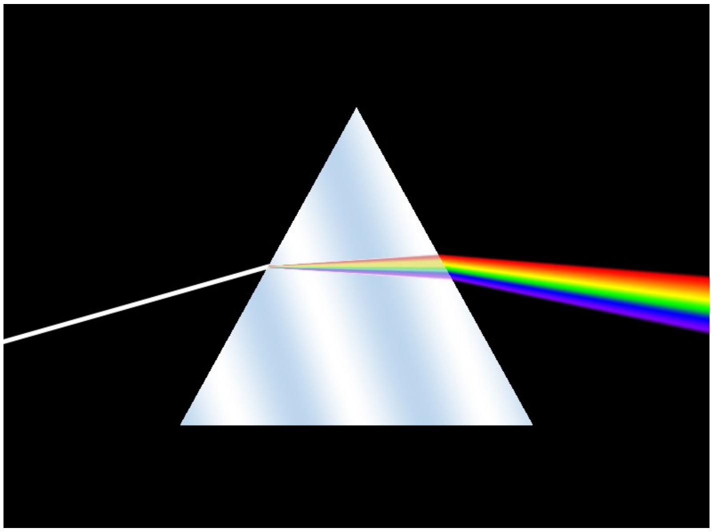
Washington State Patrol



Crime Laboratory Division

Materials Analysis
Glass Training Manual

January 2018

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This manual contains an outline for training and/or assessing a forensic scientist in the area of glass analysis. The various study segments should be covered in the order presented.

This manual endeavors to promote and maintain consistency and quality among forensic scientists performing glass analyses across the Crime Laboratory Division. Certain inherent aspects of glass analysis prohibit the establishment of a rigid set of standard procedures to cover every case. Sufficient latitude should be given to allow for independent thought and individual freedom in selecting alternative courses of action. Upon completion of this training program, the trainee will be thoroughly familiar with the options available to perform an examination of most types of evidence that may be received.

1.2 EXPECTATIONS

The trainee is expected to have successfully completed the following study segments from the Primary and Secondary Foundation Manuals: Infrared Spectroscopy, X-Ray Fluorescence, Basic Practical Microscopy, Imaging and Visualization, Evidence Recovery, Advanced Microscopy, and Special Applications in Microscopy.

Trainees who have prior related training and experience may be able to progress through the training program at an accelerated pace or skip certain study segments. The required documentation of such related training and/or experience will be left to the technical lead(s) or their designee.

The instructor must be experienced in the area of glass analysis. The instructor's casework and courtroom experiences, both prior and present, provide a unique aspect to the trainee's learning process that is impossible to duplicate in this training program. The instructor will share such experiences with the trainee. Although the trainee's primary interaction will be with the assigned instructor, this program promotes and encourages discussions with other experienced examiners.

The trainee will maintain a notebook or multiple notebooks throughout the duration of this training program and will record notes and observations for each study segment. The trainee notebook should be maintained in a neat and current fashion and should be present during conversations with the trainer. Upon completion of training, the trainee will maintain the training notebook for the duration of their career.

The trainee should be continuously evaluated throughout the training for comprehension and competency in theoretical knowledge, basic practical skills, and critical thinking skills. Training is progressive and continuously builds on and reinforces prior learning. Deficiencies on any of the training steps may occur during the course of the training and should be rectified. It is important that these deficiencies be openly and promptly discussed among the trainee, trainer, technical lead, and/or supervisor, as appropriate. Repeating training steps and testing may be necessary to satisfactorily complete this training program.

In order to successfully complete this training program the trainee must, after completion of all topic areas, successfully complete a closed book written exam passed with 80%, and successfully complete a competency exam passed with a 100%. The completion of these steps will be documented on a training checklist located at the end of this manual. If Glass is the first manufactured material subdiscipline that the trainee has learned, then the trainee will be required to successfully pass a moot court. The other manufactured material subdisciplines are Fibers, Paint and Polymers, and Tape. Supervised casework is optional and dependent on the trainee's repertoire of subdisciplines as well as performance on mock casework.

The trainer is responsible for writing an interoffice communication (IOC) to the trainee's supervisor when the trainee has successfully completed the Glass Training Manual. The trainee's supervisor will maintain copies of training IOCs and authorizations in their files.

