Forensic Paint Examination
Training Program

Scientific Working Group on Materials Analysis (SWGMAT)
Paint Subgroup

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Introduction and User's Guide

Scope of Guidelines

This training manual is intended as a guide for use by laboratories responsible for training forensic paint examiners to prepare them to perform paint examinations. It contains relevant suggested reading assignments and structured exercises for hands-on practical experience for the trainee. Other sources of information on forensic paint examination, not specifically mentioned in this manual, can be considered and added where justified. Additional training beyond that which is listed here should be made available to the trainee when possible. Such training might include off-site short courses, short internships, and special training by experienced examiners. Continuing education and training should not be limited to the training period, as the trainer cannot dictate the availability and cost of such courses. Additional training will provide a paint examiner the opportunity to remain current in the field.

This manual is in a modular format for easy adaptation to an individual laboratory's training programs. Suggestions as to lessons, practical exercises, progress monitoring, and trainee evaluation are included. Reading assignments with full citations are listed in each subsequent Block of this document.

A training program should provide a theoretical foundation and basic practical skills to prepare a trainee to become a fully qualified forensic paint examiner. At the end of the training program, the trainee, under direct supervision of a fully qualified examiner, should be capable of forming opinions based upon sound scientific knowledge, proper examinations, and practical experience.

The training manual is intended to complement the SWGMAT Forensic Paint Analysis and Comparison Guidelines which can be obtained from *Forensic Science Communications*, May 2000, www.FBI.gov.

Educational Prerequisites

Refer to SWGMAT Trace Evidence Quality Assurance Guidelines, Section 4.3

Training Program Objectives

With completion of this training program, the trainee should have gained the theoretical knowledge and practical skills needed with respect to paint examinations and comparisons. Topics should include:

1. Occurrence, transfer, and persistence of paints

2. Evidence recovery methods
3. Evidence handling to minimize contamination and loss
4. Evidence packaging and documentation
5. Use and maintenance of analytical equipment
6. Understanding of paint chemistry and relationship to end use
7. Classification of paint binder systems
8. Comparison of questioned and known paints
9. Interpretation of comparison results
10. Preparation of laboratory reports
11. Presentation and interpretation of results in court

Training Steps and Schedule

Training guidelines should give the trainee theoretical knowledge and practical skills in forensic paint examination and interpretation. This can be accomplished through a combination of the following training methods:

1. Reading of relevant literature
2. Instruction and observation of paint examiners
   - Lectures and discussions
   - Practical demonstration of basic skills
   - Casework
   - Court testimony
3. Practical skills
   - Practical exercises
   - Assisting in and performing supervised casework
4. Examinations and tests
   - Written or oral tests
   - Practical laboratory tests
5. Competency evaluation

The recommended training period is approximately 1.5 year, full time, for an inexperienced forensic examiner. For the purpose of this document, an inexperienced examiner is an individual who has little knowledge in trace evidence or minimal knowledge of paint evidence and comparison. A trainee with experience in other areas of forensic science may not require such an extensive training regimen.

Records of Training

Each stage of the training process for each trainee should be documented, reviewed, and maintained according to individual laboratory guidelines.

Responsibilities

Each trainee should be trained by and work under the guidance of one or more experienced forensic paint examiners. The trainer(s) must be technically competent and currently proficient in the field of paint examination and comparison.

The trainer may be responsible for:

- Introducing the trainee to the relevant scientific literature, proper procedures, training material, and reference collections
- Discussing readings and theory with the trainee
- Teaching basic methods
- Teaching case management
- Fostering ethical and proper professional conduct through discussion and by setting an example
- Teaching appropriate quality assurance and quality control procedures
- Reviewing tests, practical exercises, and casework samples with trainee
- Teaching expert testimony skills through moot court and/or observation

The trainer and supervisor should monitor the trainee's progress. The training must be thorough and complete to ensure the trainee becomes a competent analyst. Other members of the laboratory should be encouraged to offer relevant information regarding their specialties to the trainee.

The trainee is expected to meet the objectives set forth in the training program by:

- Self-study of reading materials
- Practicing of basic skills
- Using practical exercises
- Successful completion of written and oral tests
- Observation of case work being conducted by an experienced examiner
- Observation of court testimony given by an experienced examiner
- Conducting themselves in an ethical and professional manner
- Participating in the quality assurance and quality control program of laboratory
- Successful completion of competency tests in analysis and comparison
- Competent performance of supervised casework
- Demonstrate ability to accurately and effectively communicate paint findings in court through court testimony monitoring and/or transcript review

Each laboratory is responsible for maintaining:

- An up-to-date training program
- Documentation of competency tests and proficiency tests
- Training documents
- Documentation of court testimony

Training Program Details

The Table of Contents outlines a suggested training program by Block and topic. Individual laboratories may use this and tailor it to their own needs. Training topics may be expanded or condensed based on the availability of particular types of equipment in the laboratory.

Each Block is divided into topics that include general discussions of the subject of that particular Block; the objective to be gained by learning that particular subject; the relevant readings; practical applications of the knowledge gained; and when appropriate, testing of the trainee's knowledge and skills.

Reading assignments are selected to give the trainee a sound theoretical background in topics necessary for paint analysis. Additional references may be provided by the trainer for any remedial training that may be required. The trainee is also expected to monitor forensic science literature for journal articles relevant to their discipline. Additional references may be found in the SWGMAT Paint bibliography. If a later edition of the listed reference is available, it may be used.

Essential skills should be demonstrated by the trainer and practiced by the trainee so that such skills can be acquired and performed competently.

Practical exercises should be designed to allow the trainee to learn and practice the skills needed to perform casework. The trainer should review the trainee's performance during the exercises. Satisfactory completion of the exercises should be documented.

Written or oral tests along with practical laboratory tests are recommended as a means of determining the trainee's comprehension of the material and as a means to document the training. Questions should be designed to test the trainee's theoretical and practical knowledge. A pass criterion should be established at the beginning of the training program. Contingencies for not passing a test must also be in place. The trainer should address deficiencies through additional readings and training. All tests, training records, training documents and answer forms should be retained in the trainee's training record.

Initially, the trainee should assist an experienced paint examiner in all aspects of casework. This helps the trainee understand the various aspects of casework including record keeping; processing of evidence; sample preparation; microscopical, chemical and elemental examinations, characterization of binders and pigments, comparison, and interpretation of paint evidence. The experienced examiner should provide guidance to the trainee; however, the examiner must perform all case examinations and comparisons and is responsible for all conclusions.

When the trainer, trainee, and supervisor conclude that the trainee is competent and sufficiently practiced, the trainee can proceed to supervised casework. The trainer or case supervisor must verify all laboratory results obtained by the trainee. At the end of the

training program, the trainee should be ready to analyze cases and compare paints independently. The results should then be reviewed in accordance with laboratory quality assurance procedures.

A comprehensive competency test must be administered prior to the trainee analyzing and comparing paint cases independently. The test should be designed to mimic actual casework, requiring the trainee to demonstrate his/her knowledge of the actual analysis and comparison of paint evidence, as well as the laboratory's procedures in handling evidence, taking notes, maintaining chain of custody, and report writing.

The trainee should attempt to observe experienced examiners testifying in court as often as possible. The trainee should pay attention to general courtroom procedures, the witness's appearance and demeanor, and the presentation of technical or expert knowledge. After each observation, the trainee and this examiner should discuss the courtroom experience.

A moot court experience should be given to the trainee. The trainee's moot court should be challenging and mimic as closely as possible a real courtroom experience. The trainee should be evaluated on appearance, demeanor, knowledge of the case, knowledge of the discipline, scientific accuracy, and presentation skills.

The trainee's progress should be continually monitored according to objective criteria established by the laboratory. Periodic progress assessments involving the trainee, trainer, and supervisor should be conducted and documented. Deficiencies in the trainee's performance should be addressed immediately. Remediation should be made available through additional training, practice, or a re-evaluation of the training program. Continued deficiencies may suggest the unsuitability of the trainee for casework in this area.

Training Course Evaluation

The successful trainee should be given a chance to evaluate the paint-training program and the trainer. Perceived deficiencies in the training program or the trainer should be addressed.

Evaluation and Certification of Competency

Upon successful completion of the training program, the trainee should receive a certificate or letter of competency in forensic paint analysis. After receipt of such certification, the trainee will be allowed to perform independent casework including forensic paint comparisons.

Block One: General Background
Topic A: Encountering Paint Evidence

Objective:
Upon completion of this topic, the student will be able to give a brief presentation on the ways in which the following types of paints and coatings are encountered as physical evidence:

A. Automotive Paint
B. Other vehicle Paint (i.e. motorcycle, aircraft, marine, trains, bicycle etc.)
C. Architectural Paint
D. Maintenance Paint
E. Artistic and Craft Paints

Suggested Reading:

Crown, D.A. *The Forensic Examination of Paints and Pigments*. Charles C. Thomas, Springfield, IL, 1968, pp. v and vi, 3-7.

Moennsens, A., Moses, R.E., and Inbau, F.E. *Scientific Evidence in Criminal Cases*. The Foundation Press, Inc. 1973, pp. 367-371.

Ryland, S.G. Infrared Microspectroscopy of Forensic Paint Evidence. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 163-170 and pp. 185 (Section 3.1.1) -191.

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 430-431.

Practical Exercises:
Not applicable

Method of Instruction:
Lecture with visual aids
Self-study

Method of Evaluation:
Review of Presentation

Estimated Time for Completion:
8 hours

Block One: General Background
Topic B: History of Paint, General & Forensic Terminology

Objective:
Upon completion of this unit the student will be able to:

1. Briefly discuss the history of paint usage and the significant events leading to the development of modern paints.
2. Define the following terms:

A. Paint	G. Latex	M. Plasticizer
B. Vehicle	H. Pigment	N. Thermoplastic polymer
C. Lacquer	I. Drier	O. Thermosetting polymer
D. Varnish	J. Extender	P. Binder (resin)
E. Stain	K. Solvent	Q. Coating
F. Enamel	L. Drying Oils	R. Additives

Suggested Reading:

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 431-435.

Lambourne, R. Paint Composition and Applications – a General Introduction. In: *Paint and Surface Coatings, Theory and Practice*, R. Lambourne and T.A. Strivens, eds., William Andrew Publishing, 1999, pp.1-3.

Coatings Encyclopedic Dictionary. S. LeSota, ed. Federation of Societies for Coatings Technology, Blue Bell, PA, 1995.

Practical Exercises:
None

Method of Instruction:
Self-study
Lecture

Method of Evaluation:
Written and/or oral quiz

Estimated Time for Completion:
16 hours

Block One: General Background
Topic C: The Use and Composition of Paint

Objective:
Upon completion of this unit the student will be able to:

1. A. Discuss in general terms the significance of each of the following paint components in the formation of a paint film. (see below)
   B. Give examples of materials used in each component.
   C. Discuss the difference between a liquid paint and a dried paint film in terms of each component.

   a. Oils
   b. Driers
   c. Solvent
   d. Plasticizers
   e. Resinous Vehicles
   f. Extenders
   g. Pigments

2. Discuss the manner in which latex, thermoplastic and thermosetting paint films are formed.
3. Discuss the impact of the film formation mechanism on a forensic paint examination.
4. Relate various types of paints to end-use applications.
5. List additives used in latex paints.

Suggested Reading:

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 435-458.

Coatings Encyclopedic Dictionary. S. LeSota, ed. Federation of Societies for Coatings Technology, Blue Bell, PA, 1995.

