Designation: ~~E1610 – 02 (Reapproved 2008)~~ E1610 – 14

Standard Guide for Forensic Paint Analysis and Comparison[1]

This standard is issued under the fixed designation E1610; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Forensic paint analyses and comparisons are typically distinguished by sample size that precludes the application of many standard industrial paint analysis procedures or protocols. The forensic paint examiner must address concerns such as the issues of a case or investigation, sample size, complexity and condition, environmental effects, and collection methods. These factors require that the forensic paint examiner choose test methods, sample preparation schemes, test sequence, and degree of sample alteration and consumption that are suitable to each specific case.

1.2 This guide is intended as an introduction to standard guides for forensic examination of paints and coatings. It is intended to assist individuals who conduct forensic paint analyses in their evaluation, selection, and application of tests that may be of value to their investigations. This guide describes methods to develop discriminatory information using an efficient and reasonable order of testing. The need for validated methods and quality assurance guidelines is also addressed. This document is not intended as a detailed methods description or rigid scheme for the analysis and comparison of paints, but as a guide to the strengths and limitations of each analytical method. The goal is to provide a consistent approach to forensic paint analysis.

1.3 This guide cannot replace knowledge, skill, or ability acquired through appropriate education, training, and experience and should be used in conjunction with sound professional judgment.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *Some of the methods discussed in this guide involve the use of dangerous chemicals, temperatures, and radiation sources. This guide does not purport to address the possible safety hazards or precautions associated with its application. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D16 Terminology for Paint, Related Coatings, Materials, and Applications
D1535 Practice for Specifying Color by the Munsell System
E308 Practice for Computing the Colors of Objects by Using the CIE System
E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory
E2808 Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis
E2809 Guide for Using Scanning Electron Microscopy/X-Ray Spectrometry in Forensic Paint Examinations
E2937 Guide for Using Infrared Spectroscopy in Forensic Paint Examinations

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide other than those listed in 3.2, see Terminology D16.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *additive (modifier)*—any substance added in a small quantity to improve properties. Additives may include substances such as ~~dryers,~~driers, corrosion inhibitors, catalysts, ultraviolet absorbers, plasticizers, etc.

3.2.2 *binder*—a non-volatile portion of a paint which serves to bind or cement the pigment particles together.

[1] This guide is under the jurisdiction of ASTM Committee E30 on Forensic Sciences and is the direct responsibility of Subcommittee E30.01 on Criminalistics.

Current edition approved ~~April 1, 2008~~Jan. 15, 2014. Published ~~July 2008~~February 2014. Originally approved in 1994. Last previous edition approved in ~~2002~~2008 as ~~E1610 – 02.~~E1610 – 02 (2008). DOI: ~~10.1520/E1610-02R08.~~10.1520/E1610-14.

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

3.2.3 *coating*—a generic term for paint, lacquer, enamel, or other liquid or liquifiable material which is converted to a solid, protective and/or decorative film after application.

3.2.4 *discriminate*—to distinguish between two samples based on significant differences; to differentiate.

3.2.5 *discriminating power*—the ability of an analytical procedure to distinguish between two items of different origin.

3.2.6 *known sample*—a coating sample of established origin.

3.2.7 *paint*—commonly known as a pigmented coating (see 3.2.3).

3.2.8 *pigment*—a finely ground, inorganic or organic, insoluble, dispersed particle. Besides color, a pigment may provide many of the essential properties of paint, such as opacity, hardness, durability and corrosion resistance. The term pigment includes extenders.

3.2.9 *questioned sample*—a coating sample whose original source is unknown.

3.2.10 *significant difference*—a difference between two samples that indicates that the two samples do not have a common origin.

4. Quality Assurance Considerations

4.1 A quality assurance program must be used to ensure that analytical testing procedures and reporting of results are monitored by means of proficiency tests and technical audits. General quality assurance guidelines may be found in "Trace Evidence Quality Assurance Guidelines" (**1**).[3]

5. Summary of Practice

5.1 Paint films are characterized by a number of physical and chemical features. The physical characteristics may include color, layer sequence and thickness, surface and layer features, contaminants and weathering. Chemical components may include pigments, polymers, additives and solvents. These features can be determined and evaluated by a variety of macroscopical, microscopical, chemical, and instrumental methods. Limited sample size and sample preservation requirements mandate that these methods be selected and applied in a reasonable sequence to maximize the discriminating power of the analytical scheme.