1.3 ORGANIZATION OF THE TRAINING MANUAL

This training manual consists of several study segments, each covering different aspects of glass analysis. The study segments are organized in a specific manner to build on each other. Understanding what glass is comes first with the study segment on manufacturing. This segment includes the chemistry and classification schemes for glass. The next topic is how to recognize glass with a study segment on visual and microscopic exams. Recognition then expands into the forensic aspects of glass with a study segment on transference, persistence, and recovery. The techniques used for forensic comparisons are then covered with study segments on x-ray fluorescence (XRF) and glass refractive index measurements (GRIM). The final study segment is putting everything learned together with a segment on glass casework. This segment will cover types of case questions, the significance of comparisons, review of previous cases, performing a series of mocks cases, and learning court preparation.

Each study segment is comprised of six sections:

Objectives – Summarize the purpose of each study segment.

Topic Areas – Designates topics to be included in the study segment.

Readings – Lists the reference materials that should be read to complete the study segment.

Study Questions – Lists questions that assist the trainee in comprehension of the readings, promotes active discussion between the trainer and trainee, and documents understanding of the topic areas. Written answers to these questions will be maintained in the training notebook as documentation of training.

Practical Exercises – Hands on activities that are designed to provide the trainee first-hand experience with the main concepts of each study segment. Data or written explanation for each exercise must be maintained in the training notebooks.

1.4 SAFETY

Care should be used when handling glass. Eye and body protection should be worn whenever glass is being broken.

Good chemical safety practices should be employed.

2 MANUFACTURING

2.1 OBJECTIVES

- To become familiar with the manufacture of glass and how its production affects the properties of glass related to forensic examinations
- To recognize the uses and limitations of glass evidence in forensic work
- To become familiar with the various compositions and types of glass and how these variations may be useful in glass comparisons
- To become familiar with the terminology related to glass production and analysis
- To review the history of glass manufacturing

2.2 TOPIC AREAS

1. Chemistry
    a. Color
        i. Colorants
        ii. Decolorants
    b. Formation
        i. Formers
        ii. Modifiers
        iii. Intermediates
    c. Additional Properties
        i. Chemical Resistance
        ii. Impact Resistance
        iii. Thermal Expansion
2. Types of Glass
    a. By Chemistry
        i. Soda Lime
        ii. Lead
        iii. Borosilicate
        iv. Aluminum-silicate
    b. By Manufacturing
        i. Rolled
        ii. Float
        iii. Plate
        iv. Blown
    c. By End Use
        i. Container
        ii. Window
            1. Building
            2. Vehicle
        iii. Art/Objects
        iv. Tableware
        v. Heat Resistant
        vi. Headlight

d. Safety Glass
   i. Tempered
   ii. Laminate
   iii. Wire

3. Manufacturing
   a. Batch
      i. Raw Materials
      ii. Cullet
   b. Furnace
      i. Forming
      ii. Sheets
         1. Single Roll Method
         2. Double Roll Method
         3. Vertical Draw Method
         4. Float Process
   c. Container
      i. Blow and Blow
      ii. Press and Blow
   d. Annealing
4. Coatings
   a. Dichroic
   b. Mirrors
   c. Low-E
      i. Soft Coat – silver
      ii. Hard Coat – tin
5. Additional Materials
   a. Window Films
   b. Lamination Materials
   c. Ceramics – Frit
   d. Adhesives
   e. Paints
6. Determination of Type of Glass
   a. Physical Properties
   b. Chemical Properties

2.3 READINGS

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18. SWGMAT, “Introduction to Forensic Glass Examination”, Forensic Science Communications, January 2005, Volume 7, Number 1

2.4 STUDY QUESTIONS

1. Define glass.
2. What are the purposes of Si, Na, and Ca in ordinary soda lime glass?
3. Which elements can be used to provide glass with improved resistance to thermal expansion or chemical corrosion?
4. What are some of the colorants and decolorants used in the formulation of glass?
5. Explain formers, modifiers, and intermediates.
6. What is meant by the term “glassy” state of matter?
7. Describe the differences between soda lime, lead, and borosilicate glasses. What characteristics can be used by a forensic scientist to differentiate these glass types?
8. Define / describe the following types of glass: sheet, flat, float, plate, safety, toughened, and tempered.
9. What are some possible ways to determine the glass type of a 1 cm by 1 cm-sized fragment? How would these procedures be different if the piece were a glass sliver only 2 mm in length?