Brandau, A. Introduction to Coatings Technology. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1990.

Wickes, Z.W., Jr. Film Formation. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1986.

Walker, F.H. Introduction to Polymers and Resins. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1999.

Morgans, W.M. *Outlines of Paint Technology*, 3rd ed., Halsted Press, NY, 1990, Chapters 18 through 24, pp. 316-422.

Practical Exercises:
None

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Written and/or oral quiz

Estimated Time for Completion:
16 hours

Block One: General Background
Topic D: Manufacturing Processes

Objective:
Upon completion of this unit the student will be able to describe in general terms:

1. How raw materials are acquired and mixed.
2. What variations may be present in raw materials.
3. What variations may exist in binders from different companies.
4. What a batch of paint is and how large it is.
5. What quality control procedures are used in the manufacture of paint.
6. How paint is packaged and distributed.
7. The application process of OEM finishes to motor vehicles.
8. Processes used in repainting and repairing vehicles.
9. Analytical and physical testing methods used by the paint industry.

Suggested Reading:

Automotive Paints and Coatings. G. Fettis, ed., VCH Publishers, NY, 1995, Chapters 1, 2, 3, 4, 5, 6, 7.

Bentley, J. Composition, Manufacture and Use of Paint. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 123-141.

Farkas, F.K. the Industrial Paint-making Process. In: *Paint and Surface Coatings, Theory and Practice*, R. Lambourne and T.A. Strivens, eds., William Andrew Publishing, 1999, pp.286-329.

Practical Exercises:
None

Method of Instruction:
Discussion
Self-study

Method of Evaluation:
Written and/or oral quiz

Estimated Time for Completion:
16 hours

Block One: General Background
Topic E: Overview of Forensic Paint Examinations

Objective:
Upon completion of this unit the student will be able to:

1. Describe the basic steps in forensic paint examinations in common terms and explain how these steps are used to identify the components of a paint film.
2. Briefly discuss the significant events in the development of forensic paint examinations.

Suggested Readings:

Scientific Working Group for Materials Analysis. Trace Evidence Recovery Guidelines, *Forensic Science Communications* (October 1999) 1(3). Available: http://www.fbi.gov/hq/lab/fsc/backissue/oct1999/trace.htm

ASTM E1610-02, Standard Guide for Forensic Paint Analysis and Comparison, ASTM International, West Conshohocken, PA.

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

Ryland, S., Jergovich, T. and Kirkbride, P. Current trends in forensic paint examination, *Forensic Science Review* (2006) 18(2):97.

Nielsen, H.K.R. Forensic analysis of coatings, *Journal of Coatings Technology* (Nov. 1984) 56 (718): 21-32.

Kirk, P. Crime Investigation, 2nd Edition. J.I. Thornton, ed. Robert Krieger Publishing Co., Malabar, FL, 1985, Chapter 19.

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 458-472.

Stoecklein, W. Forensic Science: Paints, varnishes and lacquers. *Encyclopedia of Analytical Science,* Academic Press Ltd., 1995, pp. 1625-1635.

Stoecklein, W. Forensic analysis of automotive paints at the Bundeskriminalamt: The evidential value of automotive paints, *Crime Laboratory Digest* (1995) 22(3):98.

Triplett, T. Lab Tests: Where the finish starts. *Industrial Paint & Powder*, April 1996, 34-37.

Practical Exercises:
None

Method of Instruction:
Observation of a paint case being worked involving a full protocol comparison
Discussion
Self-study

Method of Evaluation:
Oral presentation of objective 1

Estimated Time for Completion:
40 hours

Block Two: Search, Collection and Preservation Techniques
Topic A: Clothing

Objective:
Upon completion of this unit the student will be able to:

1. Locate, collect and preserve paint particles from clothing using the unaided eye and low power magnification.
2. Locate, collect and preserve paint smears from clothing and recognize high impact transfers.
3. Collect and preserve loose paint and debris from clothing using the scraping method and an appropriate packaging technique.

Suggested Readings:

Scientific Working Group for Materials Analysis. Trace Evidence Recovery Guidelines, *Forensic Science Communications* (October 1999) 1(3). Available: http://www.fbi.gov/hq/lab/fsc/backissue/oct1999/trace.htm

Palenik, S. Microscopy and Microchemistry of Physical Evidence. In: *Forensic Science Handbook, Vol. II*, R. Saferstein, ed. Prentice Hall, Englewood Cliffs, NJ, 1988, pp.164-171.

ASTM E 1492-05, Standard Practice for Receiving, Documenting, Storing and Retrieving Evidence in a Forensic Science Laboratory, ASTM International, West Conshohocken, PA.

ASTM E 1459-92(2005), Standard Guide for Physical Evidence Labeling and Related Documentation, ASTM International, West Conshohocken, PA.

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

ASTM E1610-02, Standard Guide for Forensic Paint Analysis and Comparison, ASTM International, West Conshohocken, PA.

Practical Exercises:
1. Search clothing from at least one (real or mock) case using the unaided eye and low power magnification. Collect the particles under the direct observation of the trainer.
2. Locate paint smears/abrasions on clothing from at least two pedestrian hit and run cases (real or mock) under the direct observation of the trainer.
3. Collect loose debris from clothing (real or mock) under the direct observation of the trainer using the scraping method. Package the debris using an appropriate technique.

Method of Instruction:
Discussion
Observation of a case involving the search, collection and preservation of paint evidence.
Practical Exercises

Method of Evaluation:
Observation and Evaluation of Practical Exercises

Estimated Time for Completion:
24 hours

Block Two: Search, Collection and Preservation Techniques
Topic B: Motor Vehicle

Objective:
Upon completion of this unit the student will be able to:

1. Recognize damage and questioned transfers on a motor vehicle.
2. Collect and preserve questioned paint from a motor vehicle.
3. Collect and preserve known paint samples from a motor vehicle.

Suggested Readings:

Scientific Working Group for Materials Analysis. Trace Evidence Recovery Guidelines, *Forensic Science Communications* (October 1999) 1(3). Available: http://www.fbi.gov/hq/lab/fsc/backissue/oct1999/trace.htm

Palenik, S. Microscopy and microchemistry of physical evidence. In: *Forensic Science Handbook, Vol. II*, R. Saferstein, ed. Prentice Hall, Englewood Cliffs, NJ, 1988, pp. 164-171.

ASTM E 1492-05, Standard Practice for Receiving, Documenting, Storing and Retrieving Evidence in a Forensic Science Laboratory, ASTM International, West Conshohocken, PA, 2007.

ASTM E 1459-92(2005), Standard Guide for Physical Evidence Labeling and Related Documentation, ASTM International, West Conshohocken, PA.

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

ASTM E1610-02, Standard Guide for Forensic Paint Analysis and Comparison, ASTM International, West Conshohocken, PA

Practical Exercises:
1. Under the direct observation of the trainer, search at least one motor vehicle and collect and preserve appropriate questioned and known paint samples.

Method of Instruction:
Discussion
Observation of the processing of a vehicle.
Practical Exercises

Method of Evaluation:
Observation and Evaluation of Practical Exercises

Estimated Time for Completion:
8 hours

Block Two: Search, Collection and Preservation Techniques
Topic C: Other objects (excluding clothing and motor vehicles)

Objective:
Upon completion of this unit the student will be able to:

1. Recognize paint transfers on a variety of materials.
2. Collect and preserve questioned and known samples from a variety of materials.

Suggested Readings:

Scientific Working Group for Materials Analysis. Trace Evidence Recovery Guidelines, *Forensic Science Communications* (October 1999) 1(3). Available: http://www.fbi.gov/hq/lab/fsc/backissu/oct1999/trace.htm

Palenik, S. Microscopy and microchemistry of physical evidence. In: *Forensic Science Handbook, Vol. II*, R. Saferstein, ed. Prentice Hall, Englewood Cliffs, NJ, 1988, pp 164-171.

ASTM E 1492-05, Standard Practice for Receiving, Documenting, Storing and Retrieving Evidence in a Forensic Science Laboratory, ASTM International, West Conshohocken, PA.

ASTM E 1459-92(2005), Standard Guide for Physical Evidence Labeling and Related Documentation, ASTM International, West Conshohocken, PA.

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

ASTM E1610-02, Standard Guide for Forensic Paint Analysis and Comparison, ASTM International, West Conshohocken, PA.

Practical Exercises:
1. Collect and preserve questioned and known samples from at least three objects, including at least one prying type tool, under the direct observation of the trainer.

Method of Instruction:
Discussion
Supervised observation of the examination, collection and preservation of evidence from objects other than clothing or vehicles.
Practical Exercises

Method of Evaluation:

Observation and Evaluation by the trainer of Practical Exercises

Estimated Time for Completion:
8 hours

Block Three: Microscopical Examination and Characterization
Topic A: Basic Microscopy

Objective:
Upon completion of this unit the student will be able to:

1. Name the important parts on a stereomicroscope, polarizing light microscope, comparison microscope and a reflected fluorescence microscope (and any other microscopes used in the laboratory for paint examination and analysis).
2. Explain the basic theory of optics and how magnification is achieved.
3. Explain the basic theory of the different light microscopy techniques (e.g. fluorescence, PLM, brightfield, darkfield, reflectance, etc.) used in their laboratory.
4. Setup and align any of the light microscopes used in the examination and analysis of paint.

Suggested Readings:

Microscope operating manuals

Delly, J.G., McCrone, L., and McCrone, W. *Polarized Light Microscopy*. Fifth Printing, Microscope Publications, Division of McCrone Research Institute, Chicago, Il, 1985.

De Forest, P.R. Foundations of forensic microscopy. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 216-319.

McCrone, W.C. Particle characterization by PLM: Part I: No Polars, *Microscope* (1982) 30(3):185-196.

McCrone, W.C. Particle characterization by PLM: Part II: Single Polar, *Microscope* (1982) 30(4):315-331.

McCrone, W.C. Particle characterization by PLM: Part III: Crossed Polar, *Microscope* (1982) 30(2):187-206.

Practical Exercises:

1. Properly setup a stereomicroscope.
2. Properly setup and align a transmitted light microscope (e.g. Kohler illumination).
3. Properly setup a reflected light microscope.
4. Properly setup a reflected fluorescence microscope.

Method of Instruction:
Discussion and observation
Self-study
Practical exercises

Estimated Time for Completion:
24 hours

Block Three: Microscopical Examination and Characterization
Topic B: Sample Preparation Techniques

Objective:
Upon completion of this unit the student will be able to:

1. Perform manual manipulation of a paint chip with a scalpel or other cutting tool to expose underlying layers.
2. Prepare samples of individual layers for transmitted and reflected light microscopical examinations.
3. Prepare manual thin cross-sections using a scalpel or other cutting tool.
4. Successfully prepare thin cross-sections of at least 3 paint chips (embedded and/or unembedded) using a microtome.
5. Successfully polish paint cross-sections.

Suggested Readings:

Cartwright, et.al. A microtome technique for sectioning multilayer paint samples for microanalysis, *Canadian Society of Forensic Science Journal* (1977) 10(1):7-12.

Derrick, M.R. Infrared microspectroscopy in the analysis of cultural artifacts. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 294-298.

Teetsov, A.S. Unique preparation techniques for nanogram samples. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 417-443.

Welsh, Frank S. A polished paint layer cross section in 30 minutes, *Microscope* (1997) 45(2):37-40.

Laing, D.K., et. al. The examination of paint films and fibers as thin sections. *The Microscope*, (1987) 35(3):233-248.

