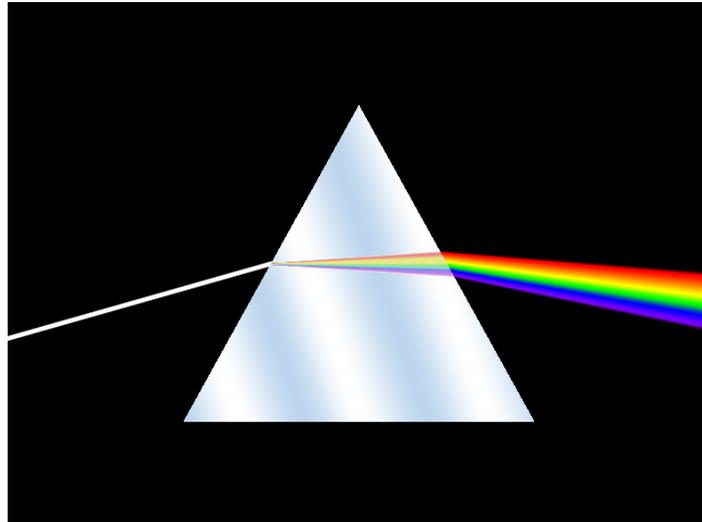




Washington State Patrol



Crime Laboratory Division

Materials Analysis Glass Training Manual

June 2016

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1. INTRODUCTION

This training manual is designed to result in expert examiners who possess specialized knowledge, skills, and training in the discipline of glass examinations. In addition, this training program aims to improve the quality of glass examination services provided to our customers, to promote and maintain consistency and quality among analysts conducting glass analysis.

The trainee will maintain a notebook throughout the duration of this training program and will record notes and observations for each topic area.

In order to successfully complete this training program the trainee must, after completion of all topic areas, demonstrate their capability to apply learned knowledge and skills to supervised casework and successfully complete a competency exam.

2. HISTORY, COMPOSITION AND 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. READINGS

Required

1. Almirall, J., et. al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J., et. al. ed., CRC Press, New York, 2000, pp. 1-6.
2. Almirall, J. "Raw Materials Lecture", California Criminalistics Institute Glass Examination and Comparison Class, December 1998.
3. ASTM C 162 - 94, "Standard Terminology of Glass and Glass Products", Vol. 15.02, American Society for Testing and Materials, Philadelphia, PA.
4. Copley, G.J., "The Composition and Manufacture of Glass and its Domestic and Industrial Applications", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, B. ed., Taylor and Francis Inc., 2001, pp. 27-46.
5. International Association of Chiefs of Police, Professional Standards Division, Training Key, #202, 1973.
6. Koons, R.D., Buscaglia, J., Bottrell, M., Miller, E.T., "Forensic Glass Comparisons", Forensic Science Handbook Volume I, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp.161-173.
7. Pilkington Libby-Owens-Ford, "The ABC's of Auto Glass Replacement".
8. Rawson, H., "Physics of Glass Manufacturing Processes", University of Sheffield, Departments of Ceramics.
9. Smith, K.A., Glass Resource Manual, California State Department of Justice – Bureau of Forensic Services, July 1979, pp. 1-42.
10. Stadler, L. E. and Cronin, D., "Container Glass Composition, Part I," The Glass Industry, 1977, pp. 10-14, 33.
11. Stadler, L. E. and Cronin, D., "Container Glass Composition, Part II," The Glass Industry, 1978, pp. 10-13.
12. SWGMAT, "Introduction to Forensic Glass Examination", Forensic Science Communications, January 2005, Volume 7, Number 1

Suggested

Almirall, J. "Lecture #2 (Composition) and #3 (Manufacturing) Presentations", California Criminalistics Institute Glass Examination and Comparison Class, December 1998.

2.3. STUDY/DISCUSSION EXERCISES

1. Define glass.
2. 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?
3. What are the purposes of Si, Na and Ca in ordinary soda lime glass?
4. Which elements can be used to provide glass with improved resistance to thermal expansion or chemical corrosion?
5. What are some of the colorants and decolorants used in the formulation of glass?
6. Explain formers, modifiers and intermediates.
7. What is meant by the term "glassy" state of matter?
8. What is the purpose of annealing in the manufacturing process of glass?