10. Define cullet. What are some of the advantages of the use of cullet in the manufacture of glass? What are the forensic advantages and disadvantages to the use of cullet in the manufacture of glass?
11. What is the purpose of the molten tin bath in the float glass process? What characteristics can be utilized by a forensic scientist to identify a piece of glass manufactured from the float glass process?
12. What is the purpose of annealing in the manufacturing process of glass?
13. What are some of the coatings of glass and their uses?
14. What types of contaminants may be found in glass from the manufacturing process?
15. Is it possible for a drinking glass to be manufactured from tempered glass? If so, how could it be done? Could it be strengthened by other means?
16. How may glass be useful as forensic evidence? What are the properties of glass that make it good forensic evidence? What properties decrease its usefulness as evidence?

2.5 PRACTICAL EXERCISES

1. If possible, tour a glass manufacturing facility.
2. Compare an “old” glass container to a new one. What differences are observed between the two samples?
3. Observe the markings and differences between multiple vehicle windows. You may need to go to a parking lot, on street parking, an impound yard, or a junk yard. Look for automobile “bugs”, ceramic frittings, stickers, tints, and other materials present on vehicle windows. Note which windows have these types of markings. Are you able to tell if the windshield or side/rear windows of a vehicle are the original windows?

3 VISUAL AND MICROSCOPIC EXAMS

3.1 OBJECTIVES

- To demonstrate the techniques utilized in assessing the physical properties of glass (thickness, color, surface characteristics, and type)
- To develop an understanding of how the physical properties of glass can be used during examinations and comparisons
- To demonstrate various visual and microscopic exams for glass identification and comparison

3.2 TOPIC AREAS

1. Visual Characteristics
   a. Color
   b. Thickness
   c. Overall Shape
   d. Luminosity
   e. Adherent Materials
2. UV Light (short wave and long wave)
   a. Chemistry
      i. Barium
      ii. Lead
      iii. Tin
   b. Classification
      i. Float
      ii. Non-Float
   c. Other Materials
      i. Films
      ii. Adhesives
3. Microscopic Characteristics
   a. Texture
   b. Luminosity
   c. Isotropic or Low Strain with polarized light
4. Common Materials that could be mistakenly submitted as Glass
   a. Minerals – Quartz
   b. Sand
   c. Plastic

3.3 READINGS

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2. Glass Manual on the Web, http://www.glassonweb.com/glassmanual/index.php http://www.glassonweb.com/
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3.4 STUDY QUESTIONS

1. What characteristics can be observed from a visual examination of a glass particle? From a stereomicroscopic examination? From a PLM examination?
2. What is the purpose of interferometry with glass fragments?
3. What visual and microscopic characteristics distinguish tempered and non-tempered glass?
4. How do we differentiate between float or non-float type glass samples?
5. What are some identifiable characteristics of container glass, including surface and physical characteristics that can be determined visually and microscopically?
6. What is low e-glass and how is it identified?
7. What is laminated glass and how is it identified?
8. What is fiberglass and where is it used?
9. Describe the distinguishing characteristics (physical properties) that can be determined for mineral wool samples.
10. What physical properties are normally measured or noted in glass analysis?
11. What precautions should be taken when comparing the color of glass?
12. What requirements are there for making thickness measurements of known and questioned glass fragments?
13. What variations in thickness are acceptable in sheet glass?

3.5 PRACTICAL EXERCISES

1. Examine various sized pieces of colored glass from the same source. How does the color of a very small fragment compare to a large fragment?
2. Use calipers for the following exercises:

   a. Using several large panes of glass, measure the thickness at multiple locations. What is the range observed over a pane of glass? What factors may influence the amount of variation in thickness?

   b. Measure the thickness of both panes of a laminated windshield at various points.

   c. Measure the thickness of a glass bottle at various points.

3. Break a piece of float glass (such as a glass slide) in half. Observe both faces at the same time with short wave UV light. Observations should be made in a pitch dark room.

4. Observe known materials:

   a. Obtain the following labeled sample sets from your instructor:

      i. Glass Fragments - This set should include at a minimum fragments from tempered float, laminated, art, colorless container, brown container, green container, blue container, leaded crystal, borosilicate glass, low E glass, mirror, glass wool, fiberglass, fused silica, and glass samples with adherent materials.

      ii. Mineral/Translucent Materials - This set should include at a minimum sand, quartz, plastic, and obsidian.

   b. Perform and photo-document (where possible) the following exams on each set:

      i. Visual characteristics (fracture characteristics, color, clarity, edges, shape, texture)

      ii. UV Characteristics (short wave and long wave)

      iii. Stereomicroscopic characteristics (fracture characteristics, color, clarity, edges, shape, and texture) with reflected light, transmitted polarized light, and transmitted cross polarized light

      iv. PLM characteristics – smaller samples mounted in different Cargille liquids

5. Analyze an unknown sample set. Use the visual, UV, and stereo exams for each sample. Determine if each sample is glass or not. If glass, what type of glass and why?