5.2 Searching for differences between questioned and known samples is the basic thrust of forensic paint analysis and comparison. However, differences in appearance, layer sequence, size, shape, thickness, or some other physical or chemical feature can exist even in samples that are known to be from the same source. A forensic paint examiner's goal is to assess the significance of any observed differences. The absence of significant differences at the conclusion of an analysis suggests that the paint samples could have a common origin. The strength of such an interpretation is a function of the type ~~and/or~~or number of corresponding ~~features.~~features, or both.

5.3 An important aspect of forensic automotive paint analysis is the identification of the possible makes, models and years of manufacture of motor vehicles from paint collected at the scene of a crime or accident. The color comparison and chemical analysis of both the undercoat and top coat systems requires ~~a~~ knowledge of paint formulations and processes, collections of paint standards, and databases of color and compositional information.

5.4 The test procedure selected in a paint analysis and comparison begins with thorough sample documentation. Some features of that documentation are described in Practice E1492. Analysis generally begins with appropriate nondestructive tests. If these initial tests are inconclusive or not exclusionary, the examination may proceed with ~~additional tests, which are selected,~~the selection of additional tests based on their potential for use in evaluating ~~and/or~~or discriminating the samples of ~~interest.~~interest, or both.

6. Significance and Use

6.1 ~~The~~This guide is designed to assist the forensic paint examiner in selecting and organizing an analytical scheme for identifying and comparing paints and coatings. The size and condition of the sample(s) will influence the selected analytical scheme.

7. Collection of Suitable Samples

7.1 The potential for physical matches between known and questioned samples must be considered before selecting the method of paint sample collection. Care should be taken to preserve the potential for a physical match.

7.2 *Questioned Samples:*

7.2.1 Questioned samples should include all loose or transferred paint materials. Sources of questioned samples can include tools, floors, walls, glass fragments, hair, fingernails, roadways, adjacent structures, transfers or smears on vehicles, or transfers to or from individuals such as damaged fabric with paint inclusions. Whenever possible, items with paint transfers should be appropriately packaged and submitted in their entirety for examination. If sampling is necessary, the procedures listed in "Trace

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

Evidence Recovery Guidelines" (2) may be used. When paint evidence is recognized, every effort should be made to manually remove it before using tape lifts to collect other types of evidence. If paint is collected with tape lifts, one should be aware of the possible difficulty encountered when attempting to manipulate paint samples bearing adhesive residues. In addition, components of the adhesive could contaminate the paint sample and change its apparent chemistry.

7.2.2 Smeared transfers can exhibit mingling of components from several layers or films that could preclude application of some of the analytical methods discussed in this guide. Due to the difficulties associated with collecting smeared or abraded samples, the entire object bearing the questioned paint should be submitted to the laboratory whenever possible.

7.2.3 When contact between two coated surfaces is indicated, the possibility of cross-transfers must be considered. Therefore, if available, samples from both surfaces should be collected.

7.3 *Known Samples:*

7.3.1 When feasible, known paint samples ~~must~~should be collected from areas as close as possible to, but not within, the point(s) of damage or transfer. ~~These~~ Due to the possible presence of cross transferred materials, these damaged areas are usually not suitable sources of known samples. The collected known samples should contain all layers of the undamaged paint film. Substantial variations in thickness and layer sequences over short distances can exist across a painted surface. This is particularly true in architectural paint and for automotive films where the curves, corners, and edges are often impact points and may have been subjected to previous damage, sanding or over-painting. If necessary, several known paint samples should be taken to properly represent all damaged ~~areas.~~ areas because different areas of the painted surface may contain different paint systems. Known paint samples collected from different areas should be packaged separately and labeled appropriately.

7.3.2 When possible, the surface underlying the suspected transfer area should be included for analysis. ~~Adjacent sections removed from a wall, ceiling, door, window, implement handle, and automobile door, fender, and hood are examples of items that~~ Sections adjacent to a suspect transfer area can be valuable for assessing questioned and known sample differences and evaluating the possible cross transfer of trace materials. Wall and ceiling, door and window, implement handle and automobile door, fender and hood are examples of adjacent items.

