

- 26.3.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.3.5.3 Review of practical exercises.

26.4 Microsolubility Testing

26.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to correctly describe the solubility of adhesives when subjected to different solvents.

26.4.2 Required Readings

- 26.4.2.1 Johnston, J., Serra, J., “The Examination of Pressure Sensitive Adhesive Tapes”, *International Association for Microanalysis*, 2005, Vol. 5, Issue 1, pp. 19-31.

26.4.3 Questions

The trainee will provide written answers to the following questions:

- Should two adhesives that have different reactions to any chemical be eliminated or should more testing be done on them?

26.4.4 Practical Exercises

- 26.4.4.1 The trainer will provide the trainee with adhesive samples to be examined. The trainee will examine the adhesives and characterize as to colors, textures, solubility, and determine if there are meaningful differences.

26.4.5 Evaluation

- 26.4.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.4.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.4.5.3 Review of practical exercises.

26.5 Polarized Light

26.5.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Apply polarized light to tape and adhesive samples; and
- Recognize unique features and/or characteristics in tapes or adhesives;

26.5.2 Required Readings

- 26.5.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see PLM section only).
- 26.5.2.2 Maynard, P., Gates, K., Roux, C., and Lennard, C., “Adhesive Tape Analysis: Establishing the Evidential Value of Specific Techniques”, Journal of Forensic Sciences, 2001, Vol. 46, No. 2, pp. 280-287.
- 26.5.2.3 Smith, J. M, and Weaver, R., “PLM Examinations of Clear Polymer Films: Identification of Monoaxial and Biaxial Orientation and Other Observations”, Microscope, 2004, Vol. 52:3/4, pp. 112-118.
- 26.5.2.4 Smith, Jenny M., “Forensic Examination of Pressure Sensitive Tape”, Blackledge, Robert D., ed., Forensic Analysis on the Cutting Edge, John Wiley & Sons, 2007, pp. 309-312, 325-326.

26.5.3 Questions

The trainee will provide written answers to the following questions:

- What is the difference between monoaxial and biaxial?
- How can PLM be helpful in the application to tape analysis?

26.5.4 Practical Exercises

- 26.5.4.1 The trainee will successfully complete the Light Microscopy Section of the Trace Evidence Training Manual.

- 26.5.4.2 The trainer will demonstrate how to determine if a tape backing is monoaxial vs. biaxial, the backing extinction angle, and the backing relative retardation.
- 26.5.4.3 The trainer will issue the trainee with packaging or office tape samples. The trainee will record physical observations, observations made on the PLM, and observations when visualized between crossed polarizing sheets to determine if there are meaningful differences.

26.5.5 Evaluation

- 26.5.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.5.5.3 Review of practical exercises.

26.6 Fluorescence

26.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to successfully assess and document known and questioned tape and adhesive samples.

26.6.2 Required Readings

- 26.6.2.1 Blackledge, R.D., “Comparison of Masking Tapes by Fluorescence Spectroscopy”, Proceedings of the International Symposium on the Analysis and Identification of Polymers, FBI Academy, Quantico, VA, 1984, pp. 135.
- 26.6.2.2 Maynard, P., Gates, K., Roux, C., and Lennard, C., “Adhesive Tape Analysis: Establishing the Evidential Value of Specific Techniques”, Journal of Forensic Sciences, 2001, Vol. 46, No. 2, pp. 280-287.
- 26.6.2.3 Rost, F.W.D., Fluorescence Microscopy, Vol. 1, Cambridge University Press, Great Britain, 1996, pp. 1-63 and 104-128.
- 26.6.2.4 Johnston, J., Serra, J., “The Examination of Pressure Sensitive Adhesive Tapes”, International Association for Microanalysis, 2005, Vol. 5, Issue 1, pp. 30.

26.6.3 Questions

The trainee will provide written answers to the following questions:

- Explain when a Q sample would or would not be excluded from being associated with a K sample when observing differences in fluorescence?