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9. Define cullet. What are some of the advantages of the use of cullet in the manufacture of glass? Are there forensic benefits to the use of cullet in the manufacture of glass? If so, what are they?
10. Describe the differences between soda lime, lead, and borosilicate glasses. What characteristics can be used by a forensic scientist to differentiate these glass types?
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. Define / describe the following types of glass: sheet, flat, float, plate, safety, toughened and tempered.
13. Is it likely for a drinking glass to be manufactured from tempered glass? If so, how could it be done? Could it be strengthened by other means?

2.4. 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. Locate an automobile "bug" on a vehicle window. Describe the markings. Are you able to tell if the windshield or side/rear windows of a vehicle are the original windows?
4. Visually compare various types of glass (laminated, tempered, flat, container, etc.)

3. PHYSICAL PROPERTIES

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

3.2. READINGS

Required

1. Almirall, J., et. al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J., et. al. ed., CRC Press, New York, 2000, pp. 10-14.
2. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 169-173, 180-186.
3. Smith, K.A., Glass Resource Manual, California State Department of Justice – Bureau of Forensic Services, July 1979, pp. 43-46.
4. SWGMAT, "Initial Examinations of Glass", Forensic Science Communications, January 2005, Volume 7, Number 1
5. Thornton, J. I., "Interpretation of Physical Aspects of Glass Evidence", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, B., ed., Taylor & Francis, New York, NY, 2001, pp. 97-106.
6. Glass Manual on the Web, <http://www.glassonweb.com/glassmanual/index.php>
7. Oregon State Police – Trace Processing Training PowerPoint presentation: "Glass Evidence" 2008

Recommended

Goodwin, D. G., "The Use of Surface Characteristics for Identification and Comparison of Glass" MSPFL Report No. 15, 1982, pp. 1- 12.

3.3. STUDY/DISCUSSION EXERCISES

1. What is tempered glass and how is it identified?
2. How do we differentiate between float or non-float type glass samples?
3. What are some identifiable characteristics of container glass, including surface and physical characteristics that can be determined visually and microscopically?
4. What is low e-glass and how is it identified?
5. What is laminated glass and how is it identified?
6. What is fiberglass and where it is used?
7. Describe the distinguishing characteristics (physical properties) that can be determined for mineral wool samples.
8. What physical properties are normally measured or noted in glass analysis?
9. What precautions should be taken when comparing the color of glass?
10. Discuss the types of density processes that may be used for glass examination. Why is density not routinely measured by this laboratory on casework samples?
11. What requirements are there for making thickness measurements of known and questioned glass fragments?
12. What variations in thickness are acceptable in sheet glass?

3.4. PRACTICAL EXERCISES

1. Examine both sides of various types of glass with short wave UV light. Record your observations. What causes some glass to fluoresce on one side but not the other? What other test can indicate float manufacture?
2. 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?
3. Measure the thickness of both panes of a laminated windshield at various points.
4. Measure the thickness of a glass bottle at various points.
5. Examine the glass samples provided by your trainer. Determine the origin of these samples (tempered, float, low e-glass, or container). On what characteristics did you base your decision?
6. 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?

4. FRACTURE EXAMINATIONS

4.1. OBJECTIVES

- To develop an understanding of the dynamics of glass breakage and its significance in forensic analysis
- To demonstrate the ability to interpret the characteristics of different types of glass fractures

4.2. READINGS

Required

1. Almirall, J., et. al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J., et. al. ed., CRC Press, New York, 2000, pp. 6-10.
2. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp.173-179.
3. Locke, J., and Unikowski J. A., "Breaking of Flat Glass Part 1: Size and Distribution of Particles from Plain Glass Windows", Forensic Science International, 1991; 51: 251-262.
4. Locke, J., and Unikowski, J. A., "Breaking of Flat Glass Part 2: Effect of Pane Parameters on Particle Distribution", Forensic Science International, 1992; 56:95-106.
5. Locke, J., and Scranage, J. K., "Breaking of Flat Glass Part 3: Surface Particles from Windows", Forensic Science International, 1992; 57: 73-80.
6. Luce R. W., Buckle J. L. and McInnis I., " A Study on the Backward Fragmentation of Window Glass and the Transfer of Glass Fragments to Individual's Clothing", Journal of the Canadian Society of Forensic Science, 1991; 24: 79-89.
7. Miller, J., "Examination of Glass Fractures Caused by Thermal Break or Mechanical Impact", AFTE Journal, 1999; 31: pp370-375.
8. Pounds, C. A. and Smalldon, K. W., "The Distribution of Glass Fragments in Front of a Broken Window and the Transfer of Fragments to Individuals Standing Nearby", Journal of the Forensic Science Society, 1978; 18: 197-203.
9. SWGMAT, "Glass Fractures", Forensic Science Communications, January 2005, Volume 7, Number 1
10. Thornton, J. I., "Interpretation of Physical Aspects of Glass Evidence", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, B., ed., Taylor & Francis, New York, NY, 2001, pp. 106-116.
11. Thornton, J. I. and Cashman. P. J., "Glass Fracture Mechanism – A Rethinking," Journal of Forensic Sciences, July 1986; 31(3): 818-824.
12. Zoro J. A., "Observations on the Backward Fragmentation of Float Glass", Forensic Science International, 1983; 22: 213-219.