4 TRANSFERENCE, PERSISTENCE, AND RECOVERY

4.1 OBJECTIVES

- To develop an understanding of the dynamics of glass breakage To develop an understanding of transference and persistence of glass
- To demonstrate the recovery of glass on a wide variety of evidence items such as clothing, shoes, upholstery, and flooring
- To be able to recognize other types of potential trace evidence on items and handle appropriately
- To demonstrate the ability to interpret the characteristics of different types of glass fractures
- To recognize the uses and limitations of glass evidence in forensic work

4.2 TOPIC AREAS

1. Transference
    a. Breakage Mechanisms
        i. Cutting
        ii. Low Velocity Impact (Mechanical)
            1. Tempered
            2. Flat
            3. Container
        iii. High Velocity Impact (Bullets)
            1. Tempered
            2. Flat
            3. Laminated
        iv. Thermal
    b. Primary Transference
        i. Distribution Patterns
        ii. Distance
    c. Secondary Transference
    d. Appearance of Broken Glass Fragments
        i. Freshly Broken
        ii. Abraded
        iii. Conchoidal Fractures
        iv. Hackle Marks
        v. 4R Rule
2. Persistence
    a. Fragment Size
    b. Primary Transference Mechanism
    c. Transference Substrate
3. Recovery
    a. At the Scene versus at the Lab
    b. Identification of Questioned versus Known
    c. Substrate Types

i. Fabric Construction (Clothing/Bedding/Upholstery)
ii. Shoes (Soles/Laces/Interior)
iii. Tools (Handheld/Power)
iv. Interior Flooring (Carpeting/Wood/Vinyl)
v. Roadways (Roads/Driveways/Parking Lots)
vi. Outdoors (Lawn/Garden/Forest)
vii. Vehicles (Cars/Bicycles)

4. Choice of Recovery Method
   a. Picking
   b. Taping
   c. Scraping
   d. Vacuuming
5. Potential of Other Evidence in Sample
6. Choice of Packaging
   a. Type of Packing Material
   b. Presence of Other Evidence

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4.4 STUDY QUESTIONS

1. Describe the edge of a glass fragment that has been cut using a glass cutter.
2. Describe the characteristics of a heat fracture.
3. Describe what a "freshly broken" glass fragment looks like.
4. What characteristics may be used to identify an "original surface"?
5. What is a hackle mark?
6. What is a conchoidal fracture?
7. What is the 4R rule?
8. Explain how to determine the direction of force for a low velocity impact.
9. Explain how to determine the direction of force for a high velocity impact.
10. Explain how to determine the sequence of projectile impacts on a windshield.
11. Why is it difficult to determine directionality on a tempered glass fragment?
12. Explain how and why broken glass can be transferred.

13. What is the maximum distance glass fragments may be found from a broken pane? What influences this range?
14. Summarize the general distribution and characteristics of backward-scattered glass when a pane is shattered by a low-velocity impact such as a thrown brick.
15. How do fabric types and construction affect the retention of glass particles on clothing?
16. What size of glass particles are most likely to be found on the clothing of a person who has recently broken glass?
17. How long does glass typically persist on a person's clothing? Are there locations where glass may reside for longer period of time?
18. What are possible sources of "background" glass from the environment?
19. What are some of the factors that influence the number of fragments of glass that may be found on an item of clothing?
20. Describe how glass particles may be retained on a tool/object.
21. How should known and questioned glass fragments be packaged?
22. Explain the types of packaging used with glass evidence, including the advantages and disadvantages.
23. How should shoes be processed if an impressions examination is requested?
24. Discuss how an item of clothing should be processed for glass collection. How about a tool? How should the tool be processed if a latent prints examination is also requested?
25. Describe how evidence should be collected and packaged for each of the following scenarios as it would be described to an investigator who has made an inquiry: multiple suspects, multiple scenes, and multiple windows broken.
26. Why should a sample of glass be collected from every broken window at the scene?
27. Why should glass evidence be collected from the frame or frames rather than the ground/floor? Should glass ever be collected from the ground?
28. What information must be documented at the scene for direction-of-force requests?