26.6.4 Practical Exercises

- 26.6.4.1 The trainer will provide the trainee with tape and adhesive samples for the determination of their fluorescent properties. All four fluorescent cubes will be used and the results recorded using the fluorescence worksheet.

26.6.5 Evaluation

- 26.6.5.1 The trainer will review the written answers to the questions with the trainee.

26.6.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

27.1.1.1 Review of practical exercises.

26.7 FTIR

26.7.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Obtain consistent spectral data from different samples from the same source;
- Prepare tape and adhesive samples using the ATR and micro compression cell with diamond windows; and
- Interpret spectral data from different tapes in order to reach a conclusion whether there are meaningful differences.

26.7.2 Required Readings

- 26.7.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see FTIR section only).
- 26.7.2.2 Johnston, J., Serra, J., “The Examination of Pressure Sensitive Adhesive Tapes”, *International Association for Microanalysis*, 2005, Vol. 5, Issue 1, pp. 19-28.
- 26.7.2.3 Maynard, P., Gates, K., Roux, C., and Lennard, C., “Adhesive Tape Analysis: Establishing the Evidential Value of Specific Techniques”, *Journal of Forensic Sciences*, 2001, Vol. 46, No. 2, pp. 280-287.
- 26.7.2.4 Merrill, R.A. and Bartick, E.G., “Analysis of Pressure Sensitive Adhesive Tape: I. Evaluation of Infrared ATR Accessory Advances”, *Journal of Forensic Sciences*, 2000, Vol. 45, No. 1, pp. 93-98.
- 26.7.2.5 Pattacini, S.C., “Infrared Identification of Adhesive Formulations”, *Perkin-Elmer INFRARED Bulletin*, 1974, 43, 1-11.
- 26.7.2.6 Sakayanagi, M., Konda, Y., Watanabe, K., and Harigaya, Y., “Identification of Pressure-Sensitive Adhesive Polypropylene Tape”, *Journal of Forensic Sciences*, 2003, Vol. 48, No. 1, pp. 68-76.
- 26.7.2.7 Smith, Jenny M., “Forensic Examination of Pressure Sensitive Tape”, Blackledge, Robert D., ed., *Forensic Analysis on the Cutting Edge*, John Wiley & Sons, 2007, pp. 320.

26.7.3 Questions

The trainee will provide written answers to the following questions:

- Describe sample preparation for tape and adhesive samples on the FTIR.
- Are additives likely to be present in the FTIR spectrum?
- What are the advantages and disadvantages of the FTIR analysis of tapes and adhesives?

26.7.4 Practical Exercises

- 26.7.4.1 The trainee will successfully complete the FTIR section of the Trace Evidence Training Manual.

- 26.7.4.2 The trainee will be given a set of tapes for which they will obtain IR spectra from the components.

26.7.5 Evaluation

- 26.7.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.7.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.7.5.3 Review of practical exercises.

26.8 Color Measurements

26.8.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Analyze tape samples via the microspectrophotometer and interpret results; and
- Determine when MSP of tapes may be useful.

26.8.2 Required Readings

- 26.8.2.1 Adolf, F. and Dunlop, J., “Microspectrophotometry/Colour Measurement”, Robertson J. and Grieve M., ed. (s), *Forensic Examination of Fibres*, 2nd ed., 1999, pp 251-289.
- 26.8.2.2 Berns, R.S., Billmeyer and Saltzman’s *Principles of Color Technology*, 2nd ed., New York, New York, John Wiley and Sons, 2000, pp. 1-74, 82-92.
- 26.8.2.3 Eyring, M.B., “Visible Microscopical Spectrophotometry in the Forensic Sciences”, Saferstein, Richard, ed., *Forensic Science Handbook*, Volume 1, 2nd edition, 2002, Chapter 6, pp. 354-364, 367-376.
- 26.8.2.4 Gaudette, B.D., “The Forensic Aspects of Textile Fiber Examination”, Saferstein, R., *Forensic Science Handbook*, Vol. 2, Prentice Hall, Englewood Cliffs, NJ, 1988, pp. 245-248.
- 26.8.2.5 Maynard, P., Gates, K., Roux, C., and Lennard, C., “Adhesive Tape Analysis: Establishing the Evidential Value of Specific Techniques”, *Journal of Forensic Sciences*, 2001, Vol. 46, No. 2, pp. 280-287.
- 26.8.2.6 Saferstein, R., *Criminalistics: An Introduction to Forensic Science*, 8th ed., New Jersey, Pearson, Prentice Hall, 2004, pp. 178-179.
- 26.8.2.7 Stoecklein, W., “The Role of Colour and Microscopic Techniques for the Characterisation of Paint Fragments”, *Forensic Examination of Glass and Paint Analysis and Interpretation*, Caddy, Brian, ed., Taylor and Francis, New York, 2001, Chapter 8, pp. 143-163.