7.3.3 Paint flakes can be removed from the parent surface by a number of methods. These include, but are not limited ~~to the following:~~ to, lifting or prying loosely attached flakes, cutting samples of the entire paint layer structure using a clean knife or blade, or dislodging by gently impacting the opposite side of the painted surface. When cutting, it is important that the blade be inserted down to the parent surface. It should be noted that no one method of sampling should be relied upon exclusively.

8. Procedure

8.1 Discussions of forensic paint analysis are provided in dated but detailed form by Crown (3), and more recently by Nielsen (4), Thornton (5), Maehly and Strömberg (6~~)~~, ~~and~~ Stoecklein (7), Caddy (8), and Ryland and Suzuki (9).

8.2 A reasonable scheme for forensic paint examinations is outlined in Figs. 1-4. Potentially useful techniques for the discrimination of paint binders, pigments, and additives are listed. The major steps in Fig. 1 are numbered to correspond to the discussions presented in this guide (for example 8.8, Solvent Tests). For any given comparison, not all the techniques listed in the same area in Fig. 1 are necessarily required. Sample size, condition and layer structure complexity should be considered when determining which techniques to use. The forensic coatings examiner should always use the more specific and least destructive tests prior to those that require more sample preparation or consumption. A review of the general technique descriptions, listed in 8.8 – 8.15, will provide guidance for the selection of appropriate methods.

8.3 Fig. 1 does not imply that other examinations should be excluded or that the order of the procedures in the chart is irrevocable. Samples that are neither constrained by amount nor condition should be subjected to analyses that will determine the color and texture of the paint as well as the number, order, colors and textures of the layers in a multi-layered sample. In most cases, instrumental techniques should be employed to analyze and compare both the pigment and binder portions of the sample. A combination of techniques, which provide discrimination between as many types of paints and coatings as possible, should be used. These techniques should also be selected to provide classification and/or component identification information to be used in significance assessments. For samples that are limited in layer structure complexity, techniques for the comparison of both the binder and pigment portion of the coating must be used. The choice of techniques may change depending upon sample characteristics. For instance, pyrolysis-gas chromatography (PGC) may be utilized for identifying and comparing the binder portion of samples that exhibit a low binder concentration. Likewise, scanning electron microscopy-energy dispersive X-ray analysis (SEM-EDS), X-ray fluorescence (XRF) and X-ray diffraction (XRD) may be used for identifying and comparing the pigment portion of samples that exhibit a low pigment concentration.

8.4 The flow-chart in Fig. 5 is a guide to the determination of the possible origins of a motor vehicle ~~paint in an investigative case.~~ paint. It is usually possible to differentiate a motor vehicle repaint from the original equipment manufacturer (OEM) paint by microscopical ~~examination.~~ examination of the layer structure. If no OEM paint is present, then only the vehicle color (or partial vehicle color) can be reported. For OEM paint, ~~the color of the topcoat layers and of the undercoat layers will each~~ both the topcoat and undercoat layers can be useful in identifying manufacturer, model and year. ~~Often the two systems provide complementary information.~~ Both finish coat colors and primer colors can provide complementary information, since not all finish coat colors may be used for the period a particular primer system was employed. In most cases a range of possible makes/models/years will be