Recommended

Nelson D. F. and Revell B. C., "Backward Fragmentation from Breaking Glass", Journal of the Forensic Science Society, 1967; 7: 58-61.

4.3. STUDY/DISCUSSION EXERCISES

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. What is the maximum distance glass fragments may be found from a broken pane? What influences this range?
4. 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.

4.4. PRACTICAL EXERCISES

1. Break several glass bottles and examine the fracture characteristics of the fragments. Document the size, shape and edge characteristics of the recovered fragments. This exercise should include bottle breakage by throwing and using the bottle as a weapon. Collect representative

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samples from each broken bottle to be used in later Modules. Look at several 1-2mm pieces under the stereoscope to observe microscopic characteristics of broken glass.

2. Using the glass holder, break a pane of glass with a hammer, 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 and the glass is broken vacuum their clothing and comb their hair as well. Compare the number and size of the fragments from each person.
3. After breaking the glass in the previous experiments, visually examine the shoes of both individuals. Recheck the shoes after about an hour of normal wear.
4. Repeat exercise 2 using tempered glass.
5. Heat a piece of glass until it fractures – Examine and document the edge characteristics.
6. Heat a piece of glass and place it under cold water. Observe and document the general fracture characteristics.
7. Cut a pane of non-tempered glass with a glass cutter and observe and document the edge characteristics.

5. RECOGNITION, RECOVERY AND COLLECTION

5.1. OBJECTIVES

- To be able to recognize and collect glass evidence from evidentiary items
- To be able to recognize other types of potential trace evidence on evidentiary items and handle appropriately
- To be able to screen evidence from a variety of collection methods (e.g., adhesive lifts, vacuum sweepings) and itemize appropriately.
- Develop an understanding of transfer and persistence of glass particles on clothing and other items

5.2. READINGS

Required

1. Almirall, J., et. al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J., et. al. ed., CRC Press, New York, 2000, pp. 14-17.
2. Brewster, F., Thorpe J.W., Gettinby, G. and Caddy, B., "The Retention of Glass Particles on Woven Fabrics", Journal of Forensic Sciences, 1985; 30: pp. 798-805.
3. Curran, J. M., et. al., ed., "Glass Found at Random and Frequency of Glass", Forensic Interpretation of Glass Evidence, CRC Press, Washington, D.C., 2000, pp. 87-102.
4. Curran, J. M., et. al., ed., "Transfer and Persistence Studies", Forensic Interpretation of Glass Evidence, CRC Press, Washington, D.C., 2000, pp. 103-122.
5. Hicks, T., Vanina, R., and Margot, P., "Transfer and Persistence of Glass Fragments on Garments," Science and Justice, 1996; 36, pp. 101-107.
6. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp.179.
7. Lau, L., Beveridge, A. D., Callowhill, B. C., Connors, N., Foster, K., Groves, R. J., Shasi, K. N., Summer, A. M., Wong, H., "The Frequency of Occurrence of Paint and Glass on the Clothing of High School Students," Journal of the Canadian Society of Forensic Science., 1997; 30, 233-240.
8. Lambert, J. A., Satterthwaite, M. J., and Harrison P. H., "A Survey of Glass Fragments Recovered from Clothing of Persons Suspected of Involvement in Crime", Science and Justice 1995; 35 (4), pp. 273-281.
9. McQuillan J., Edgar K., "A Survey of the Distribution of Glass on Clothing", Journal of the Forensic Science Society, 1992; 32(4): pp. 333-348.
10. Petterd, C. I., Hamshere, J., Stewart, S., Brinch, K., Masi, T., and Roux, C., "Glass Particles on the Clothing of Members of the Public in South-Eastern Australia – a Survey," Forensic Science International, 1999; 103: pp. 193-198.
11. SWGMAT, "Trace Evidence Recovery Guidelines", Forensic Science Communications, October 1999, Volume 1, Number 3
12. SWGMAT, "Collection, Handling and Identification of Glass", Forensic Science Communications, January 2005, Volume 7, Number 1
13. Thornton, J. I., "Interpretation of Physical Aspects of Glass Evidence", Forensic Examination of Glass and Paint: Analysis and Interpretation, Caddy, B., ed., Taylor & Francis, New York, NY, 2001, pp. 114, 116-118.

