Technical Procedure for Fired Projectile Examination

1.0 Purpose – To outline the procedures for examination and comparison of fired projectile evidence.

2.0 Scope – This procedure applies to cases submitted to the Firearms Unit that contain fired projectiles.

3.0 Definitions

- **Air gap** – The distance between the measuring surfaces (the face of the anvil and the face of the spindle) of a micrometer.
- **Anvil** – The part of a micrometer bearing the fixed measuring surface.
- **Axial engraving** – Reproducible striations on a bullet which occur during firing and before engagement with the rifling. These are caused by the misalignment of the bullet with the axis of the bore.
- **Bearing surface –** The portion of a bullet's outer surface that comes into direct contact with the interior surface of the barrel.
- **Caliber (Ammunition)** – A numerical term, without the decimal point, included in a cartridge name to indicate the nominal bullet diameter.
- **Cannelure** – A circumferential groove generally of a knurled or plain appearance on a bullet or cartridge case that is typically used for crimping, lubrication, and identification.
- **Class characteristics** – Measurable features of a specimen which indicate a restricted group source. They result from design factors, and are therefore determined prior to manufacture.
- **Comparison microscope** – Essentially two microscopes connected to an optical bridge which allows the viewer to observe two objects simultaneously with the same degree of magnification.
- **Gauge** – A term used in the identification of a shotgun bore. The number of round lead balls of bore diameter that equal one pound. Thus 12 gauge is the diameter of a round lead ball weighing 1/12 pound.
- **Grain** – A unit of weight. 7000 grains equal one pound. The grain unit is commonly used in American and English ammunition practice to measure the weight of components.
- **Groove impression –** The impression on the bearing surface of a fired bullet created by the groove of a rifled barrel.
- **Individual characteristics** – Marks produced by the random imperfections or irregularities of tool surfaces. These random imperfections or irregularities are produced incidental to manufacture and/or caused by use, corrosion, or damage. They are unique to that tool and distinguish it from all other tools.
- **Land impression** – The impression on the bearing surface of a fired bullet created by the land of a rifled barrel.
- **Nominal caliber** – The caliber family to which a particular ammunition component belongs (e.g., .22, .30, .32, .38, 9mm, .45, etc.).
- **Oblique lighting** – A method of illumination where the light source is placed at an angle, generally to produce shadows or enhance edges.
- **Pellet** – A common name for the small spherical projectiles loaded in shotshells. Also known as shot. May also refer to a nonspherical projectile used in some air rifles and air pistols.
- **Projectile** – An object propelled by the force of rapidly burning gases or other means.
- **Shave mark** – A mark caused by the cutting of metal from a bullet due to cylinder misalignment in a revolver.
- **Shot** – Spherical pellets used in loading shotshells or cartridges.
- **Skid mark** – Rifling mark formed on the bearing surface of bullets as they enter the rifling of the barrel before rotation of the bullet starts. Skid marks are typically produced by revolvers and have the appearance of widening the land impressions at their beginning point.

- **Slippage** – The widening of land impressions seen when a bullet slips across the land of a rifled barrel; may widen the land impression along its length and at the base.
- **Slug** – A term applied to a single projectile for shotshells.
- **Spindle** – The part of a micrometer bearing the moveable measuring surface.
- **Stereomicroscope** – An optical instrument which provides three dimensional viewing of an object through paired objectives and eyepieces. Some models share a common main objective.
- **Sufficient agreement** – Agreement is sufficient when it exceeds the best agreement demonstrated between tool marks known to have been produced by different tools and is consistent with the agreement demonstrated by tool marks known to have been produced by the same tool.

4.0 Equipment, Materials, and Reagents

- Comparison microscope
- Stereomicroscope
- Balance
- Caliper
- Micrometer
- Engraver
- Magnet
- Leica Application Software (LAS)
- AFTE Glossary
- FBI General Rifling Characteristics File
- Ammunition Reference Collection
- Cotton-tipped swabs
- Cleaning solutions such as Terg-A-Zyme, Hibiclens, ethanol, and acetone
- Personal protective equipment
- Soft bristle brush

5.0 Procedure

5.1 Fired Projectile Examination

5.1.1 Item Preparation

5.1.1.1 Prior to analysis, ensure that any additional examinations (e.g., Forensic Biology, Trace, Latent, etc.) that must be completed before analysis by the Firearms Unit have been completed.

5.1.1.2 Visually inspect the projectile for possible trace evidence such as hair, fibers, wood, etc. Note the location on the projectile where the trace material was found. Carefully remove the material and place in a container suitable for return to the submitting agency or submission to the appropriate Laboratory section for further examination.