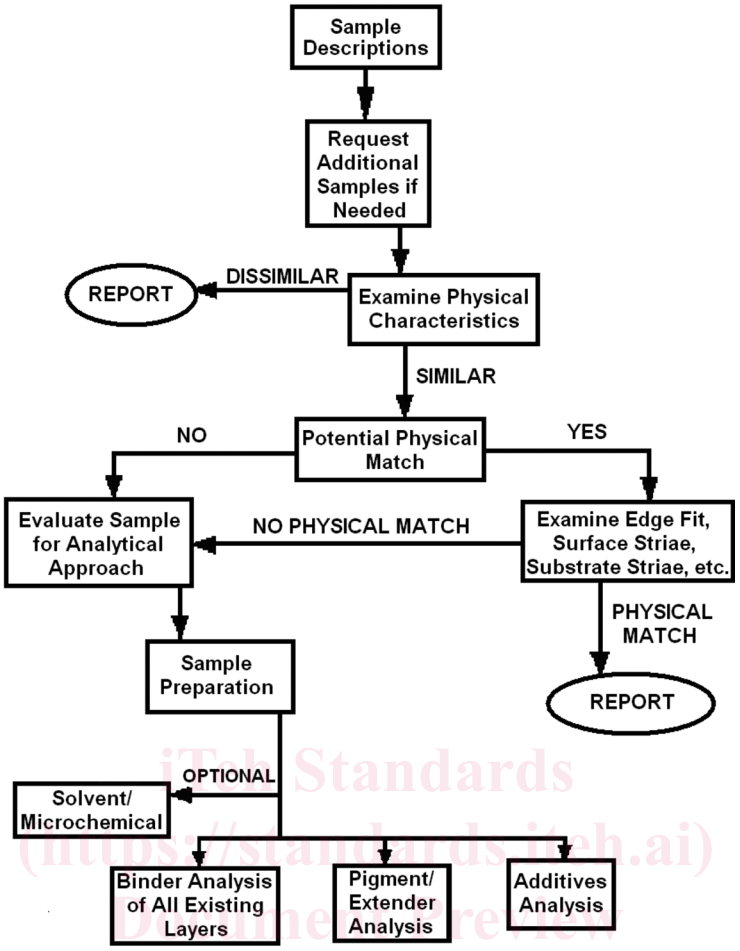

FIG. 1 Scheme for Forensic Paint Examinations

generated by the search. Further specific information can often be developed through chemical analysis of the individual layers. ~~Any~~Many of the techniques shown in ~~Fig. 1~~Figs. 2-4 can be used, depending on the databases available. Reference collections and databases include books of color chips produced by automotive refinish paint manufacturers for use by body shops and automotive repair facilities, manufacturer topcoat and undercoat color and chemical standards, "street" samples collected from damaged motor vehicles, OEM information on paint formulations and collections of infrared spectra or pyrograms of known paints. Examples of these include the Royal Canadian Mounted ~~Police/Technical Working Group on Materials Analysis (RCMP/TWGMAT) database,~~Police (RCMP) Paint Data Query (PDQ) database and the National Automotive Paint File (NAPF) which is maintained by the Federal Bureau of Investigation ~~(FBI), the Collaborative Testing Services reference collection of automotive paints and the Georgia Bureau of Investigation Paint Library of infrared spectra.~~(FBI).

8.5 *Sample Description:*

~~8.5.1 The first step in forensic paint analysis is the visual and macroscopical evaluation, description, and documentation of the original condition of the sample(s). Occasionally, this can be the final step in an analysis if exclusionary features or conditions in the sample(s) are identified during the initial evaluation.~~

8.5.1 The initial evaluation should begin with a critical review of ~~the~~each samples' chain of custody, package sealing, identification markings, and any potential cross-contamination between samples. If the items are found to be suitable for further evaluation, a detailed accounting and description of the paint ~~fragments~~sample and any co-mingled material should be documented. ~~This involves describing the general condition, weathering characteristics, size, shape, exterior colors, and major layers present in each sample. This description can be accomplished by examining each item using a stereomicroscope.~~

8.5.2 The first step in forensic paint analysis is the visual evaluation, description, and documentation of the original condition of the sample(s). This involves describing the general condition, weathering characteristics, size, shape, exterior colors, and major layers present in each sample. This description can be accomplished by examining each item using a stereomicroscope. In some instances, this may be the final step in an analysis if exclusionary features or conditions in the sample(s) are identified.

8.5.3 Written descriptions, sketches, photography or other imaging methods must be used to document each sample's characteristics. The goal is to produce documentation that will be meaningful to a ~~reviewer in the absence of the recording~~