Allen, T.J. Modifications of sample mounting procedures and microtome equipment for paint sectioning, *Forensic Science International* (1991) 52:93-100.

Practical Exercises:
1. Expose layers of at least three paint chips using both bevel cuts and stair-step configurations.
2. Prepare microscope slides of individual layers within a chip.
3. Manually prepare thin cross-sections using a scalpel or other cutting tool of at least three paint chips
4. Prepare thin cross-sections of at least three paint chips using a microtome.

5. Prepare pigment dispersions of at least two single paint layers in a suitable medium.
6. Prepare polished cross-sections of at least two multi-layered paint samples.

Method of Instruction:
Discussion and observation
Self-study
Practical exercises

Method of Evaluation:
Evaluation of Practical Exercises

Estimated Time for Completion:
24 hours

Block Three: Microscopical Examination and Characterization
Topic C: Microscopical Recognition/ End Use Classification

Objective:
Upon completion of this unit the student will be able to:

1. Recognize paint utilizing a variety of microscopical techniques including stereomicroscopy, brightfield, fluorescence & polarized light microscopy.
2. Recognize and recover paint from debris.
3. Correctly describe paint layers in terms of color, layer sequence, layer thickness, gloss, and texture.
4. Recognize and describe surface defects, contaminants, damage, and intra/inter layer features.
5. Correctly classify/identify automotive, bicycle, & structural/architectural and maintenance paint layer structures.
6. Correctly classify/identify automotive OEM finishes and automotive repaints by their layer structures. This shall include the recognition of spot putties and body fillers. This shall also include the recognition of color coordinated primers and tri-coat systems.
7. Recognize various types of effect pigments including metal flake, pearlescent and interference pigments.

Suggested Readings:

Hudson, G.D., Andahl, R.O., and Butcher, S.J. The paint index - the colour classification and use of a collection of paint samples taken from scenes of crime, *Journal of the Forensic Science Society* (1977)17:27-32.

Norwicki, J. and Patten, R. Examination of U.S. automotive Paints: I. Make & model determination of hit-and-run vehicles by reflectance micro-spectrophotometry, *Journal of Forensic Science* (1986) 31(2):464-470.

Orzechowski, A. An optical microscopy method to display pigment agglomerates in polymer particles, *The Microscope* (1979) 27(1):5-9.

Boudreau, A.J., Cortner, G.V. Application of differential interference contrast microscopy to the examination of paints. *Journal of Forensic Science* (1979) 24(1):148-153.

McBane, B. Automotive Coatings. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1987.

Pierce, P.E., and Schoff, C.K. Coating Film Defects. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1988.

Philadelphia Society for Coatings Technology. *Pictoral Standards of Coatings Defects*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1979.

Hamer, P.S. Pigment analysis in the forensic examination of paints III: A guide to motor vehicle paint examination by transmitted light microscopy, *Journal of the Forensic Science Society* (1982) 22:187-192.

Paul, F.W., Dougherty, P.M., Bradford, C., and Parker, B. Reflection spectra of small paint samples: a potential solution, *Journal of the Forensic Science Society* (1971) 16(2):241-244.

Home, J.M., Twibell, J.D., and Smalldon, K.W. The characterization of motor vehicle body fillers, *Medicine, Science, and the Law* (1980) 20(3):163-175.

McNorton, S.C., Nutter, G. W., and Siegel, J. A. The characterization of automobile body fillers, *Journal of Forensic Science* (2008) 53(1):116-124.

Walsh, B.A.J., et. al. New Zealand bodyfillers: Discrimination using IR spectroscopy, visible microspectrophotometry, density and SEM-EDAX, *Forensic Science International* (1986) 32(3):193-204.

Kilbourn, J.H. and Marx, R. Polarized light microscopy of extenders in structural paints – forensic applications, *Microscope* (1994) 42(2):167-175.

Schoff, C.K. Surface defects: diagnosis and cure, *Journal of Coatings Technology* (January 1999) 71(888):57-73.

Practical Exercises:

1. Search debris and recover paint from debris containing a known number of fragments.
2. Microscopically characterize at least thirty paint samples in terms of color, layer sequence, layer thickness, gloss, and texture. Include a variety of paint systems including automotive, bicycle, & structural/architectural and maintenance coatings. Include automotive systems with color coordinated primers, tri-coat systems and a variety of effect pigments.

Method of Instruction:
Discussion and demonstration
Practical Exercises

Method of Evaluation:
Evaluation of Practical Exercises

Estimated Time for Completion:
120 hours

Block Three: Microscopical Examination and Characterization
Topic D: Fracture Characteristics and Comparisons

Objective:
Upon completion of this unit of instruction the student will be able to:

1. Describe the random individualizing characteristics which permit a fracture match of two paint fragments to be effected and defend why they are conclusive proof of individuality of source.
2. Discover corresponding fracture contours and surface features of paint samples indicating a fracture match and record observations.
3. Write reports reflecting conclusions of fracture match comparisons.

Suggested Readings:

Kirk, P. Crime Investigation, 2nd Edition. J.I. Thornton, ed. Robert Krieger Publishing Co., Malabar, FL, 1985, pp.245-247.

VanHoven, H., and Fraysier, H. The matching of automotive paint chips by surface striation alignment, *Journal of Forensic Science* (1983) 28(2):463-467.

Practical Exercises:
Supervised observation of fracture and surface characteristics of at least five paint samples.

Method of Instruction:
Discussion and demonstration
Self-study
Practical exercises

Method of Evaluation:
Evaluation of Practical Exercises

Estimated Time for Completion:
16 hours

Block Three: Microscopical Examination and Characterization
Topic E: Microscopical Comparisons

Objective:
Upon completion of this unit the student will be able to:

1. Use stereomicroscopy and comparison microscopy to determine whether paint chips are distinguishable from one another.
2. Compare paint chips utilizing other microscopical techniques which may include polarized light and fluorescence microscopy.

Suggested Readings:
None

Practical Exercises:
1. Compare at least five sets of samples provided by the trainer and determine whether any items within a set can be distinguished from the others.

Method of Instruction:
Discussion
Practical Exercises

Method of Evaluation:
Evaluation of Practical Exercises

Estimated Time for Completion:
16 hours

Block Four: Solvent/Microchemical Examinations
Topic A: Binder Classification

Objective:
Upon completion of this unit the student will be able to:

1. Use solvent tests to correctly classify an automotive paint layer in terms of enamel, acrylic lacquer, nitrocellulose lacquer, solution lacquer, or dispersion lacquer.
2. Use solvent tests to correctly classify automotive paints as OEM or repaint (if possible).
3. Use solvent tests to correctly classify non-automotive paints in terms of enamel or lacquer.

Suggested Readings:

Thornton, J., Krause, S., Lerner, B., and Kahane, D. Solubility characterization of automotive paints, *Journal of Forensic Science* (1983) 28(4):1004-1007.

Ryland, S.G. Infrared Microspectroscopy of Forensic Paint Evidence. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 163-243.

Practical Exercises:
1. Correctly classify at least thirty paint samples using microchemical tests.

Method of Instruction:
Discussion
Reading
Practical exercises

Method of Evaluation:
Evaluation of practical exercises

Estimated Time for Completion:
24 hours

Block Four: Solvent/Microchemical Examinations
Topic B: Pigment Identification

Objective:
Upon completion of this unit the student will be able to:

1. Use microchemical tests to correctly identify paint pigments.
2. Interpret the results of microchemical tests in situ.

Suggested Reading:

Palenik, S. Applying chemical microscopy to the coatings industry, *Paint and Coatings Industry* (March 1998):48-56.

Practical Exercises:

1. Classify paint pigments individually and/or in situ in at least five samples.

Method of Instruction
Practical exercises
Discussion

Method of Evaluation:
Evaluation of practical exercises

Estimated Time for Completion:
32 hrs

Block Four: Solvent/Microchemical Examinations
Topic C: Microchemical Tests

Objective:
Upon completion of this unit the student will be able to:

1. Use microchemical tests to determine whether or not paint samples are distinguishable from one another.
2. Interpret the results of microchemical testing.

Suggested Readings:

Beattie, B., Dudley, R.J., and Smalldon, K.W. The use of Morin staining for the microscopic characterization of multilayered white paint flakes, *Forensic Science International* (1979) 13:41-49.

Linde, H.G., Stone, R.P. Application of the LeRosen test to paint analysis, *Journal of the Forensic Science Society* (1979) 24:650-655.

Home, J.M., Laing, D.K., and Richardson, S. The discrimination of small fragments of household gloss paint using chemical tests, *Journal of the Forensic Science Society* (1983) 23(1):43-47.

Practical Exercises:
1. Compare at least five sets of samples provided by the trainer and determine whether any items within a set are distinguishable from one another.

Method of Instruction
Practical exercises
Discussion
Method of Evaluation:
Evaluation of practical exercises

Estimated Time for Completion:
16 hours

Block Five: Binder Examinations
Topic A: Binder Classification

Objective:
Upon completion of this unit the student will be able to:

1. Recognize the chemical structures of different polymer types used in paint binders.
2. Discuss a classification scheme for binders based upon their polymer type (automotive and structural paints).
3. Discuss a classification scheme for binders suspended in different solvents. (i.e. emulsion, dispersion etc.)
4. Discuss a classification scheme for binders based upon their mode of cure (i.e. thermoset, thermoplastic etc.)
5. Recognize the distinguishing characteristics of automotive OEM finishes and after-market refinishes.
6. Recognize the distinguishing characteristics of automotive finishes, architectural and other industrial finishes.

Suggested Readings:

Wickes, Z.W., Jr. Film Formation. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1986.

Walker, F.H. Introduction to Polymers and Resins. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1999.

Crown, D.A. *The Forensic Examination of Paints and Pigments*, Charles C. Thomas, Springfield, IL, 1968, pp. 95-114.

McBane, B. Automotive Coatings. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1987.

Bleile, H.R., and Rodgers, S. Marine Coatings. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1989.

Chattopadhyay, A.D., and Zentner, M.R. Aerospace and Aircraft Coatings. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1990.

Ryntz, R.A. Automotive Coatings: Current Trends for Coating Plastic - Part 1. *Paint and Coatings Industry* (March 1997):36-43.

Ryntz, R.A. Painting of Plastics. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1994.

Automotive Paints and Coatings. G. Fettis, ed., VCH Publishers, NY, 1995, Chapters 1, 2, 3, 4, 5, 6, 7.

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 448-458.

Martens, C.R. *Waterborne Coatings, Emulsion and Water-Soluble Paints*, Van Nostrand Reinhold Co., New York, 1981, pp. 13, 14, and 52-91.

Bentley, J. Organic Film Formers. In: *Paint and Surface Coatings, Theory and Practice*, R. Lambourne and T.A. Strivens, eds., William Andrew Publishing, 1999, pp.19-89.

Ryer, D. Alkyd chemistry and new technology trends in coatings resin synthesis, *Paint & Coatings Industry* (January 1998):76-83.

Beveridge, A., Fong, F., and McDougall, D., Use of infrared spectroscopy for the characterization of paint fragments. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 201-207.