5.3. STUDY/DISCUSSION EXERCISES

1. 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.
2. How should known and questioned glass fragments be packaged?
3. Why should a sample of glass be collected from every broken window at the scene?
4. Why should glass evidence be collected from the frame or frames rather than the ground/floor? Should glass ever be collected from the ground?

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5. Explain the types of packaging used with glass evidence, include the advantages and disadvantages.
6. Explain how and why broken glass can be transferred.
7. How do fabric type and construction affect the retention of glass particles on clothing?
8. What size of glass particles are most likely to be found on the clothing of a person who has recently broken glass?
9. How long does glass typically persist on a person's clothing? Are there locations where glass may reside for longer times?
10. What are possible sources of "background" glass from the environment?
11. How does time affect the retention of glass particles on clothing?
12. What are some of the factors that influence the number of fragments of glass that may be found on an item of clothing?
13. How should shoes be processed if an impressions examination is requested?
14. Discuss how an item of clothing or a tool should be processed for glass collection. How should a tool be processed if a latent prints examination is requested?
15. Describe how glass particles may be retained on a tool/object.
16. What is a hackle mark? Conchoidal fracture?
17. Describe what a fragment of glass looks like when it is "fresh"? What characteristics may be used to identify an "original surface"?
18. What level of glass analysis may be performed by a Trace Processing analyst?

5.4. PRACTICAL EXERCISES

1. Examine the glass samples provided. Document via macro photography and diagrams the shape and macro surface characteristics of these glass fragments
2. Examine the vacuum sweeping and/or adhesive lift provided - recover at least 20 glass particles for future analysis – clean a portion of these particles for future RI and elemental testing. Store cleaned and uncleaned particles separately.
3. Screen the provided items of clothing for glass and other trace evidence– document the process as you would in a case.
4. Screen the provided tools for glass – document the process as you would in a case.
5. Examine a debris sample collected from along a roadside for glass fragments. Document your results.

6. MICROSCOPIC ANALYSIS

6.1. OBJECTIVES

- To demonstrate various microscopic methods and techniques used for glass identification and comparison
- To demonstrate the use of the stereomicroscope and the polarized light microscope
- Demonstrate the procedure for adjusting a microscope to Kohler Illumination

6.2. READINGS

Required

1. DeForest, P. R., "Foundations of Forensic Microscopy", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 216-311.
2. Hamer, P. S., "Microscopic Techniques for Glass Examination", Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor and Francis Inc., 2001, pp. 47-55.
3. Petraco, N., and Kubic, T., Microscopy for Criminalists, Chemists, and Conservators, CRC Press, New York, 2004, pp. 1-14 and 37-47.
4. Materials Analysis Primary and Secondary Foundation Training Manuals

6.3. STUDY/DISCUSSION EXERCISES

1. What characteristics can be observed from the stereomicroscopic examination of a glass particle? PLM examination?
2. Prepare a brief technical explanation of a polarized light microscope.
3. Define and explain the terms isotropic, anisotropic, birefringence and interference colors.
4. What information can be determined from the observed degree of contrast between a particle and the oil medium?
5. What information can be determined using the Becke Line technique?
6. Describe the procedure for adjusting a microscope to Kohler Illumination.
7. What is the purpose of interferometry with glass fragments?

6.4. PRACTICAL EXERCISES

1. Demonstrate the adjustment of Kohler illumination on a microscope.
2. Using a stereomicroscope examine tempered and non-tempered glass, sand, quartz, plastic and other common translucent materials. Record your observations including fracture characteristics, color, clarity, edges, shape and texture.
3. Conduct PLM examinations of tempered and non-tempered glass, sand, quartz, plastic and other common translucent materials – both in and out of oil. Which samples are isotropic and which are anisotropic? Are interference colors observed? Note the location of the Becke line in the oil mounts.
4. Observe glass samples mounted in Cargille® oils with the refractive indices below, near and above that of the glass sample. Evaluate the isotropic property, degree of contrast and the refractive index relative to the mounting oil.
5. Using microscopic observations, determine which of the examine them using the stereomicroscope and PLM. Use the particles collected in Recognition, Recovery, and Collection - Practical Exercise 2.