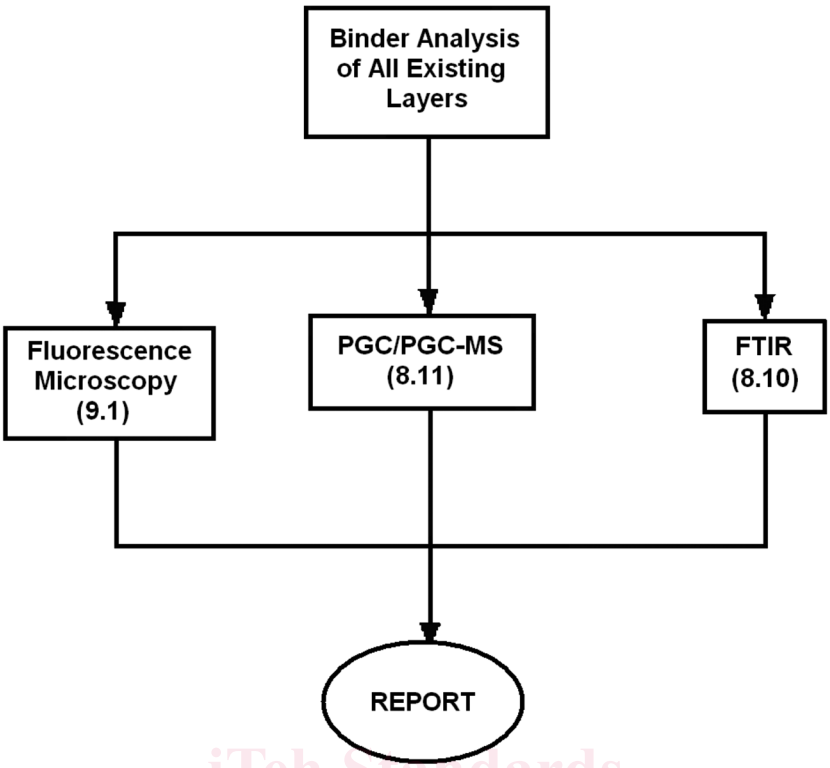

FIG. 2 Scheme for Forensic Paint Examinations

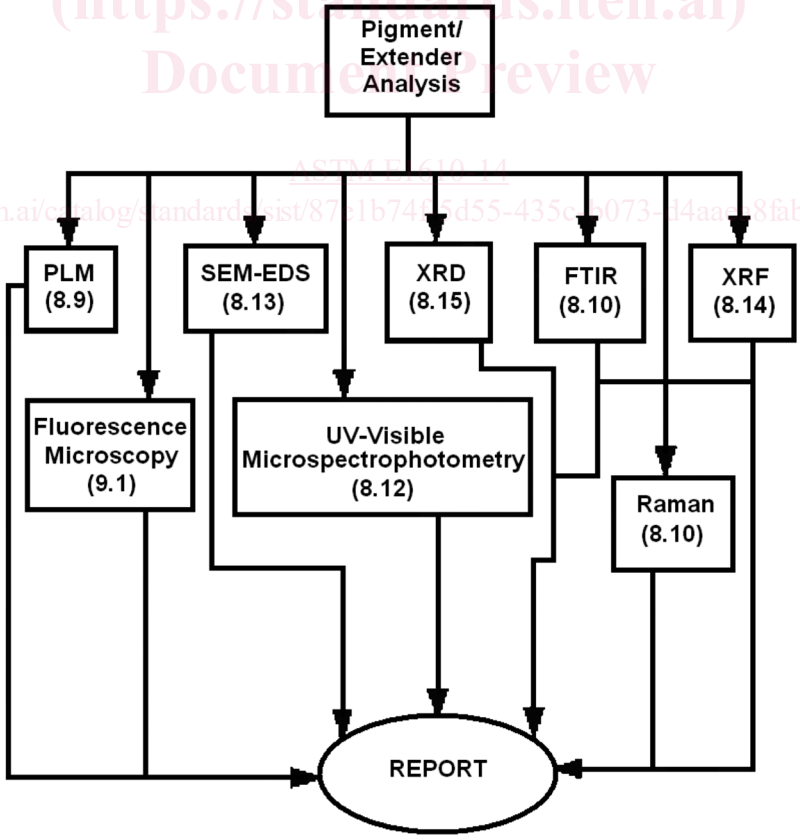

FIG. 3 Scheme for Forensic Paint Examinations

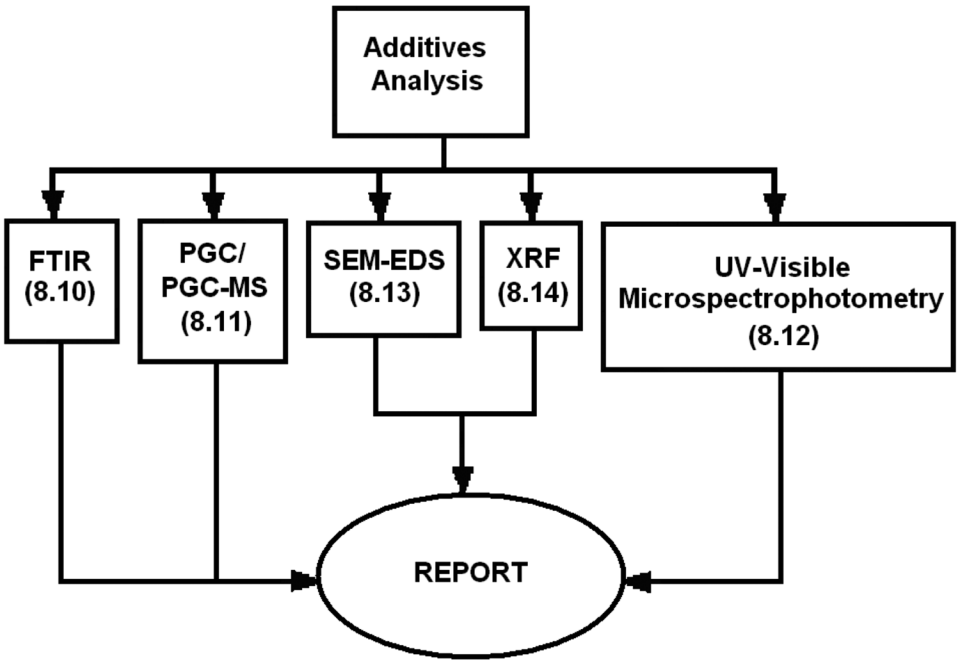

FIG. 4 Scheme for Forensic Paint Examinations

~~examiner.~~ reviewer. The resulting notes must be sufficient to document the conclusions reached in the examiner's report. Although documentation is discussed at this point in ~~the~~this guide, it is an essential part of all steps in an analysis.

8.6 *Physical Match:*

8.6.1 The most conclusive type of examination that can be performed on paint samples is ~~the physical matching of samples.~~ physical matching. This may involve the comparison of ~~edges and surface striae~~ edges, surface striae, or other surface irregularities between samples or ~~the comparison of surface striae~~between samples and an area on a damaged object e.g. a motor vehicle. Additional comparisons can be attempted between surface features on the underside of ~~a questioned paint fragment to those of a parent surface. The edges and/or striae in question must possess unique~~paint samples and a substrate. The corresponding features must possess individualizing characteristics.

8.6.2 Physical matches must be documented with descriptive notes. Photography, phototransparency overlays or other appropriate imaging techniques ~~may be a useful adjunct. When imaging methods are used to document a physical match, the examiner must ensure that the method employed is dimensionally accurate and has associated measuring scales. Images must be well preserved and~~ should be used. The resulting images should contain measuring scales and be retained as part of the documentation.

8.7 *Sample Preparation and Layer Analysis:*