Practical Exercises:
None

Method of Instruction
Lecture and Discussion
Self-study

Method of Evaluation:
Written quiz

Estimated Time for Completion:
24 hours

Block Five: Binder Examinations
Topic B: Infrared Spectroscopy (IR)

Objective:
Upon completion of this unit the student will be able to :

1. Explain the basic theory and instrumentation used in infrared spectroscopy (IR).
2. Compare and contrast dispersive and Fourier transform IR.
3. Discuss the use of IR accessories for paint examinations, including the beam condenser, diamond cell, ATR (attenuated total reflectance), diffuse reflectance, and the IR microscope. This discussion shall include sample preparation techniques.
4. Perform appropriate calibrations and/or quality checks.
5. Prepare and analyze single layer paint samples using one or more of the techniques in Objective 3.
6. Prepare and analyze single layers from a multiple-layer paint fragment using one or more of the techniques in Objective 3.
7. Demonstrate and discuss the precision and accuracy of IR. Discuss factors that can affect results, including user dependant variables, instrumental variations (stability) and parameter selections.
8. Compare and contrast absorbance and % transmittance formats, emphasizing each format's strengths and weaknesses.
9. Demonstrate and discuss the discriminating power of IR for similar colors and binder types designed for different end-uses.
10. Perform spectral subtraction via software, if available.
11. Perform proper computer searches of spectral libraries, if available.
12. Demonstrate the ability to use IR to chemically classify binders found in automotive and structural paints using case-size samples.

Suggested Readings:

Infrared Spectroscopy Atlas Working Committee. An Infrared Spectroscopy Atlas for the Coatings Industry, Fourth Edition, Vol. I , Federation of Societies for Paint Technology, Philadelphia, PA, 1991, pp 1-62.

Rodgers, P.G., Cameron, R., Cartwright, N.S., Clark, W.H., Deak, J.S. and Norman, E.W.W. The classification of automobile paint by diamond window infrared spectrophotometry, Part I: Binders and Pigments, *Canadian Society of Forensic Science Journal* (1976) 9(1):1-14.

Rodgers, P.G., Cameron, R., Cartwright, N.S., Clark, W.H., Deak, J.S. and Norman, E.W.W. The classification of automobile paint by diamond window infrared spectrophotometry, Part II: Automotive topcoats and undercoats, *Canadian Society of Forensic Science Journal* (1976) 9(2):49-68.

Rodgers, P.G., Cameron, R., Cartwright, N.S., Clark, W.H., Deak, J.S. and Norman, E.W.W. The classification of automobile paint by diamond window infrared spectrophotometry, Part III: Case Histories, *Canadian Society of Forensic Science Journal* (1976) 9(3):103-111.

Suzuki, E.M., and Gresham, W.R. Forensic science applications of diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS): I, Principles, sampling methods and advantages, *Journal of Forensic Science* (1986) 31(3):931-952.

Norman, E.W.W., Cameron, R., Cartwright, L.J., Cartwright, N.S., Clark,W.H., and MacDougall, D.A. The classification of automotive paint primers using infrared spectroscopy-a collaborative study, *Canadian Society of Forensic Science Journal* (1983)16(4):163-173.

Ryland, S.G. Infrared Microspectroscopy of Forensic Paint Evidence. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 163-243.

McEwen, D.J. and Cheever, G.D. Infrared microscopic analysis of multiple layers of automotive paints, *Journal of Coatings Technology* (1983) 65(819): 35-41.

Wilkinson, J.M., Locke, J., and Laing, D.K. The examination of paints as thin sections using visible microspectrophotometry and Fourier transform infrared microscopy, *Forensic Science International* (1988) 38:43-52.

Home, J.M., Twibell, J.D., and Smalldon, K.W. The characterization of motor vehicle body fillers, *Medicine, Science, and the Law* (1980) 20(3):163-174.

McNorton, S.C., Nutter, G.W., Siegel, J.A. The characterization of automobile body fillers, *Journal of Forensic Science* (2008) 53(1):116-124.

Ryland, S.G., et. al. Discrimination of 1990s original automotive paint systems: A collaborative study of black nonmetallic base coat/clear coat finishes using infrared spectroscopy, *Journal of Forensic Science* (2001) 46(1):31-45.

Practical Exercises:

1. Perform all appropriate calibration and/or quality checks before using the instrument. Evaluate and document results.
2. Analyze common paint resins.
3. Prepare and analyze at least five single layer paint samples using one or more of the techniques listed in objective 3.
4. Prepare and analyze individual layers of at least five multiple-layered paint chips using one or more of the techniques listed in objective 3.
5. Prepare and analyze a series of paints having similar binder types (structural and automotive).

6. Prepare and analyze a series of paints having similar colors (structural and automotive).
7. Perform spectral subtraction using a single layered paint smeared on top of a painted substrate.
8. Search at least five spectra against a spectral library.
9. Perform binder classification from the spectra of at least 10 unknowns.
10. Demonstrate the effects of varying instrumental parameters including, but not limited to, number of scans, microscope aperture sizes, apodization, gain, and wavenumber resolution.

Method of Instruction:
Lecture
Self-study
Demonstrations
Practical exercises

Method of Evaluation:
Written quiz
Evaluation of practical exercises

Estimated Time for Completion:
120 hours

Block Five: Binder Examinations
Topic C: Pyrolysis Gas Chromatography (PGC)

Objective:
Upon completion of this unit the student will be able to:

1. Explain the basic theory and instrumentation used in gas chromatography, and pyrolysis gas chromatography.
2. Change a column and properly set all flow rates.
3. Perform appropriate calibrations and/or quality checks.
4. Prepare and analyze single layered paint samples.
5. Prepare and analyze single layers from a multiple-layered paint fragment given a case-sized sample.
6. Demonstrate and discuss the precision (reproducibility) and accuracy of PGC. Discuss factors that can affect results, including user dependant variables, instrumental variations (stability), parameter selections and physical condition of the sample. Explain causes of peak variations.
7. Demonstrate and discuss the discriminating power of PGC for similar colors and binder types designed for different end-uses.
8. Discuss and/or demonstrate the ability to use PGC to aid in the classification of binders found in automotive and structural paints.
9. Discuss and/or demonstrate the use of derivatization techniques for the analysis of paint.

Suggested Readings:

Cardosi, P.J. Pyrolysis gas chromatographic examination of paints, *Journal of Forensic Science* (1982) 27(3):695-703.

Fukuda, K. The Pyrolysis gas chromatographic examination of Japanese car paint flakes, *Forensic Science International* (1985) 29:227-236.

Challinor, J.M. Forensic applications of pyrolysis capillary gas chromatography, *Forensic Science International* (1983) 21:269-285.

Applied Pyrolysis Handbook. T.P. Wampler, ed., Marcel Dekker Inc., New York, 1995, Chapters 1, 2, 3, and 8.

Stafford, D.T. Forensic capillary gas chromatography. In: *Forensic Science Handbook, Vol. II*, R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 1988, pp. 38-65.

Stewart, W.D. Pyrolysis-gas chromatographic techniques for the analysis of automobile finishes: a collaborative study, *Journal of the Association of Official Analytical Chemists (AOAC)* (1976) 59:35.

Walker, J.Q. Pyrolysis gas chromatographic correlation trials of the American Society for Testing and Materials, *Journal of Chromatographic Science* (1977) 15:267-274.

Practical Exercises:

1. Perform all appropriate calibration and/or quality checks before using the instrument. Evaluate and document results.
2. Analyze reference materials of polymers commonly used in paints.
3. Run five replicate single layered samples of a variety of types of paints. (Include single layers of at least one multiple layered sample).
4. Run five replicate runs of the intact multiple layered samples used in exercise three.
5. Run a series of at least 3 paints having similar colors to assess discriminating power.
6. Run a series of at least 3 paints having similar binder types to assess discriminating power.
7. Properly classify at least 3 unknowns using PGC.

Method of Instruction:
Lecture
Self-study
Demonstrations
Practical exercises

Method of Evaluation:
Written quiz
Evaluation of practical exercises

Estimated Time for Completion: 160 hours

Block Five: Binder Examinations
Topic D: Pyrolysis Gas Chromatography/Mass Spectrometry

Objective:
Upon completion of this unit the student will be able to:

1. Explain the basic theory and instrumentation used in pyrolysis gas chromatography/mass spectrometry.
2. Compare and contrast PGC/FID and PGC/MS techniques.
3. Perform all appropriate calibration and/or quality checks.
4. Perform routine maintenance (e.g. source cleaning, septum changes, injection port liner changes, etc.)
5. Prepare and analyze single layer paint samples.
6. Prepare and analyze single layers from a multiple-layer paint fragment given a case size sample.
7. Demonstrate and/or discuss from personal experience, the precision of PGC/MS over the short term and long term. Explain causes of peak variations.
8. Demonstrate and discuss from personal experience, the discriminating power of PGC/MS for similar colors of automotive and structural paints and for similar color and binder types of automotive paints.
9. Demonstrate the ability to use PGC/MS to chemically classify binders found in automotive and structural paints given actual case-size samples.
10. Discuss the use of derivatization techniques for the analysis of paint.
11. Discuss the complications in the identification of pyrolyzate fragments using available mass spectral libraries.

Suggested Readings:

McMinn, D.G., Carlson, T.L., and Munson, T.O. Pyrolysis capillary gas chromatography/mass spectrometry for analysis of automotive paints, *Journal of Forensic Science* (1985) 30(4):1064-1073.

Burke, P., Curry, C.J., Davies, L.M., and Cousins, D.R. A comparison of pyrolysis mass spectrometry, pyrolysis gas chromatography and infrared spectroscopy for the analysis of paint resins, *Forensic Science International* (1985) 28:201-219.

Challinor, J.M. Examination of forensic evidence. In: *Applied Pyrolysis Handbook*, 2nd ed., T.P. Wampler, ed., CRC Press, Taylor & Francis, Boca Raton, FL, 2007, pp. 175-199.

Challinor, J.M. A pyrolysis-derivatisation-gas chromatography technique for the structural elucidation of some synthetic polymers, *Journal of Analytical and Applied Pyrolysis* (1989) 16:323-333.

Challinor, J.M. The scope of pyrolysis methylation reactions, *Journal of Analytical and Applied Pyrolysis* (1991) 20:15-24.

Challinor, J.M. Structure determination of alkyd resins by simultaneous pyrolysis methylation, *Journal of Analytical and Applied Pyrolysis* (1991) 18:233-244.

Challinor, J.M. Characterisation of rosin-based commercial resins by pyrolysis-and simultaneous pyrolysis methylation-gas chromatography/mass spectrometry techniques, *Journal of Analytical and Applied Pyrolysis* (1993) 25:349-360

Challinor, J.M. On the mechanism of high temperature reactions of quaternary ammonium hydroxides with polymers, *Journal of Analytical and Applied Pyrolysis* (1994) 29:223-224.

Wampler, T., Bishea, G., and Simonsick, W.J. Recent changes in automotive paint formulation using pyrolosis-gas chromotography/mass spectrometry for identification, *Journal of Analytical and Applied Pyrolysis* (1997) 40-41:79-89.

Challinor, J.M. Pyrolysis techniques for the characterization and discrimination of paint. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 165-182.

Practical Exercises:

1. Perform all appropriate calibration and/or quality checks before using the instrument. Evaluate and document results.
2. Analyze reference materials of polymers commonly used in paints.
3. Run five replicate single layered samples of a variety of types of paints. (Include single layers of at least one multiple layered sample).
4. Run five replicate runs of the intact multiple layered samples used in exercise three.
5. Run a series of at least 3 paints having similar colors to assess discriminating power.
6. Run a series of at least 3 paints having similar binder types to assess discriminating power.
7. Properly classify at least 3 unknowns using PGC/MS.