7. ELEMENTAL ANALYSIS

7.1. OBJECTIVES

- To develop an understanding of elemental analysis of glass via the x-ray fluorescence (XRF) microspectrometer
- 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 statistical methods

7.2. READINGS

Required

1. Almirall JR, Trejos T: Advances in the Forensic Analysis of Glass Fragments with a Focus on Refractive Index and Elemental Analysis; Forensic Science Review 18:73; 2006.
2. Almirall, J. R., "Elemental Analysis of Glass Fragments", Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor and Francis Inc., 2001, pp. 65-83.
3. ASTM E2926-13, Standard Test Method for Forensic Comparison of Glass Using Micro X-ray Fluorescence (u-XRF) Spectrometry
4. Dudley, J. L., Howden, C. R., Taylor, T. J. and Smalldon, K. W., "The Discrimination and Classification of Small Fragments of Window and Non-Window Glasses Using Energy-dispersive X-Ray Fluorescence Spectrometry," X-Ray Spectrometry 1980; 9: pp. 119–122.
5. Ernst, T., et. al., Signal-to-noise Ratios in Forensic Glass Analysis by micro X-ray Fluorescence Spectrometry, X-Ray Spectrometry, 2012.
6. Jochum, K.P., et. al., Determination of Reference Values for NIST SRM 610-617 Glasses Following ISO Guidelines, Geostandards and Geoanalytical Research, 2011.
7. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 202-209.
8. Koons, R.D., Buscaglia, J., "Interpretation of Glass Composition Measurements: the Effects of Match Criteria on Discrimination Capability", Journal of Forensic Sciences, 2002; 47: pp. 505-512.
9. Koons, R. D., Peters, C., and Rebbert, P., "Comparison of Refractive Index, Energy Dispersive X-Ray Fluorescence and Inductively Coupled Plasma Atomic Emission Spectrometry for Forensic Characterization of Sheet Glass Fragments", Journal of Analytical Atomic Spectrometry, 1991; 6: pp. 451-456.
10. Naes, B., et. al., A Comparison of Laser Ablation Inductively Coupled Plasma Mass Spectrometry, micro X-ray Fluorescence Spectroscopy, and Laser Induced Breakdown Spectroscopy for the Discrimination of Automotive Glass, Spectrochimica Acta Part B, 63 (2008), 1145-1150.
11. Reeve, V., Mathiesen, J., and Fong, W., "Elemental Analysis by Energy Dispersive X-Ray: A Significant Factor in the Forensic Analysis of Glass," Journal of Forensic Sciences, 1976; 21(2): pp. 291-306.
12. SWGMAT, "Elemental Analysis of Glass", Forensic Science Communications, January 2005, Volume 7, Number 1
13. Swift, H. R., "How Surface Chemistry Affects Float Glass Properties," Glass Industry, May 1986, pp. 27-30.
14. Trejos, T., et. al., Cross-validation and Evaluation of the Performance of Methods for the Elemental Analysis of Forensic Glass by u-XRF, ICP-MS, and LA-ICP-MS, Analytical and Bioanalytical Chemistry 05/2013

7.3. STUDY/DISCUSSION EXERCISES

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.

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4. What element found in glass is often associated with the degradation of refractory brick in a glass melt tank?
5. What are some of the coatings of glass and their uses?
6. Compare the sensitivities of XRF, ICP-MS and ICP-AES?
7. How would you 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 questions 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?

7.4. PRACTICAL EXERCISES

1. Analyze various types of glass (including float, container, art, leaded, borosilicate, glass wool, TV tube, fused silica, optical, heat-conductive, etc.) on the x-ray fluorescence microspectrometer. 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 on the x-ray fluorescence microspectrometer. 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 on the XRF. Using elemental analysis, are you able to determine it was coated?
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 on the x-ray fluorescence microspectrometer. 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. Analyze the laminate layer by FTIR or Raman. Is useful data obtained?
10. Examine quartz and obsidian on the XRF. How do these substances differ elementally from glass?
11. Examine several types of fiber glass insulation and fiberglass composites on the XRF. Do the coatings and matrix materials interfere with the XRF results?
12. Determine the Limits of Quantitation and Limits of Detection for 5 different elements that are common to 3 different NIST SRM glasses.
13. 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.
14. 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.