8.7.1 The layers in a paint film are identified by viewing ~~of~~ sample edges at magnifications ranging between 5× and 100×. The more obvious layers are generally visible without sample preparation. Definitive paint layer ~~identification~~ system characterization usually requires sample preparation techniques such as manual or microtome sectioning and/or edge mounting and polishing. A combination of techniques may be required to fully characterize the layer structure. The extent of sample manipulation and preparation will depend on the amount of paint available and its characteristics.

8.7.2 Paint layer structure can be observed by using a scalpel or razor blade to ~~make an~~ prepare a thin section. An oblique cut through a ~~sample. The larger surface area created by this angled cut~~ sample may enhance layer visualization and assist in the detection of layer inhomogeneities. ~~The preparation of thin-sections and~~ Additionally, the separation of paint layers can be accomplished with a scalpel blade. ~~Preliminary solvent tests can be conducted on the manually prepared sections and layer fractions.~~

8.7.3 ~~Subtle~~ Observations of subtle differences in color, pigment appearance, surface details, inclusions, metallic and pearlescent flake size and distribution, and layer defects, may require microscopical comparisons of the edge, oblique cut and surface views of known and questioned paint samples. These comparisons must be carried out with both samples positioned side by side and in the same field of view.

8.7.4 Cross-sections (embedded or thin-section preparations) may provide additional information as to the layer sequence, layer thickness, color, pigment distribution, pigment size, and composition of the individual layers that may not be possible to obtain with gross examination. Embedded preparations can be prepared by polishing and/or microtomy. Thin-sections can be prepared using a variety of microtomy techniques. Examination and analysis of the cross-sections can be conducted using a variety of