Method of Instruction:
Lecture
Self-study
Demonstrations
Practical exercises

Method of Evaluation:

Oral quiz
Evaluation of practical exercises

Estimated Time for Completion:
160 hours

Block Five: Binder Examinations
Topic E: Other Methods of Binder Analysis

Objective:
Upon completion of this unit the student will be able to:

1. Discuss the application of pyrolysis mass spectroscopy (PMS).

Suggested Readings:

Hughes, J.C., Wheals, B.B., and Whitehouse, M.J. Pyrolysis mass spectrometry – a technique of forensic potential? *Forensic Science* (1977) 10(3):217-228.

Saferstein, R. and Manura, J.J. Pyrolysis mass spectrometry - a new forensic science technique, *Journal of Forensic Science* (1977) 22(4):748-756.

Practical Exercises:
None

Method of Instruction:
Lecture
Self-study
Discussion

Method of Evaluation:
Oral evaluation

Estimated Time for Completion:
2 hours

Block Five: Binder Examinations
Topic F: Binder Characterization and Comparison

Objective:
Upon completion of this unit the student will be able to:

1. Correctly characterize and compare the binder portion of various types of paint samples in mock cases provided by the instructor utilizing all binder comparison techniques available.

Suggested Readings:
None

Practical Exercises:
1. Characterize and compare paint samples, including single layer and multiple layer automotive and non-automotive paints.

Method of Instruction:
Practical exercises
Discussion and review

Method of Evaluation:
Practical examination

Estimated Time for Completion:
80 hours

Block Six: Pigment & Extender Examinations
Topic A: Pigments & Extenders

Objective:
Upon completion of this unit the student will be able to do the following:

1. List general classes of inorganic pigments.
2. List general classes of organic pigments.
3. List commonly encountered extenders.
4. List commonly encountered effect pigments.

Suggested Readings:

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 435-441.

Morgans, W.M. *Outlines of Paint Technology*, 3rd ed., Halsted Press, NY, 1990, Chapters 2-7, pp. 9-133.

Braun, J. Introduction to Pigments. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1993.

Smith, A. Inorganic Primer Pigments. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1988.

Lewis, P. Organic Pigments. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 2000.

Wickes, Z. Corrosion Protection by Coatings. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1987.

Crown, D.A. *The Forensic Examination of Paints and Pigments*, Charles C. Thomas, Springfield, IL, 1968, pp. 24-94.

Droll, F.J. Just what color is that car? *Paint and Coatings Industry* (February 1998):54-57.

Iden, R. Teamwork brings innovative effect pigments to light, *Journal of Coatings Technology*, (April 1995) 67(843):57-59.

New special effects almost "mystical", *Industrial Paint & Powder* (April 1996): 22.

Wanlass, M. Holographic pigments – add new dimension to paint, *Paint and Coatings Industry* (August 1997):48-49.

Novinski, S.J., Noak, P., and Venturini, M. Employing pearlescent pigments in high-performance coatings, *Paint and Coatings Industry* (May 1998):62-68.

Skanden, G., et. al. Production of nanopowders by chemical vapor, *Vacuum and Thin Film* (November 1999) 2(11):28-33.

Coatings Encyclopedic Dictionary. S. LeSota, ed. Federation of Societies for Coatings Technology, Blue Bell, PA, 1995.

Bentley, J. Composition, manufacture, and use of paint. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 127-128.

Practical Exercises:

1. Define and describe the following terms and give examples:

pigment	extender	pearlescent pigment
interference pigment	metallic flake	effect pigment
anti-corrosive pigment		

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Oral quiz

Estimated Time for Completion:
32 hours

Block Six: Pigment & Extender Examinations
Topic B: Light Microscopy of Pigments/Extenders

Objective:
Upon completion of this unit the student will be able to:

1. Characterize and describe the physical/optical properties of pigment/extender particles (and identify where possible) by reflected and transmitted light microscopy, in particular polarized light microscopy.

Suggested Readings:

McCrone, W. The microscopical identification of artists' pigments, *Journal of the International Institute for Conservation – Canadian Group* (1982) 7(1-2): 11-34.

Kilbourn, J.H., and Marx, R.B., Polarized light microscopy of extenders in structural paint - forensic applications, *Microscope* (1994) 42(4):167-175

McCrone, W.C. Application of Particle Study in Art and Archaeology. In: *The Particle Atlas, Edition Two, Volume V*, W. McCrone, J.G. Delly, and S.J. Palenick. Ann Arbor Scientific Publishers, Ann Arbor, Michigan, 1979, pp. 1042-1413.

Govaert, F., and Bernard, M. Discriminating red spray paints by optical microscopy, Fourier transform infrared spectroscopy, and X-ray fluorescence, *Forensic Science International*, (2004) 140(1):61-70.

Practical Exercises:
1. Mount reference standards of at least five different pigments/extenders and characterize their physical and optical properties by reflected and transmitted light microscopy in particular polarized light microscopy.
2. Determine the number of pigment/extender types that are present in a prepared sample containing at least two pigments/extenders.
3. Characterize and identify as many pigments/extenders as possible in at least five paint samples.

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Evaluation of practical exercises

Estimated Time for Completion:
16 hours

Block Six: Pigment & Extender Examinations
Topic C: Infrared Spectroscopy

Objective:
Upon completion of this unit the student will be able to:

1. Recognize characteristic absorptions of extenders from infrared spectra.
2. Recognize characteristic absorptions of common pigments from infrared spectra.
3. Compare and contrast micro spectroscopy with extended range techniques.
4. Recognize the impact of sample size and inhomogeneity on infrared micro spectroscopy.
5. Perform spectral subtraction via software if available.
6. Perform proper computer searches of spectral libraries and discuss proper evaluation of results.

Suggested Readings:

Harkins, T.R., Harris, J.T., and Shereve, O.D. Identification of pigments in paint products by infrared spectroscopy, *Analytical Chemistry* (1959) 31(4):541-545.

Infrared Spectroscopy Atlas Working Committee. An Infrared Spectroscopy Atlas for the Coatings Industry, Fourth Edition, Vol. I , Federation of Societies for Paint Technology, Philadelphia, PA, 1991.

Ryland, S.G. Infrared Microspectroscopy of Forensic Paint Evidence. In *Practical Guide to Infrared Microspectroscopy*, H.J. Humecki, ed. Marcel Dekker, NY, 1995, pp. 163-243.

Suzuki, E.M. Infrared spectra of U.S. automobile original topcoats (1974-1989): II. Identification of some topcoat inorganic pigments using an extended range (4000-220 cm^{-1}) Fourier transform spectrometer, *Journal of Forensic Sciences* (1996) 41(3):393-406.

Suzuki, E.M., and Marshall, W.P. Infrared spectra of U.S. automobile original topcoats (1974-1989): III. In Situ Identification of some organic pigments used in yellow, orange, red, and brown nonmetallic and brown metallic finishes - Benzimidazolones, *Journal of Forensic Sciences* (1997) 42(4):619-648.

Suzuki, E.M., and Marshall, W.P. Infrared spectra of U.S. automobile original topcoats (1974-1989): IV. Identification of some organic pigments used in red and brown nonmetallic and metallic monocoats – Quinacridones, *Journal of Forensic Sciences* (1998) 43(3): 514-542.

Suzuki, E.M. Infrared spectra of U.S. automobile original topcoats (1974-1989): V. Identification of organic pigments used in red nonmetallic and brown nonmetallic and

metallic monocoats - DPP Red BO and Thioindigo Bordeaux, *Journal of Forensic Sciences* (1999) 44( ):297-313.

Suzuki, E.M. Infrared spectra of U.S. automobile original topcoats (1974-1989): VI. Identification and analysis of yellow organic automotive paint pigments-Isoindolinone Yellow 3R, Isoindoline Yellow, Anthrapyrimidine Yellow, and Miscellaneous Yellows*, *Journal of Forensic Sciences* (1999) 44(6):1151-1175.

Buzzini, P., and Massonnet, G. A market study of green spray paints by Fourier transform infrared (FTIR) and Raman spectroscopy, *Science and Justice* (2004) 44(3):123-131.

Bell, S., Fido, L.A., Speers, S.J., and Armstrong, W.J. Rapid forensic analysis and identification of "Lilac" architectural finishes using Raman spectroscopy, *Applied Spectroscopy* (2005) 59(1):100-108.

Bell, S., Fido, L.A., Speers, S.J., Armstrong, W.J, and Spratt, S. Forensic analysis of architectural finishes using Fourier Transform infrared and Raman spectroscopy, Part I: The resin bases, *Applied Spectroscopy* (2005) 59(11):1333-1339.

Bell, S., Fido, L.A., Speers, S.J., Armstrong, W.J, and Spratt, S. Forensic analysis of architectural finishes using Fourier Transform infrared and Raman spectroscopy, Part II: White paint, *Applied Spectroscopy* (2005) 59(11):1340-1346.

Govaert, F., and Bernard, M. Discriminating red spray paints by optical microscopy, Fourier transform infrared spectroscopy, and X-ray fluorescence, *Forensic Science International* (2004) 140(1):61-70.

Practical Exercises:

1. Interpret IR spectra and recognize pigment(s) and extender(s) in at least 10 paint samples.
2. Demonstrate the effects of varying instrumental parameters including, but not limited to, number of scans, microscope aperture sizes, apodization, gain, and wavenumber resolution.
3. Prepare and analyze at least five single layer paint samples using one or more of the techniques listed in objective 3.
4. Prepare and analyze individual layers of at least five multiple-layered paint chips using one or more of the techniques listed in objective 3.
5. Prepare and analyze a series of paints having similar colors (architectural and automotive).
6. Perform spectral subtraction using a single layered paint smeared on top of a painted substrate.
7. Search at least five spectra against a spectral library.

Method of Instruction:

Self-study
Discussion
Practical Exercises

Method of Evaluation:
Written quiz
Evaluation of practical exercises

Estimated Time for Completion:
40 hours

Block Six: Pigment & Extender Examinations
Topic D: Scanning Electron Microscopy/Energy Dispersive X-ray Spectrometry

Objective:
Upon completion of this unit the student will be able to do the following:

1. Draw a Block diagram and explain the basic operation of the SEM.
2. Perform all appropriate calibration and/or quality checks before using the instrument.
3. Operate a scanning electron microscope.
4. Optimize parameters for image documentation/capture.
5. Recognize the need for and perform routine maintenance on a SEM.
6. Draw a block diagram and explain the basic operation of the EDS system.
7. Operate the EDS system.
8. Optimize parameters for elemental analysis.
9. Compare and contrast various methods of sample preparation (e.g. stair-step, cross-section, thin peels, coating) and their effects on the analytical results.
10. Use available equipment to add conductive coatings to samples for SEM/EDS analysis.
11. Recognize the presence of and explain factors contributing to escape peaks, sum peaks, peak overlaps, and peak ratio shifts in a spectrum. Change instrumental parameters to minimize these effects, if possible.
12. Properly identify peaks.
13. Discuss qualitative, semi-quantitative and standard quantitative EDS analyses.
14. Demonstrate the effects of varying magnification/raster size on the EDS analysis of paint samples.
15. Discuss the use of line scans and elemental composition mapping in paint analysis.
16. Discuss the effects of varying take-off angles in specimen analysis.
17. Demonstrate the use of spot analysis mode for associating elements in extender pigments.

Suggested Readings:

Goldstein, J.I., et. al., *Scanning Electron Microscopy and X-Ray Microanalysis*. 2nd ed., Plenum Press, NY, 1992, pp. 1-415.