4.5 PRACTICAL EXERCISES

1. Cut a pane of non-tempered glass with a glass cutter and observe and document the edge characteristics with a stereomicroscope.
2. Heat a glass slide until it fractures. Allow it to air cool. Examine and document the edge characteristics with a stereomicroscope.
3. Heat a glass slide and place it under cold water. Observe and document the general fracture characteristics with a stereomicroscope.
4. The following exercises should be performed in a confined space, such as a Firearms Caswell.
    a. Clean the space first and remove any debris.
    b. Take shoe impressions with an adhesive lift (to be used a clean control). Later, when back in the lab, verify the controls do not have glass fragments.
    c. Using a frame to hold glass, break a pane of non-tempered glass with a hammer or baseball bat. Observe the size, direction, and distance that the fragments travel. Vacuum the clothing and comb the hair of the person who broke the glass. Additionally, have a bystander stand about 4' behind the breaker while the glass is broken. Vacuum their clothing and comb their hair as well. Document the break patterns with camera and/or

diagrams. Collect and properly identify the fragments as concentric or radial fractures. When back in the lab, examine the edge characteristics to determine the direction of force. When back in the lab, compare the number and size of the fragments from each person.

d. Repeat exercise c with tempered glass.

e. Break several types of containers by throwing samples against a wall. Collect variety of pieces from each object thrown. Clean up the floor and area with a broom between each sample. Break multiple samples to be used for these exercises as well as those for the µXRF and GRIM. Back in the lab, document the size, shape, and edge characteristics of the recovered fragments. Look at several 1-2 mm pieces under the stereoscope to observe microscopic characteristics of broken glass.

f. Clean up the area.

g. Take second shoe impressions immediately after clean up and then 1 hour later (after walking around). Back in the lab compare number of particles immediately after and 1 hour later. Examine types of particles. Practice different methods for recovering glass fragments from the adhesive lifts. How many recovered fragments were glass?

5. Screen a tool that was used to break glass using visual and stereomicroscope exams. Document the process as you would in a case.

6. Screen a sample of debris collected from the side of a road for glass fragments using visual and stereomicroscopic exams. Document the process and your results as you would in a case.

7. Work with a firearms examiner for the following exercises:

   a. Shoot a hole through a pane of non-tempered glass. Examine the hole visually. Document and explain the formation of the cratered hole.

   b. Shoot several holes through an automotive windshield. Examine the holes visually. Document and explain their formation of the cratered hole. Examine the fracture lines between the holes. Can the shots be sequenced?

   c. Determine the direction of force on a provided sample of non-tempered glass with a bullet hole.

   d. Determine the sequence of shots on a provided sample of a windshield with bullet holes.

5 X-RAY FLOURESCENCE (XRF)

5.1 OBJECTIVES

- To develop an understanding of elemental analysis of glass via XRF
- To gain knowledge of other types of instruments available for elemental analysis of glass and the advantages and limitations of each type
- To demonstrate the use of the XRF on glass samples
- To become familiar with the uses and limitations of elemental analysis for glass discrimination, including semi-quantitative comparative methods

5.2 TOPIC AREAS

1. Comparison of XRF to Other Related Techniques
   a. Other Techniques
      i. SEM-EDX
      ii. LIBS
      iii. ICP-MS
      iv. ICP-AES
   b. Advantages
   c. Limitations
2. Practical Considerations
   a. Instrument
      i. Calibration
      ii. Verification
      iii. Settings
      iv. Accuracy
      v. Precision
   b. Sample
      i. Particle Limitations
      ii. Preparation Methods
      iii. Background/Substrates
      iv. Orientation
      v. Reproducibility
   c. Printouts
3. Classification Exams
   a. Float vs Non-Float sides of Glass
   b. Container versus Flat
   c. Coatings
4. Comparative Exams
   a. Quantity of Known and Questioned Pieces
   b. Quality of Known and Questioned Pieces
   c. Intravariation versus Intervariation
   d. Exclusions versus Inclusions
   e. Statistics versus Range Overlap
   f. ASTM E2926-17

g. Limits of Detection
h. Limit of Quantification

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5.4 STUDY QUESTIONS

1. Which elements are common to most types of glass?
2. What are some of the trace elements that may help in distinguishing glass samples?