26.8.3 Questions

The trainee will provide written answers to the following questions:

- Define Microspectrophotometry.
- Describe when MSP or Colorimetry might be used on tape or adhesive evidence?
- Is a difference in spectral curves a basis for elimination of K and Q tapes?
- Are lighter colors or darker colors better for MSP purposes?
- Discuss the expected results from near colorless and near opaque samples.

- Describe some surface characteristics that are incompatible with Colorimetry analysis.

26.8.4 Practical Exercises

- 26.8.4.1 The trainee will successfully complete the Microspectrophotometry Section of the Trace Evidence Training Manual (or designated sections therein).
- 26.8.4.2 The trainer will issue the trainee with colored transparent tapes. The trainee will collect MSP spectra and evaluate the reproducibility of the spectra and give reasons for possible differences.
- 26.8.4.3 The trainer will issue the trainee with opaque tapes. The trainee will either collect data or interpret data successfully in at least three different tape case scenarios.

26.8.5 Evaluation

- 26.8.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.8.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.8.5.3 Review of practical exercises.

26.9 SEM-EDS

26.9.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the theory and operation of the SEM-EDS system and its application to tape and/or adhesive analysis;
- Explain how to prepare samples for analysis via the SEM-EDS system;
- Explain the appropriate approach and common pitfalls to data interpretation; and
- Discuss the strengths and limitations of the technique including factors which may affect the resulting spectrum, such as escape peaks, sum peaks, etc.

26.9.2 Required Readings

- 26.9.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see SEM-EDS section only).
- 26.9.2.2 Goodpaster, J.V., Sturdevant, A.B., Andrews, K.L., Brun-Conti, L., "Identification and Comparison of Electrical Tapes using Instrumental and Statistical Techniques: I. Microscopic Surface Texture and Elemental Composition", *Journal of Forensic Sciences*, 2007, Vol. 52, No. 3.
- 26.9.2.3 Jenkins Jr., T.L., "Elemental Examination of Silver Duct Tape using Dispersive X-Ray Spectrometry", *Proceedings of the International Symposium on the Analysis and Identification of Polymers*, FBI Academy, Quantico, VA, 1984, pp. 147-149.
- 26.9.2.4 Smith, Jenny M., "Forensic Examination of Pressure Sensitive Tape", Blackledge, Robert D., ed., *Forensic Analysis on the Cutting Edge*, John Wiley & Sons, 2007, pp. 320-325.

26.9.3 Questions

The trainee will provide written answers to the following questions:

- Explain how to prepare tape and adhesive samples for SEM-EDS analysis?
- How small a percentage of an element can generally be detected by this instrumental technique?

26.9.4 Practical Exercises

- 26.9.4.1 The trainee will successfully complete designated sections of the SEM-EDS Section of the Trace Evidence Training Manual.
- 26.9.4.2 The trainee will work with an examiner qualified to use the SEM-EDS for an orientation to the instrument.
- 26.9.4.3 The trainee will analyze one of the three K and Q tape and/or adhesive sets. Alternatively, items from an actual case may be analyzed in lieu of sample sets.

26.9.5 Evaluation

- 26.9.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.9.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.9.5.3 Review of practical exercises.