Whiston, C., *X-Ray Methods,* ACOL Series, John Wiley & Sons, NY, 1987.

Lawes, G., *Scanning Electron Microscopy and X-Ray Microanalysis,* ACOL Series, John Wiley & Sons, NY, 1987.

Scientific Working Group for Materials Analysis. Standard Guide for Using Scanning Electron Microscopy/X-ray Spectrometry in Forensic Paint Examination*, Forensic*

Science Communications (October 2002) 4(4). Available:
http://www.fbi.gov/hq/lab/fsc/backissu/oct2002/bottrell.htm

Henson, M.L. and Jergovich, T.A. Scanning electron microscopy and energy dispersive x-ray spectrometry (SEM/EDS) for the forensic examination of paints and coatings. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 243-271.

Crown, D.A. *The Forensic Examination of Paints and Pigments*, Charles C. Thomas, Springfield, IL, 1968, pp 142-143.

Flegler, S.L., Heckman, J.W., and Klomparens, K.L. *Scanning and Transmission Electron Microscopy: An Introduction*. Oxford University Press, 1995.

McCrone, W.C., Delly, J.G., and Palenik, S.J. *The Particle Atlas, Volumes 3 and 6*. Ann Arbor Scientific Publishers, Ann Arbor, Michigan, 1973 and 1980.

Practical Exercises:

1. Perform all appropriate calibration and/or quality checks before using the instrument. Evaluate and document results.
2. Acquire secondary and backscattered images of paint.
3. Store and print images on available media.
4. Prepare and analyze embedded and non-embedded multi-layered paint chips.
5. Perform peak deconvolution on overlapping elements.
6. Vary the excitation voltage and describe the effects on the detection of various elements.
7. Vary raster size and describe the effects on the analytical results obtained from an architectural paint and/or primer.
8. Sum or average spectra from multiple areas within a layer and compare that result with each individual spectrum.
9. Correctly identify the elements present in at least ten paint layers.
10. Identify associated elements in extender pigment grains in situ for at least three different types of extender pigments utilizing spot mode analysis.

Method of Instruction:
Lecture
Practical Exercises

Method of Evaluation:
Oral exam
Written exam
Practical exam

Estimated Time for Completion:
160 hours

Block Six: Pigment & Extender Examinations
Topic E: X-ray Fluorescence Spectrometry (XRF)

Objective:
Upon completion of this unit the student will be able to do the following:

1. Draw a block diagram and explain the theoretical operation of the XRF.
2. Perform all appropriate calibration and/or quality checks before using the instrument.
3. Operate a X-ray fluorescence spectrometer.
4. Optimize parameters for elemental analysis.
5. Compare and contrast various methods of sample preparation (e.g. bulk samples, cross-sectional view, single layer peels) and their effects on the analytical results.
6. Recognize the presence of and explain factors contributing to escape peaks, sum peaks, peak overlaps, diffraction peaks, scatter peaks (Compton and Raleigh) and peak ratio shifts in a spectrum. Change instrumental parameters to minimize these effects, if possible.
7. Properly identify peaks.
8. Discuss qualitative, semi-quantitative and standard quantitative XRF analyses.
9. Recognize the effects of changing instrument parameters (e.g. voltage, current, vacuum level, multi-channel analyzer settings, energy scale, secondary targets, degree of beam collimation).
10. Discuss the use of elemental composition mapping in paint analysis.
11. Discuss the pros and cons of EDS and XRF spectrometry.

Suggested Readings:

Jenkins, R., Gould, R.W., and Gidcke, D. *Quantitative X-ray Spectrometry*, 2nd ed., Marcel Dekker, Inc., New York, N.Y., 1995, Chapters 1-4, 7, 8, 11,and 12.

Haag, L.C. Element profiles of automotive paint chips by X-ray fluorescence spectrometry, *Society of Forensic Science Journal* (1977) 16:255.

Howden, C.R., Dudley, R.J., and Smalldon, K.W. The non-destructive analysis of single layered household paints using energy dispersive X-ray fluorescence spectrometry, *Society of Forensic Science Journal* (1977) 17:161-167.

Massonnet, G. Comparison of X-ray fluorescence and X-ray diffraction techniques for the analysis of metallic automotive paints, *Crime Laboratory Digest*, (1995) 22(3):95.

Reeve, V., and Keener, T. Programmed energy dispersive X-ray analysis of top coats of automotive paint, *Journal of Forensic Science Journal* (1976) 21(4):883-907.

Krishnan, S.S. Examination of paints by trace elemental analysis, *Journal of Forensic Science* (1976) 21(4):908-916.

Jenkins, R. X-Ray fluorescence analysis, *Analytical Chemistry*, (1984) 56(9):1099-1106.

C982-03, Standard Guide for Selecting Components for Energy-Dispersive X-Ray Fluorescence (XRF) Systems, ASTM International, West Conshohocken, PA.

ASTM D5381-93(2003), Standard Guide for X-Ray Fluorescence (XRF) Spectroscopy of Pigments and Extenders, ASTM International, West Conshohocken, PA.

ASTM D4764-01(2006), Standard Test Method for Determination by X-Ray Fluorescence Spectroscopy of Titanium Dioxide Content in Paint, ASTM International, West Conshohocken, PA.

ASTM D5380-93 (2003), Standard Test Method for Identification of Crystalline Pigments and Extenders in Paint by X-Ray Diffraction Analysis, ASTM International, West Conshohocken, PA

Govaert, F., and Bernard, M. Discriminating red spray paints by optical microscopy, Fourier transform infrared spectroscopy, and X-ray fluorescence, *Forensic Science International* (2004) 140(1):61-70.

Practical Exercises:

1. Perform appropriate calibrations and quality checks.
2. Prepare and analyze single layered and multi-layered paint samples. Evaluate effects of different methods of sample preparation and mounting materials.
3. Identify the elements present and evaluate the data for the presence of escape peaks, sum peaks, peak overlaps, diffraction peaks, scatter peaks (Compton and Raleigh), and peak ratio shifts.
4. For a single sample, independently change each parameter of the instrument (e.g. voltage, current, vacuum level, multi-channel analyzer settings, energy scale, secondary targets, degree of beam collimation) and observe the effects.
5. Acquire data from a variety of paint types. Include a series of automotive finish coats, primers and architectural paints. Evaluate the discrimination potential of the method.
6. Perform comparisons of elemental profiles of different paints using XRF.
7. Collect an elemental map for a single layered paint.
8. Collect spectra from a multi-layered paint sample (intact chip) and from portions of each layer excised from that chip. Evaluate the depth of beam penetration and contribution from underlying layers or substrate.

Method of Instruction:
Self-study

Method of Evaluation:
Written quiz

Estimated Time for Completion:
80 hours

Block Six: Pigment & Extender Examinations
Topic F: X-ray diffraction Analysis (XRD)

Objective:
Upon completion of this unit the student will be able to do the following:

1. Draw a Block diagram and explain the theoretical operation of the XRD. Include various types of instruments.
2. Discuss appropriate safety precautions.
3. Operate an x-ray diffractometer.
4. Perform appropriate calibrations and quality checks.
5. Optimize parameters for analysis.
6. Properly prepare samples for analysis.
7. Recognize the influence of sample displacement, preferred orientation, fluorescence, amorphous substances, sample flatness and crystal size on the resulting diffraction pattern.
8. Recognize the effects of changing instrument parameters (e.g. voltage, current, goniometer scan rate and range).
9. Properly identify component(s) from the diffraction pattern.
10. Perform comparisons of samples using XRD.

Suggested Readings:

Curry, C.J., Rendle, D.F., and Rogers, A. Pigment analysis in the forensic examination of Paints. I. Pigment Analysis by X-ray powder diffraction, *Society of Forensic Science Journal*, (1982) 22(2):173-177.

Jenkins, R., and Snyder, R.L. *Introduction to X-ray Powder Diffractometry*. John Wiley and Sons, Inc., NY, 1996.

Klug, H.P., and Alexander, L.E. *X-ray Diffraction Procedures for Polychrystalline and Amorphous Materials*, 2nd ed., John Wiley and Sons, NY, 1974.

Stafford, D.T. Forensic Capillary Gas Chromatography. In: *Forensic Science Handbook, Vol. II*, R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 1988, pp. 38-65.

Snider, A.M., Jr. X-ray Techniques for Coatings Analysis. In: *Analysis of Paint and Related Materials: Current Techniques for Solving Coatings Problems*, W.C. Golton, ed. ASTM STP 1119, ASTM, Philadelphia, PA, 1992, pp 82-104.

ASTM D5380-93(2003), Standard Test Method for Identification of Crystalline Pigments and Extenders in Paint by X-Ray Diffraction Analysis, ASTM International, West Conshohocken, PA

Practical Exercises:

1. Prepare a known reference material for analysis and acquire data. Compare to published data.
2. Prepare and analyze single layers from a multi-layered paint sample.
3. Properly identify component(s), their crystalline form and degree of hydration from the resulting diffraction patterns.
4. Examine the data for any features arising from sample displacement, orientation, fluorescence, amorphous substances, sample flatness and crystal size.
5. For a single sample, independently change each parameter of the instrument (e.g. voltage, current, goniometer scan rate and range) and observe the effects.
6. Acquire data from a variety of paint types. Include a series of automotive finish coats, primers and architectural paints. Evaluate the discrimination potential of the method.

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Written quiz

Estimated Time for Completion:
80 hours

Block Six: Pigment & Extender Examinations
Topic G: Ultraviolet/Visible Microspectrophotometry (UV/VIS MSP)

Objective:
Upon completion of this unit the student will be able to:

1. Explain the basic theory of color perception, color measurement and VIS spectrophotometry.
2. Explain the theory and application of UV/VIS MSP to the analysis of pigments.
3. Explain the instrumentation used in UV/VIS MSP.
4. Discuss both transmission and diffuse reflection in UV/VIS MSP.
5. Discuss the application of UV/VIS MSP techniques to forensic paint examinations. Include the potential use in discriminating UV absorbers in clear coats.
6. Discuss methods of sample preparation and pros and cons of each (e.g. polishing, edge mounts, thin sections).
7. Perform appropriate calibration or quality checks of the instrument.
8. Prepare single and multiple layered paint samples for analysis and collect transmittance and/or reflectance spectra in both the UV and visible regions.
9. Demonstrate and discuss the precision and accuracy of UV/VIS MSP. Discuss factors that can affect results, including user dependant variables, spectrophotometer and microscope settings, and parameter selections.
10. Compare and contrast absorbance and % transmittance formats, emphasizing each format's strengths and weaknesses.
11. Compare and contrast visible range MSP with extended (UV/VIS) range techniques.
12. Recognize the impact of sample size and inhomogeneity on UV/VIS MSP.
13. Discuss the proper use of databases.
14. Discuss the discrimination potential on a series of similarly colored paints.
15. Produce spectral comparison plots from collected data.
16. Discuss the use of MSP for pigment identification of individual organic pigment agglomerates in thin section peels of automotive paints.

Suggested Readings:

Nowicki, J., and Patten, R. Examination of U.S. automotive paints: I. Make and model determination of hit-and-run vehicles by reflectance microspectrophotometry, *Journal of Forensic Science* (1986) 31(2):464-470.

Wilkinson, J.M., Locke, J., and Laing, D.K. The examination of paints as thin sections using visible microspectrophotometry and Fourier transform infrared microscopy, *Forensic Science International* (1988) 38:43-52.