3. Explain the elemental differences between the float and non-float sides of glass.
4. What element found in glass is often associated with the degradation of refractory brick in a glass melt tank?
5. What elements are found in the various coatings of glass?
6. Compare the sensitivities of XRF, ICP-MS, and ICP-AES?
7. Summarize the discriminating ability of XRF.
8. Explain why the orientation of an irregular shaped glass particle may affect XRF spectra.
9. Why is it important to clean a glass sample prior to XRF analysis?
10. How many measurements of the known and questions are required in the ASTM standard?
11. What are the methods of comparing elemental composition of questioned and known samples?
12. Explain why elemental intensity ratios are used rather than raw data or weight percentages generated by the instrument.
13. What is the formula for standard deviation?
14. Should you run XRF prior to or after refractive index determinations? Why?
15. What is live time and how do you determination the minimum number of live seconds a scan should last?
16. Explain the difference between Level of Detection and Level of Quantitation.
17. Why can't you use elements below the level of quantitation in elemental ratio comparisons?

5.5 PRACTICAL EXERCISES

1. Analyze various types of glass (including float, container, art, leaded, borosilicate, glass wool, TV tube, fused silica, optical, heat-conductive, etc.) with XRF. Retain your data and record your observations. What elements may be useful in the classification of glass?
2. Analyze three cleaned and three uncleaned fragments of glass from Module 4 (Exercise 2). Can you tell if any differences you observe are due to the glass itself or to surface contamination? Clean the previously uncleaned particles and re-analyze. Discuss your observations.
3. Analyze both original surfaces of a piece of float glass with XRF. Record your observations. Are there any differences? If so, what caused these differences?
4. Analyze an irregularly shaped glass fragment from several orientations (use NIST glass sample with known concentration). Compare the results. How does shape affect the XRF results? What would be the ideal orientation for elemental analysis? How can this orientation effect be compensated for in casework?
5. Examine an e-coated fragment of glass with XRF. Using elemental analysis, are you able to determine the composition of the coating?
6. Examine both sides of a mirror via XRF. Does the x-ray beam penetrate through the glass fragment to the opposite surface?
7. Examine various shades and colors of glass with XRF. How do the elements vary as the color changes?
8. Examine a portion of laminated windshield glass. Analyze both sides of each pane and the flexible layer separately and then analyze an intact portion from each direction. Does the center layer interfere with the analysis of the intact fragment? Can the panes be distinguished?

9. Examine quartz and obsidian with XRF. How do these substances differ elementally from glass?
10. Examine several types of fiber-glass insulation and fiberglass composites with XRF. Do the coatings and matrix materials interfere with the XRF results?
11. Determine the Limits of Quantitation and Limits of Detection for 5 different elements that are common to 3 different NIST SRM glasses.
12. Using sets of glass provided by your trainer, determine several different elemental ratios and their acceptable match ranges. Develop the ranges for +/- 2 SD, +/- 3SD, and range overlap. Make sure to check to determine if the elements in the ratios are above the level of quantitation.
13. Your trainer will supply sets of known and questioned glasses. Compare their elemental composition according to Glass section of the Materials Analysis Technical Procedures manual and determine whether any of them may share a common source.

6 GLASS REFRACTIVE INDEX MEASUREMENT (GRIM)

6.1 OBJECTIVES

- To develop an understanding of the theory of RI measurements on the GRIM instrument
- To demonstrate the proper operation and calibration of the GRIM instrument
- To understand the situations in which annealing maybe appropriate in casework
- To be able to perform annealing on glass fragments and draw conclusions from the results

6.2 TOPIC AREAS

1. Comparison of GRIM to Other Related Techniques
   a. Other Techniques
      i. Emmon's Double Variation Method
      ii. Density Measurements
      iii. Dispersion
   b. Advantages
   c. Limitations
2. Practical Considerations
   a. Instrument
      i. Calibration
      ii. Verification
      iii. Settings
      iv. Accuracy
      v. Precision
   b. Sample
      i. Particle Limitations
      ii. Preparation Methods
      iii. Annealing
      iv. Manufactured Edges
      v. Reproducibility
   c. Printouts
3. Classification Exams
   a. Container versus Flat
   b. Borosilicates
   c. Tempered
4. Comparative Exams
   a. Quantity of Known and Questioned Pieces
   b. Quality of Known and Questioned Pieces
   c. Intravariation versus Intervariation
   d. Exclusions versus Inclusions
   e. Statistics versus Range Overlap
   f. ASTM E1967