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8. REFRACTIVE INDEX

8.1. 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

8.2. READINGS

Required

1. Almirall, J., et. al., "Examination of Glass", Forensic Interpretation of Glass Evidence, Curran, J., et. al. ed., CRC Press, New York, 2000, pp. 17-22.
2. ASTM E 1967-98, "Standard Test Method for the Automated Determination of Refractive Index of Glass", Vol. 14.02, American Society for Testing and Materials, Philadelphia, PA.
3. Cassista, A. R. and Sandercock, P. M. L., "Precision of Glass Refractive Index Measurements: Temperature, Variation and Double Variation Methods, and the Value of Dispersion," Journal of the Canadian Society of Forensic Science, 1994; 27: pp. 203-207.
4. GRIM3 Installation and Instruction Manual
5. GRIM3 Installation and Instruction Manual, Part Two: Application Notes
6. Hamer, P. S. "Microscopic Techniques for Glass Examination", Forensic Examination of Glass and Paint, Caddy, B., ed., Taylor and Francis Inc., 2001, pp. 56-63.
7. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 187-202.
8. Koons, R.D., Buscaglia, J., "The Forensic Significance of Glass Composition and Refractive Index Measurements", Journal of Forensic Sciences, 1999; 44: pp. 496-503.
9. Koons, R., Buscaglia, J., "Distribution of Refractive Index Values in Sheet Glasses", Forensic Science Communications, 2001; 3(1).
10. Reference Glasses and Silicone Oils for Refractive Index Determination (Parts 1-6), Locke Scientific Manual, 1998.
11. Locke, J., "Improvements in the Use of Silicone Oils for the Determination of Glass Refractive Indices", Journal of the Forensic Science Society, 1982; 22: pp. 257-262.
12. Locke, J., Underhill, M., "Automatic Refractive Index Measurement of Glass Particles", Forensic Science International, 1985; 27: pp. 247-260.
13. Munger, C., Gates, K., Hamburg, C. Technical Note: "Determining the Refractive Index Variation within Panes of Vehicle Windshield Glass", Journal of Forensic Sciences, 2014; 59(5): pp.1351-1357
14. SWGMAT, "Glass Refractive Index Determination", Forensic Science Communications, January 2005, Volume 7, Number 1
15. Underhill, M., "Multiple Refractive Index in Float Glass," Journal of the Forensic Science Society, 1980; 20: pp. 169-176.

Recommended

1. Ojena, S. M., De Forest, P. R., "A Study of the Refractive Index Variations Within and Between Sealed Beam Headlamps Using a Precise Method", Journal of Forensic Sciences, 1972; 12: 315-329, 409-425.
2. Slater, D. P. and Fong, W., "Density, Refractive Index, and Dispersion in the Examination of Glass: Their Relative Worth as Proof", Journal of Forensic Sciences, July 1982; 27(3): pp. 474-483.

8.3. STUDY/DISCUSSION EXERCISES

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?

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5. What are NC, ND and NF?
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 is 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?

8.4. PRACTICAL EXERCISES

1. With the approval of your trainer, perform a calibration of the GRIM instrument. (CAUTION: do not overwrite the ND/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 red and blue 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 glass reference collection database, determine if there is a correlation between glass color and refractive index value.

9. ANNEALING

9.1. OBJECTIVES

- To understand the situations in which annealing may be appropriate in casework
- To be able to perform annealing on glass fragments and draw conclusions from the results

9.2. READINGS

1. Gates, K. "Differentiation of Glass through Annealing" Spring 2008 NWAFS Journal
2. Locke, J. and Hayes, C. A., "Refractive Index Variations Across Glass Objects and the Influence of Annealing," January 1984 CRE Report 519.
3. Locke, J., Sanger, D. G., and Roopnarine, G., "The Identification of Toughened Glass by Annealing," December 1981, HOCRE Report 421.
4. Marcouiller, J.M., "A Revised Glass Annealing Method to Distinguish Glass Types", Journal of Forensic Sciences, 1990; 35: pp. 554-559.
5. Newton, A.W.N., Kitto, L., Buckleton, J.S., "A Study of the Performance and Utility of Annealing in Forensic Glass Analysis", Forensic Science International, 2005; 155: pp. 119-125.
6. Underhill, M., "The Annealing of Glass Notes for Caseworkers," September 1992, MPFSL Report 86.
7. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", Forensic Science Handbook Volume 1, 2nd Ed., Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 194-195.