Laing, D.K., Dudley, R.J., Home, J.M., and Isaacs, M.D.J. The discrimination of small fragments of household gloss paint by microspectrophotometry, *Forensic Science International* (1982) 20:191-200.

Laing, D.K., Dudley, R.J., and Isaacs, M.D.J. Colorimetric measurements on small paint fragments using microspectrophotometry, *Forensic Science International* (1980)16:159-171.

Stoecklein,W., and Fujiwara, H. The examination of UV-absorbers in 2-coat metallic and non-metallic automotive paints, *Science and Justice*, (1999) 39(3):188-195.

Cousins, D.R., Platoni, C.R., and Russell, L.W. The variation in the colour of paint on individual vehicles, *Forensic Science International* (1984) 24(3):197-208.

Stoecklein, W. The role of colour and microscopic techniques for the characterisation of paint fragments. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp.143-162.

Eyring, M.B. Visible microscopical spectrophotometry in the forensic sciences. In: *Forensic Science Handbook*, Vol. I, 2nd ed., R. Saferstein, ed., Prentice Hall, Upper Saddle River, New Jersey, 2002, pp. 322-387.

Pierce, P.E. and Marcus, R.T. Color and Appearance. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1994.

Thornton, J.I. Visual color comparisons in forensic science, *Forensic Science Review* (1997) 9(1): 38-57.

Kopchick, K.A., and Bommarito, C.R. Color analysis of apparently achromatic automotive paints by visible microspectrophotometry, *Journal of Forensic Science* (2006) 51(2):340-343.

Scientific Working Group for Materials Analysis. Standard Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis, *Forensic Science Communications* (October 2007) 9(4). Available: http://www.fbi.gov/hq/lab/fsc/backissu/oct2007/index.htm.

Practical Exercises:

1. Prepare at least three paints for surface analysis. This should include at least one nonmetallic, one metallic, and one effect (e.g. pearlescent or other non-metal flake) paint sample.
2. Prepare edge mounts (cross-sectional view) of at least one pair of multiple layered paint samples for analysis.
3. Prepare thin cross-sections of at least two multiple layered paint samples for analysis.

4. Perform and document appropriate calibration or quality checks of the instrument.
5. Acquire several spectra from a single location on an architectural paint sample using different system parameters (e.g. user dependant variables, spectrophotometer and microscope settings). Note the degree of variation.
6. Acquire several spectra from various locations within each layer of the samples prepared in exercises 1, 2 and 3. Use transmission and/or reflection as appropriate. Compare results using one or more techniques (e.g. direct comparison, spectral averaging, normalization, standard deviation plots etc.). Note the degree of variation within a single layer of a sample.
7. Acquire transmission spectra from thick and thin areas of a single sample. Present spectra in both absorbance and % transmittance formats. Note the degree of discrimination provided by each format.
8. Acquire a spectrum from at least one clear coat in the UV/VIS range, if available. Note the additional information contained within the UV region.
9. Acquire the spectra of several similarly colored paints. Evaluate the discrimination potential of the method.

Method of Instruction:
Self-study
Discussion
Practical Exercises

Method of Evaluation:
Written quiz
Evaluation of practical exercises

Estimated Time for Completion:
80 hours

Block Six: Pigment & Extender Examinations
Topic H: Other Methods of Analysis

Objective:
Upon completion of this unit the student will be able to do the following:

1. Discuss the basic theory of these methods and discuss their advantages and limitations as applied to forensic paint analysis:

    a. Atomic absorption spectroscopy
    b. Wavelength dispersive X-ray spectrometry
    c. Emission spectroscopy
    d. Inductively coupled plasma atomic emission spectroscopy (ICP-AES)
    e. Inductively coupled plasma mass spectrometry (ICP-MS)
    f. Neutron Activation analysis
    g. Cathodoluminescence
    h. Raman spectroscopy
    i. Ion microprobe
    j. Transmission Electron Microscopy (TEM)

2. Discuss the advantages and the disadvantages of each of the above instrumental methods as they apply to forensic paint analysis.

Suggested Readings:

Instrumental Analysis textbook

Holak, W. Analysis of paints for lead by atomic absorption spectrometry, *Analytica Chimica Acta*, (1975) 74(1):216-219.

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 462-464.

Snow, K.B., and Washington, W.D. Comparison of paints by neutron activation analysis. II Colored paints, *Journal of the Association of Official Analytical Chemists (AOAC)* (1971) 54:917.

Saferstein, R., and Manura, J.J. Examination of automobile paints by laser beam emission spectroscopy, *Journal of the Association of Official Analytical Chemists (AOAC)* (1973) 56(5):1227-1233.

McCrone, W.C., and Delly, J. *The Particle Atlas, Edition 2, Vol. I.* Ann Arbor Science, Ann Arbor, MI, 1973, pp. 146-151

Stoecklein, W., and Goebel, R. Application of cathodoluminescence in paint analysis, *Scanning Microscopy* (1992) 6:669-684.

Kuptsov, A.H. Applications of Fourier transform Raman spectroscopy in forensic science, *Journal of Forensic Science* (1994) 39(2):305-318.

Massonnet, G., and Stoecklein, W. Identification of organic pigments in coatings: applications to red automotive topcoats. Part III: Raman spectroscopy (NIR FT-Raman*), Science and Justice* (1999) 39(3):181-187.

Flegler, S.L., Heckman, J.W., and Klomparens, K.L. *Scanning and Transmission Electron Microscopy: An Introduction*. Oxford University Press, 1995.

Hobbs, A.L., and Almirall, J.R. Trace elemental analysis of automotive paints by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), *Analytical and Bioanalytical Chemistry* (2003) 376:1265-1271.

Stachura, S., Desiderio, V.J., and Allison, J. Identification of organic pigments in automotive coatings using laser desorption mass spectrometry, *Journal of Forensic Science* (2007) 52(3):595-603.

Mukai, T., Nakazumi, N., Kawabata, S., Kusatani, M., Nakai, S, and Honda, S. Direct identification of various copper phthalocyanine pigments in automotive paints and paint smears by laser desorption ionization mass spectrometry, *Journal of Forensic Science* (2008) 53(1):107-115.

Buzzini, P. and Massonnet, G. A market study of green spray paints by Fourier transform infrared (FTIR) and Raman spectroscopy, *Science and Justice* (2004) 44(3):123-131.

Bell, S., Fido, L.A., Speers, S.J., and Armstrong, W.J. Rapid forensic analysis and identification of "Lilac" architectural finishes using Raman spectroscopy, *Applied Spectroscopy* (2005) 59(1):100-108.

Bell, S., Fido, L.A., Speers, S.J., Armstrong, W.J, and Spratt, S. Forensic analysis of architectural finishes using Fourier Transform infrared and Raman spectroscopy, Part I: The resin bases, *Applied Spectroscopy* (2005) 59(11):1333-1339.

Bell, S., Fido, L.A., Speers, S.J., Armstrong, W.J, and Spratt, S. Forensic analysis of architectural finishes using Fourier Transform infrared and Raman spectroscopy, Part II: White paint, *Applied Spectroscopy* (2005) 59(11):1340-1346.

Govaert, F. and Bernard, M. Discriminating red spray paints by optical microscopy, Fourier transform infrared spectroscopy, and X-ray fluorescence, *Forensic Science International* (2004) 140(1):61-70.

Suzuki, E. M., and Carrabba, M. In situ identification and analysis of automotive paint pigments using line segment excitation raman spectroscopy: I. Inorganic topcoat pigments, *Journal of Forensic Science* (2001) 46(5):1053-1069.

Practical Exercises:
None

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Quiz

Estimated Time for Completion:
24 hours

Block Six Pigment and Extender Examinations
Topic I: Pigment and Extender Comparisons

Objective:
Upon completion of this unit the student will be able to do the following:

1. Use available methods of analysis to generate and compare data from paint chips to determine whether or not they could have mutual origin.
2. Characterize and/or identify common pigments/extenders.

Suggested Readings:
None

Practical Exercises:
1. Characterize and compare paint samples, including single layer and multiple layer automotive and non-automotive paints. This should include at least three samples from each category.

Method of Instruction:
Self-study
Discussion
Practical Exercises

Method of Evaluation:
Written quiz
Evaluation of exercises

Estimated Time for Completion:
40 hours

Block Seven: Additive Examinations
Topic A: Types and Functions

Objectives:
Upon completion of this unit the student will be able to do the following:

1. List commonly used types of additives.
2. List additives used for drier materials, plasticizers, hardeners, UV absorbers, coalescing agents, flame retardants, mildew inhibitors, etc.

Suggested Readings:

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 441-448.

Koleske, J.V., Springate, R. and Brezinski, D. Additives Guide, *Paint and Coatings Industry* (2007) May:42-121.

Brandau, A., *Introduction to Coatings Technology*. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1990, pp. 12-14.

Stoecklein,W., and Fujiwara, H. The examination of UV-absorbers in 2-coat metallic and nonmetallic automotive paints, *Science and Justice*, (1999) 39(3):188-195.

Jeffs, R.A., and Jones, W. Additives for Paint. In: *Paint and Surface Coatings, Theory and Practice*, R. Lambourne and T.A. Strivens, eds., William Andrew Publishing, 1999, pp. 185-196.

Practical Exercises:
None

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Written quiz

Estimated Time for Completion:
24 hours

Block Seven: Additive Examinations
Topic B: Methods of Analysis

Objective:
Upon completion of this unit the student will be able to:

1. Discuss the application of the previously covered methods of analysis to additives. Include a general discussion of limits of detection for each technique.
2. Discuss quantities of additives used in paint and how that affects detection in forensic samples. Include a general discussion of the suitability of each technique for additive analysis.
3. Classify and/or identify common additives, such as plasticizers, UV absorbers and drier materials.

Suggested Readings:

Stoecklein,W., and Fujiwara, H. The examination of UV-absorbers in 2-coat metallic and nonmetallic automotive paints, *Science and Justice*, (1999) 39(3):188-195.

Infrared Spectroscopy Atlas Working Committee. An Infrared Spectroscopy Atlas for the Coatings Industry, Fourth Edition, Vol. I , Federation of Societies for Paint Technology, Philadelphia, PA, 1991

Practical Exercises:
1. Examine data used to classify and/or identify some common additives in situ and as pure compounds.

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Written quiz

Estimated Time for Completion:
16 hours

Block Eight: After-market Treatments, Weathering, Aging and Contaminants
Topic A: Types, Functions and methods of analysis

Objective:
Upon completion of this unit the student will be able to:

1. List commonly used types of after-market treatments and their general composition.
2. List some commonly observed types of contaminants.
3. Discuss factors that contribute to weathering and aging.
4. Discuss the extent to which after-market treatments, weathering, aging and contaminants may affect analyses.

Suggested Readings:

Spence, J.W., Lemmons, T.J. (USEPA), Hou, Y., Schadt, R.J., Fornes, R.E., and Gilbert, R.D. Effects of acidic deposition on paint: A chamber study, *Journal of Coatings Technology* , (August 1993) 65(823):47-55.

Pierce, P.D., and Schoff, C.K. Coating Film Defects. In: *Federation Series on Coatings Technology*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1988.

Philadelphia Society for Coatings Technology. *Pictoral Standards of Coatings Defects*, Federation of Societies for Coatings Technology, Blue Bell, PA, 1979.

Practical Exercises:
1. Perform analyses and/or observe data collected from paint that is treated and untreated (e.g. waxed, silicone treated, Teflon treated).
2. Perform analyses and/or observe data collected from paint that is weathered and/or aged.
3. Perform analyses and/or observe data collected from paint that is contaminated and uncontaminated.