26.10 XRD

26.10.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Explain the basic theory of XRD and its application to tape and/or adhesive analysis;
- Explain how to prepare samples for analysis via the XRD;
- Explain the strengths and limitations of this technique;
- Interpret the results obtained; and
- Explain the appropriate approach to data interpretation;

26.10.2 Required Readings

- 26.10.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see XRD section only).
- 26.10.2.2 Smith, Jenny M., "Forensic Examination of Pressure Sensitive Tape", Blackledge, Robert D., ed., Forensic Analysis on the Cutting Edge, John Wiley & Sons, 2007, pp. 320-325.

26.10.3 Questions

The trainee will provide written answers to the following questions:

- What kinds of additives or fillers can be identified by the XRD?
- What is the most widely used white pigment in adhesives? Name the two forms of this white pigment. How can these two forms of white pigment be distinguished from each other?
- How might the XRD be used for discrimination between K and Q samples?
- In general, in what percentage must a component of a mixture be present in order to be identified on XRD?
- Explain how to prepare tape and adhesive samples for XRD analysis?

26.10.4 Practical Exercises

- 26.10.4.1 The trainee will successfully complete the X-Ray Diffraction Section of the Trace Evidence Training Manual (or designated sections therein).
- 26.10.4.2 The trainee will work with an examiner qualified to use the XRD for an orientation to the instrument.
- 26.10.4.3 The trainee will analyze one of the three K and Q tape and/or adhesive sets. Alternatively, items from an actual case may be analyzed in lieu of sample sets.

26.10.5 Evaluation

- 26.10.5.1 The trainer will review the written answers to the questions with the trainee.
- 26.10.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.
- 26.10.5.3 Review of practical exercises.

26.11 PGC

26.11.1 Objectives

Through completion of this module the trainee will be familiar with the theory and application of additional instrumental techniques which are not currently available at the DFS laboratory.

26.11.2 Required Readings

- 26.11.2.1 Forensic Analysis of Pressure Sensitive Tapes Training Course Materials, F.B.I., May 2008 (see Py-GC/MS of Tape sections only).
- 26.11.2.2 Smith, Jenny M., "Forensic Examination of Pressure Sensitive Tape", Blackledge, Robert D., ed., Forensic Analysis on the Cutting Edge, John Wiley & Sons, 2007, pp. 326.
- 26.11.2.3 Maynard, P., Gates, K., Roux, C., and Lennard, C., "Adhesive Tape Analysis: Establishing the Evidential Value of Specific Techniques", *Journal of Forensic Sciences*, 2001, Vol. 46, No. 2, pp. 280-287.

26.11.3 Questions

The trainee will provide written answers to the following questions:

- Briefly explain the theory and type of data provided by PGC.
- What are the advantages and disadvantages of the PGC analysis of tapes and adhesives?

26.11.4 Evaluation

- 26.11.4.1 The trainer will review the written answers to the questions with the trainee.
- 26.11.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

26.12 Sourcing Tapes Products to a Manufacturer

26.12.1 Objectives

Through completion of this module the trainee will be familiar with the theory and application of sourcing tapes to a particular manufacturer.

26.12.2 Required Readings

- 26.12.2.1 Personal correspondence documented on Memo for Record dated December 10, 2007.
- 26.12.2.2 Smith, Jenny M., “Forensic Examination of Pressure Sensitive Tape”, Blackledge, Robert D., ed., *Forensic Analysis on the Cutting Edge*, John Wiley & Sons, 2007, pp. 326-327.
- 26.12.2.3 Snodgrass, H., “Duct Tape Analysis as Trace Evidence”, *Proceedings of the International Symposium on the Analysis and Identification of Polymers*, FBI Academy, Quantico, VA, 1991, pp. 69-73.

26.12.3 Questions

The trainee will provide written answers to the following questions:

- Explain the requirements necessary to provide for the determination of the manufacturer of a tape sample.
- What are some limitations of this capability?

26.12.4 Evaluation

- 26.12.4.1 The trainer will review the written answers to the questions with the trainee.
- 26.12.4.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.