9.3. STUDY/DISCUSSION EXERCISES

1. How does annealing affect refractive index? Why?
2. What is a typical softening temperature for glass?
3. How can annealing be used in casework to compare standard and questioned glass?
4. Why and how is the refractive index of a glass fragment altered by in-lab annealing process?
5. Summarize the annealing procedure and the data that is measured.
6. For which types of glass may annealing be useful for classification or discrimination?

9.4. PRACTICAL EXERCISES

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.

10. NON-COMPARATIVE EXAMINATIONS

10.1. OBJECTIVES

- To use glass sample data, literature references and glass reference collections to make determinations of glass type and to know the limitations of these evaluations

10.2. READINGS

1. Hickman, D. A., "Glass Types Identified By Chemical Analysis," Forensic Science International, 1987; 33: pp. 23-46.
2. Ryland, S. G., "Sheet or Container?-Forensic Glass Comparisons with an Emphasis on Source Classification", Journal of Forensic Sciences, 1986; 31: pp. 1314-1329.
3. Ryland, S.G., Koons, R., "On the Classification of Small Colorless Glass Fragments as to their Sheet or Container Origin", Journal of Forensic Sciences, 1991; 36: pp. 308-311.

10.3. STUDY/DISCUSSION EXERCISES

1. What is the 4R rule?
2. What information must be documented at the scene if a direction-of-force request is made?
3. Explain how to determine the direction of force for a low velocity impact.
4. Explain how to determine the direction of force for a high velocity impact.
5. Explain how to determine the sequence of projectile impacts on a windshield.
6. Why is it difficult to determine directionality on a tempered glass fragment?
7. What are some possible ways to determine the glass type of a 1cm x 1cm-sized fragment? How would these procedures be different if the piece were a glass sliver only 2mm in length?
8. What are the strengths and weaknesses of our reference collection database? Any glass database of this type?

10.4. PRACTICAL EXERCISES

1. Using the glass holder, use a pendulum to break a sheet of non-tempered glass. Examine the glass remaining in the frame of the previous experiment. Photograph or diagram the remnants. Collect and properly identify the fragments as concentric or radial fractures. Examine the edge characteristics to determine the direction of force.
2. Using the glass from exercise 1, tape the pieces in the frame together in a way that the remaining sheet can be removed from the holder. Collect the broken fragments from the ground and attempt to refit the pieces together to make physical match. What are the difficulties inherent in this exercise?
3. Using the glass holder, shoot a hole through a pane of glass. Examine, document and explain the formation of the cratered hole.
4. Determine the direction of force on the samples provided by your trainer. Document observations.
5. Shoot several holes in an automotive windshield. Observing the fracture lines - can the shots be sequenced?
6. Examine the windshield provided – sequence the shots or impacts.
7. Examine the glass samples provided by your trainer (~2-4 mm in size). Attempt to determine the origin of these samples (i.e., tempered, float, flat, vehicle, container). What difficulties did you encounter? What techniques did you use?
8. Use the glass reference collection database to sort by glass type. How much overlap in refractive index occurs between glasses of different types? For example, do windshields overlap with containers?

11. REPORT WRITING, DOCUMENTATION AND SIGNIFICANCE

11.1. OBJECTIVES

- To introduce the student to the logbooks, notes and other paperwork necessary to properly document the analysis of glass according to lab policies and accreditation guidelines
- 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 be able to use the glass reference collection database to assign significance to certain findings
- 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