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6.4 STUDY QUESTIONS

1. Define refractive index and explain Snell’s Law.
2. How is the property of refractive index useful for forensic glass examinations?
3. What are the limitations of refractive index for forensic glass examinations?
4. Explain the relationship between refractive index and dispersion. Is there value in determining dispersion?
5. What are N_C, N_D, and N_F?
6. Describe the Emmons’s Double Variation Method and GRIM2. Compare and contrast.
7. Why is silicone oil used versus other types of oil media for refractive index measurement?
8. What are the main components of the GRIM3 system?
9. What wavelength is used for routine refractive index measurements?
10. How is the wavelength changed on the GRIM3? Why would it be changed?
11. What data are actually measured by the GRIM3 to determine refractive index?
12. How is the edge count determined by the GRIM3 software? Does it affect the RI?
13. Explain the QC checks on the GRIM3 system and how they are tracked.
14. What is the expected variation of RI in a container, in a pane of non-tempered glass, tempered glass?
15. What are some reasons for erratic data in GRIM work? How is erratic data treated?
16. How does annealing affect refractive index? Why?
17. What is a typical softening temperature for glass?
18. How can annealing be used in casework to compare standard and questioned glass?
19. Why and how is the refractive index of a glass fragment altered by in-lab annealing process?
20. Summarize the annealing procedure and the data that are measured.
21. For which types of glass may annealing be useful for classification or discrimination?

6.5 PRACTICAL EXERCISES

1. With the approval of your trainer, perform a calibration of the GRIM instrument. (CAUTION: do not overwrite the N_D/B Oil unless instructed)
2. Using the GRIM3 instrument, determine the refractive index on at least ten of the cleaned glass fragments collected in Module 4 (Exercise 2). Can you discriminate between the fragments? How many glass sources would you say you have?

3. Determine the RI for at least ten of the uncleaned glass fragments collected in Module 4 (Exercise 2) - compare the cleaned vs. uncleaned fragments. Were there any problems with the unclean samples?
4. Perform QC checks over a 5 day period. Record your results. Determine the standard deviation of these measurements. How much variation has been seen with this instrument over the past five years?
5. Explore the range of RI on two containers, two different glass panes, and both panes of a windshield.
6. Compare the RI of surface glass to interior glass from a float glass sample. How do your findings compare to literature references?
7. Calculate the dispersion value for the sample provided. You may use old calibrations for the N_C and N_F wavelengths.
8. Determine and compare the refractive index on the sets of mock case samples provided. In which sets can the unknowns be associated with the knowns? What parameters do we use to determine a possible shared source?
9. Using the procedure provided by your coach, anneal at least two samples each of non-tempered flat glass, container glass, and tempered glass and one unusual glass sample. Measure the refractive index before and after annealing. Compare your results with literature and past in-house results.

7 INFRARED SPECTROSCOPY (IR)

7.1 OBJECTIVES

- To recognize and identify polymers and adhesives that may be associated with glass.

7.2 TOPIC AREAS

1. Laminates
   a. polyvinyl butyral (PVB)
   b. ethylene-vinyl acetate (EVA)
2. Window Tints
   a. water activated adhesive
   b. polyethylene terephthalate (PET)

7.3 READINGS

None.

7.4 STUDY QUESTIONS

1. What are the chemical structures for polyvinyl butyral, ethylene-vinal acetate, and polyethylene terephalate?
2. What other materials (beside window films and laminates) may PVB, EVA, and PET be found?
3. How is an after-market window tint applied to a vehicle?

7.5 PRACTICAL EXERCISES

1. Analyze known samples of PVB and EVA by FTIR.
2. Analyze a sample of window tint adhesive on glass by ATR-FTIR. Remove the adhesive and analyze the glass substrate alone and the adhesive alone (both with ATR-FTIR).
3. Analyze a known sample of window tint before it has been applied to glass (tint polymer with adhesive). Remove the adhesive and analyze just the tint polymer.