Method of Instruction:
Lecture
Practical Exercises
Discussion

Method of Evaluation:
Quiz
Evaluation of practical exercises

Estimated Time for Completion:
24 hours

Block Nine: Significance and Interpretation
Topic A: Presence of Paint

Objective:
Upon completion of this unit the student will be able to do the following:

1. Discuss the potential and significance of finding paint on clothing.
2. Discuss the correlation between the morphology (e.g. smears, drops or chips) of the paint as it relates to transfer mechanisms (e.g. passive or forceful).

Suggested Readings:

Pearson, E.F., May, R.W., and Dabbs, M.D.G. Glass and paint fragments found in men's outer clothing- a report of a survey, *Journal of Forensic Science* (1971) 16(3):283-302.

Lau, L., et. al. The frequency of occurrence of paint and glass on the clothing of high school students. *Canadian Society of Forensic Science Journal* (1997) 30(4):233-240.

Practical Exercises:
1. Given scenarios, the student should discuss the type, morphology and possible method of transfer of the paint evidence, as well as the significance of the findings.

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Oral quiz

Estimated Time for Completion:
8 hours

Block Nine: Significance and Interpretation
Topic B: Type of Paint (Classification)

Objective:
Upon completion of this unit the student will be able to do the following:

1. Discuss how paint appearance and composition might be used to indicate the method of application or end use of the coating.
2. Discuss how the morphology, layer structure and composition may be used to assess the forensic significance of paint evidence (e.g. how many potential sources of this type of paint are there and what are they?).

Suggested Readings:

Cartwright, L.J., Cartwright, N.S., Norman, E.W.W., Cameron, R., MacDougall, D.A., and Clark, W.H. The classification of automotive paint primers using the Munsell color coordinate system- a collaborative study. *Canadian Society of Forensic Science Journal* (1984)17(1):14-18.

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* (1997) 30(4):199-212.

Deaken, D. Automotive body primers: their application in vehicle identification, *Journal of Forensic Science* (1975) 20:283.

Dabdoub, G., and Severin, P.J. The identification of domestic and foreign automobile manufacturers through body primer characterization, *Journal of Forensic Science* (1989) 34(6):1395-1404.

Review Federation Series on Coatings Technology units on Automotive Coatings, Marine Coatings, and Aerospace and Aircraft Coatings.

Automotive Paints and Coatings. G. Fettis, ed., VCH Publishers, NY, 1995, pp. 28-192.

Practical Exercises:
None

Method of Instruction:
Self-study
Discussion

Method of Evaluation:
Written quiz

Oral quiz

Estimated Time for Completion:
16 hours

Block Nine: Significance and Interpretation
Topic C: Comparison and Discrimination of Paint

Objective:
Upon completion of this unit the student will be able to:

1. Discuss the information provided by each step in the student's "paint examination protocol" and its contribution to the protocol's overall power of discrimination.
2. Discuss potential variations in paints which are the result of manufacturing processes (e.g. batch variations, trial runs, substitute suppliers) and the ability of these variations to be detected by the examination protocol.
3. Cite literature references related to studies on the evidential value of paint comparisons.
4. Discuss the added significance of multi-layered transfers versus single layered transfers.
5. Discuss the added significance of cross transfers.
6. Discuss the added significance of transfers of multiple types of multiple-layered systems.
7. Discuss the approach and difficulties in the comparison of a liquid paint sample to a dried paint sample.

Suggested Readings:

May, R.W., and Porter, J. An evaluation of common methods of paint analysis, *Journal of the Forensic Science Society* (1975) 15(2):137-146.

Tippett, C.F., Emerson, V.J., Fereday, M.J., Lawton, F., Richardson, A, Jones, L.T., and Lampert, S.M. The evidential value of the comparison of paint flakes from sources other than vehicles, *Journal of the Forensic Science Society* (1968) 8(2):61-65.

Gothard, J.A. Evaluation of automobile paint flakes as evidence, *Journal of the Forensic Science Society* (1976) 21(3):636-642.

Ryland, S.G., and Kopec, R.J. The evidential value of automobile paint chips, *Journal of Forensic Science* (1979) 24(1):140-147.

Ryland, S.G., Kopec, R.J., and Sommerville, P.N. The evidential value of automobile paint. Part II: The frequency of occurrence of topcoat colors, *Journal of Forensic Science* (1981) 26(1):64-75.

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

Zeichner, A. et. al. A study of paint coat characteristics produced by spray paints from shaken and nonshaken spray cans, *Journal of Forensic Science* (1992) 37(2):542-555.

Krausher, C.D.J. Characteristics of aerosol paint transfer and dispersal, *Canadian Society of Forensic Science Journal* (1994) 27(3):125-142.

McDermott, S.D., and Willis, S.M., A survey of the evidential value of paint transfer evidence, *Journal of Forensic Science* (1997) 42(6):1012-1018.

McDermott, S.D., Willis, S.M., and McCullough, J.P. The evidential value of paint. Part II: A Bayesian approach, *Journal of Forensic Science* (1999) 44(2):263-269.

Willis, S., McCullough, J., and McDermott, S. The interpretation of paint evidence. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001.

Edmondstone, G., Hellman, J., Legate, K., Vardy, G.L., and Lindsay, E. An assessment of the evidential value of automotive paint comparisons. *Canadian Society of Forensic Science Journal* (2004) 37(3):147-153.

Govaert, F., and Bernard, M. Discriminating red spray paints by optical microscopy, Fourier transform infrared spectroscopy, and X-ray fluorescence, *Forensic Science International* (2004) 140(1):61-70.

Buzzini, P., and Massonnet, G. A market study of green spray paints by Fourier transform infrared (FTIR) and Raman spectroscopy, *Science and Justice* (2004) 44(3):123-131.

Buzzini P., Massonnet G., Birrer S., Egli N., Mazzella W., Fortini A. Survey of crowbar and household paints in burglary cases – population studies, transfer and interpretation, *Forensic Science International* (2005)152(2):221-234.

Thornton, J.I. Forensic Paint Examination. In: *Forensic Science Handbook, Vol. 1*, 2nd ed., R. Saferstein, ed. Prentice Hall, Englewood Cliffs, New Jersey, 2002, pp. 472-473.

Practical Exercises:

1. Perform comparisons on simulated case samples and explain the rationale for choosing the analytical scheme.
2. Formulate conclusions and assess the significance of the findings.
3. Perform a comparison of a liquid paint sample to a previously cured and aged sample of the same paint. A variety of conditions may be explored, including degree of mixing, method of application, conditions of cure, environmental conditions, etc.
4. Successfully complete one architectural and one automotive paint external proficiency test.

Method of Instruction:
Self-study
Discussion
Practical exercises

Method of Evaluation:
Oral quiz
Evaluation of practical exercises

Estimated Time for Completion:
120 hours

Block Nine: Significance and Interpretation
Topic D: Vehicle Make/Model/Year Investigations

Objective:
Upon completion of this unit the student will be able to do the following:

1. Discuss make and model determinations in terms of potential investigative information and limitations of reference collections.
2. Relate how the examiner would conduct a vehicle make model search on a "no suspect" automotive paint case.
3. Use available resources (e.g. Paint Data Query, National Automotive Paint File, spectral IR libraries, Collaborative Testing Services Paint Collection, automotive refinish books) to suggest potential source vehicle(s).

Suggested Readings:

Scientific Working Group for Materials Analysis. Forensic Paint Analysis and Comparison Guidelines, *Forensic Science Communications* (July 1999) 1(2). Available: http://www.fbi.gov/hq/lab/fsc/backissu/july1999/painta.htm.

Deaken, D. Automotive body primers: their application in vehicle identification, *Journal of Forensic Science* (1975) 20:283.

Dabdoub, G., and Severin, P.J. The identification of domestic and foreign automobile manufacturers through body primer characterization, *Journal of Forensic Science* (1989) 34(6):1395-1404.

Cartwright, L.J., Cartwright, N.S., Norman, E.W.W., Cameron, R., MacDougall, D.A., and Clark, W.H. The classification of automotive paint primers using the Munsell Color Coordinate System- a collaborative study. *Canadian Society of Forensic Science Journal* (1984) 17(1):14-18.

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* (1997) 30(4):199-212.

Beveridge, A., Fung, T., and MacDougall, D. Use of infrared spectroscopy for the characterization of paint fragments. In: *Forensic Examination of Glass and Paint; Analysis and Interpretation*, B. Caddy, ed., Taylor & Francis, London, England, 2001, pp. 220-241.

Dupont Automotive refinish Products World Color Bulletins for Domestic and Imported Cars (aka refinish color books)

PPG Industries, Inc. Refinish Color Books

The Munsell Book of Color Glossy Collection

Munsell Color Matte Finish Collection

Practical Exercises:

1. Use available resources (e.g. Paint Data Query, National Automotive Paint File, spectral IR libraries, Collaborative Testing Services Paint Collection, automotive refinish books) to provide potential make and model information on at least four automotive samples.

Method of Instruction:
Self-study
Discussion
Practical exercises

Method of Evaluation:
Oral quiz
Evaluation of practical exercises

Estimated Time for Completion:
160 hours

Block Nine: Significance and Interpretation
Topic E: Report Writing

Objective:
Upon completion of this unit the student will be able to do the following:

1. Write a report on the examination of evidence according to the policy of the student's agency on content and format. This may contain:

   A. List of Evidence
   B. Methods of Examination and Analyses
   C. Results of Examinations and Analyses
   D. Conclusions

Suggested Readings:

Reports authored by testifying paint examiners.

Agency policy manual.

Scientific Working Group for Materials Analysis. Expert Reporting Guidelines, *Forensic Science Communications* (January 2009) 11(1). Available: http://www.fbi.gov/hq/lab/fsc/current/standards/2009_01_standards02.htm

Practical Exercises:
1. Write reports on simulated cases used in Block 9, Topic C.

Method of Instruction:
Self-study
Practical exercises

Method of Evaluation:
Evaluation of practical exercises

Estimated Time for Completion:
16 hours

Block Nine: Significance and Interpretation
Topic F: Testimony

Objective:
Upon completion of this unit the student will be able to:

1. Present appropriate courtroom demeanor or etiquette.
2. Present academic qualifications and work experience in a concise and confident manner.
3. Accurately answer questions about pertinent laboratory policies and procedures.
4. Accurately convey scientific concepts simply and concisely to the jury.
5. Present the results of analyses through oral testimony. Defend the interpretations and conclusions in a court of law.

Suggested Readings:

Available court transcripts.

Moenssens, A.A., Inbau, F.E., and Starrs, J.E. *Scientific Evidence in Criminal Cases*, The Foundation Press, Inc., New York (1986).

Practical Exercises:
1. Observation of expert paint testimony.
2. Participation in practice paint testimonies and depositions.

Method of Instruction:
Practical exercises
Discussion

Method of Evaluation:
Evaluation of performance in moot court and mock depositions .

Estimated Time for Completion:
80 hours

Block Ten: Supervised Casework

Objective:

1. Upon completion of this unit the student will be able to perform independent casework.

Suggested Readings:
None

Practical Exercises:

1. Observe an experienced examiner perform casework.
2. Perform actual casework under the supervision of a qualified examiner. Completion of 10-15 cases is recommended. This should include a variety of types of paint.

Method of Instruction:
Self-study
Perform supervised casework

Method of Evaluation:
Evaluation of casework
Peer review

Estimated Time for Completion:
4 months