11.2. READINGS

1. Case Records, Reviews, and Reports provide by your instructor.
2. Technical Procedure Manuals provided by your instructor.
3. Curran, J. M., Buckleton, J., and Triggs, C. M., "The Robustness of a Continuous Likelihood Approach to Bayesian Analysis of Forensic Glass Analysis," *Forensic Science International*, 1999; 104: pp. 91-103.
4. Curran, J. M., et. al., "Reporting Glass Evidence", *Forensic Interpretation of Glass Evidence*, CRC Press, Washington, D.C., 2000, pp. 153-163.
5. Evett, I. W., Lambert, J. A., and Buckleton, J. S., "Further Observations of Glass Evidence Interpretation," *Science & Justice*, 1995; 35 (4): pp. 283-289.
6. Evett, I.W., Lambert, J.A., "The Interpretation of Refractive Index Measurements III", *Forensic Science International*, 1982; 20: pp. 237-245.
7. Feder, H.A., "How to Communicate with Attorneys: Your Final Report", *Succeeding as an Expert Witness: Increasing your Impact and Income*, Tagueh Press, Glenwood Springs, CO, 2000, pp. 90-94 (in Chemistry Section)
8. Koons, R. D., Buscaglia, J., Bottrell, M., Miller, E. T., "Forensic Glass Comparisons", *Forensic Science Handbook Volume 1, 2nd Ed.*, Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 209-210.
9. Sandercock, P.M.L., "Sample Size Considerations for Control Glass in Casework", *Canadian Society of Forensic Scientists Journal*, 2000; 33: pp. 173-185.
10. Sapir, G. I., "Legal Aspects of Forensic Science", *Forensic Science Handbook Volume 1, 2nd Ed.*, Saferstein, R., ed., Prentice-Hall, NJ, 2002, pp. 1-31.

11.3. STUDY/DISCUSSION EXERCISES

1. What criteria must be met to report an association of glass evidence?
2. Discuss the use of databases and our in-house database
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. Discuss with your trainer itemization guidelines for use when screening items for trace evidence.

11.4. PRACTICAL EXERCISES

1. Examine at least 5 glass case files from several trained analysts while reviewing documentation requirements provided by your instructor.
2. Observe court testimony on glass analysis or another trace discipline by other members of the laboratory staff. If this cannot be done in a timely manner, discuss glass-related court experiences with an experienced examiner.

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3. Work at least one mock cases provided by your trainer. Analyze and report each of these cases as if it were actual casework. A written report is required for each of the cases. If the examiner is new to the Trace discipline, this mock case should include a screening component.
4. Review the glass reference collection database and sort the data to look for patterns related to glass type and RI, thickness and RI, distribution of RI values, common and rare elements, thickness ranges of flat and window glass, etc. What are some conclusions you could draw from this data? What are the limitations of these conclusions?

12. COMPETENCY EXAMINATION

12.1. OBJECTIVES

- To ensure that the student has acquired the specialized knowledge, skills and abilities in the discipline of glass examinations
- To ensure appropriate documentation and report writing skills
- To ensure appropriate techniques and confidence for court presentation

12.2. REQUIRED READING

Feder, H.A., "How to Communicate with Attorneys: Your Final Report", Succeeding as an Expert Witness: Increasing your Impact and Income, Tague Press, Glenwood Springs, CO, 2000, pp. 1-18, 145-170.

12.3. STUDY/DISCUSSION EXERCISES

1. Discuss the results of the competency evaluation (see practical exercises) with the instructor.
2. Evaluate the training program and provide recommendations for future revisions.

12.4. PRACTICAL EXERCISES

1. Perform a competency test provided by your instructor. Work it as you would an actual case.
2. Complete one of the following:
 - a. A mock trial on the analysis of glass. This alternative is preferred for examiners who have not previously testified in court or have little court experience.
 - b. A round table discussion with other qualified examiners in the discipline. Suggested topics include Daubert (Brown) criteria and reporting of conclusions and opinions.

GLASS ANALYSIS AND COMPARISON TRAINING CHECKLIST – PAGE 1

Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
History, Composition and Manufacturing				
	Reading			
	Study Questions			
	Exercises			
Physical Properties				
	Reading			
	Study Questions			
	Exercises			
Fracture Examinations				
	Reading			
	Study Questions			
	Exercises			
Recognition, Recovery, and Collection				
	Reading			
	Study Questions			
	Exercises			
Microscopic Examinations				
	Reading			
	Study Questions			
	Exercises			
Elemental Analysis				
	Reading			
	Study Questions			
	Exercises			
Refractive Index				
	Reading			
	Study Questions			
	Exercises			
Annealing				
	Reading			
	Study Questions			
	Exercises			
Non-Comparative Exams				
	Reading			
	Study Questions			
	Exercises			
Report Writing, Documentation & Significance				
	Reading			
	Study Questions			
	Exercises			

GLASS ANALYSIS AND COMPARISON TRAINING CHECKLIST – PAGE 2

Trainee:		Trainer:		
		Trainee Initials/Date	Trainer Initials/Date	Time for Completion
Competency Examination				
	Reading			
	Study Questions			
	Exercises			