8 EVIDENTIARY SIGNIFICANCE AND MOCK CASEWORK

8.1 OBJECTIVES

- To develop an understanding of the significance and limitations of glass as evidence
- To demonstrate the ability to interpret glass analysis data and draw conclusions in a report
- To understand which types of statements must be reported as opinions
- To understand how to evaluate and generate additional requests for forensic analysis in the context of glass analysis
- To ensure appropriate documentation and report writing skills
- To ensure appropriate techniques and confidence for court presentation

8.2 TOPIC AREAS

1. Assessment of Submitted Evidence
    a. Questioned Sample(s)
        i. Sample Size
        ii. Physical Condition
        iii. Effects of Recovery Methods
        iv. Physical and/or Chemical Damage
    b. Known Sample(s)
        i. Sample Size
        ii. Physical Condition
        iii. Effects of Recovery Methods
        iv. Physical and/or Chemical Damage
2. Significance of Comparisons
    a. Expected Intravariation and Intervariation of Glass
    b. Validation Studies
    c. Bayes
3. Types of Exams
    a. Classification
        i. Is there glass?
        ii. What type of glass?
    b. Comparisons
        i. Comparison of Q and K with Sufficient Quantity of Fragments for K
        ii. Comparison of Q and K with Limited Quantity of Fragments for K
        iii. Comparison of Q and K with determination if sample can be treated as a K
        iv. Comparison of Q and Q
        v. Physical Matches
    c. Damage Assessment
        i. Type of Damage
            1. Low Velocity
            2. High Velocity
            3. Thermal
        ii. Reconstruction

1. Order of Shots Fired
2. Direction of Force

d. Presence of additional Trace Materials

e. Recovery

i. Tools

ii. Shoes

4. Technical Manual Requirements
5. Packaging
6. Report Wording

a. Classification

b. Comparisons

c. Damage Assessment

d. Presence of Additional Materials

7. Court Testimony

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8.4 STUDY QUESTIONS

1. What criteria must be met to report an association of glass evidence?
2. Discuss the use of in-house databases.
3. What factors affect the strength of the conclusion in glass comparisons?
4. What information should be included in your notes?
5. What information should be included in a report?

6. When is it appropriate to report something as an opinion?
7. What logbooks do we maintain related to glass analysis?

8.5 PRACTICAL EXERCISES

1. Review case files where classification of the type of glass was the purpose of the request. If possible, review at least 3 case files. A representative file from each glass analyst should be included in the mix. Note the wording of observations and what printouts were included. Note how the conclusion(s) were documented.
2. Work at least 2 glass classification mock cases as if they were real cases. These cases should be realistic in the type of evidence submitted. At least one of the mock cases should include evidence recovery. Follow the requirements of the Technical Manual, perform any necessary instrument checks, and include a draft report.
3. Review case files where glass comparisons were performed. If possible, review at least 5 case files. A representative file from each glass analyst should be included in the mix. Note the wording of observations and what printouts were included. Note how the conclusion(s) were documented. Note any limitations or atypical characteristics that were used to categorize the significance of the comparison.
4. Work at least 4 glass comparison mock cases as if they were real cases. These cases should be realistic in the type of evidence submitted – e.g. at least one mock case should have only a couple of pieces of known glass. Follow the requirements of the Technical Manual, perform any necessary instrument checks, and include a draft report.
5. Review case files where damage assessment (direction of force or sequence of shots) was the purpose of the request. Review at least 3 case files. A representative file from each glass analyst should be included in the mix. Note the wording of observations. Note how the conclusion(s) were documented.
6. Work at least 2 damage assessment mock cases as if they were real cases. These cases should be realistic in the type of evidence submitted. Follow the requirements of the Technical Manual, perform any necessary instrument checks, and include a draft report.
7. Perform at least 3 practice technical reviews – one for each type of case (classification, comparison, and damage assessment). These reviews may be on copies of active glass case files prior to the actual glass case files being technical reviewed by a qualified analyst or on mock glass case files created for this exercise.
8. Discuss with other glass analysts any court testimony experiences they have had.
9. Observe court testimony in glass analysis if possible.
10. Participate either in a moot court or an oral practice session to practice giving verbal answers to court type questions for glass analysis.

GLASS TRAINING CHECKLIST

Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
Manufacturing				
	Reading			
	Study Questions			
	Exercises			
Visual and Microscopic Exams				
	Reading			
	Study Questions			
	Exercises			
Transference, Persistence, and Recovery				
	Reading			
	Study Questions			
	Exercises			
Infrared Spectroscopy				
	Reading	n/a	n/a	n/a
	Study Questions			
	Exercises			
X-Ray Fluorescence (XRF)				
	Reading			
	Study Questions			
	Exercises			
Glass Refractive Index Measurement (GRIM)				
	Reading			
	Study Questions			
	Exercises			
Evidentiary Significance and Mock Casework				
	Reading			
	Study Questions			
	Exercises			
Written Test				
Competency Exam				