5.1.1.2.1 If the trace material is not to be retained, indicate as such in the case notes.

5.1.1.3 Projectiles that are contaminated with a potentially bio-hazardous material may be cleaned with a soft bristle brush and a disinfectant such as Terg-A-Zyme, Hibiclens, and/or ethanol.

5.1.1.4 Projectiles may generally be cleaned with a cotton-tipped swab saturated with ethanol or acetone.

5.1.1.5 If a portion of a jacket obscures the bearing surface, it may be carefully unfolded as needed to expose any underlying individual characteristics. Sharp or pointed surfaces (especially "talons") of metal jackets or jacket fragments may be crimped or repositioned so as to minimize the potential for injury during handling.

5.1.1.6 Mark all evidence bullets/projectiles for identification.

5.1.2 Physical Characteristics Examination

5.1.2.1 A separate entry shall be made in FA for each evidence bullet. Similar information as applicable for slugs, pellets, and wads shall be recorded on a Shotshell Worksheet.

5.1.2.2 Features of fired projectiles that shall be noted, if applicable, include:

5.1.2.2.1 Design characteristics of the fired projectile:

- Caliber/gauge (see 5.1.3)
- Weight, measured in grains
- Composition
- Type/design
- Base design
- Manufacturer/marketer, if possible to determine
- Cannelure type and location
- Damage or deformation
- Presence of gunpowder and/or powder imprints adhering to the base

5.1.2.2.2 Class characteristics of the firearm that fired the projectile:

- Number of land and groove impressions physically present (see 5.1.4.1 for calculating total number)
- Type of rifling (conventional or polygonal)
- Direction of twist of the land and groove impressions
- Width of land and groove impressions (see 5.1.4.2 for measurement methods)
- Markings that may indicate a particular type or condition of firearm, including skid marks, slippage marks, shave marks, flared base, etc.
- Striations on a wad that may be suitable for identification to the shotgun that fired it

5.1.3 Determination of Caliber or Gauge

5.1.3.1 Bullets – the following may be utilized to determine the caliber of any fired bullet. The condition of the bullet shall determine which steps may be used.

5.1.3.1.1 Compare the base diameter of the evidence bullet directly with known fired test standards.

5.1.3.1.2 Measure the base diameter of the evidence bullet using a calibrated measuring device and compare this measurement with known measurements published in reference literature.

5.1.3.1.3 Determine the number and widths of the land and groove impressions and compare to Table 6 of the Appendices section of the AFTE Glossary, 4th edition. This table provides nominal caliber only.

Nominal caliber may be calculated using the following formula:

$$\mathbf{d = N(L+G)/\pi}$$

where d = diameter of base of bullet
N = total number of lands and grooves
L = width of one land impression
G = width of one groove impression
π = pi = 3.1416

5.1.3.1.3.1 This formula is extrapolated from the formula represented in Table 6 of the Appendices section of the AFTE Glossary, 4th edition and in an article from the AFTE Journal titled "Land and Groove Tabulation."

5.1.3.1.3.2 If this formula is used to determine nominal caliber, the AFTE Journal article shall be imported into the case file.

5.1.3.1.4 Physical characteristics of the evidence bullet, such as weight, bullet shape, composition, nose configuration, and number and placement of cannelures, may aid in caliber determination.

5.1.3.2 Slugs – the following may be utilized to determine the gauge of a fired slug. The condition of the slug shall determine which steps may be used.

5.1.3.2.1 Compare the base diameter of the evidence slug directly with known standards.

5.1.3.2.2 Measure the base diameter of the evidence slug using a calibrated measuring device and compare this measurement to known

measurements published in reference literature, including Table 4 of the Appendices section of the AFTE Glossary, 4th edition.

5.1.3.2.3 Weigh the evidence slug in grains and compare to known weight published in reference literature, including Table 4 of the Appendices section of the AFTE Glossary, 4th edition.

5.1.3.3 Shot – determine the total number of pellets received, the composition of the pellets, and the number of pellets suitable for comparison purposes. Note if pellets all appear to be similar in size. If several different sizes are present, determine each individual size. The Forensic Scientist may use one or all of the following techniques to determine shot size.

5.1.3.3.1 Visual/Microscopic Comparison

Compare Laboratory standards of known shot sizes side by side with the evidence pellets until a known shot size is determined. A stereomicroscope may aid in this determination. This may be done one size at a time or several sizes at a time; however, if more than one size is used at a time, care shall be taken not to mix up the shot.

5.1.3.3.2 Comparison by Weight

5.1.3.3.2.1 Weigh the pellets in grains.

5.1.3.3.2.2 Divide weight of pellets by total number weighed.

5.1.3.3.2.3 Consult known pellet weights in Tables 1 and 2 of the Appendices section of the AFTE Glossary (4th Edition).

5.1.3.3.2.4 The weight of the evidence pellets may also be directly compared to the weight of standard shot using the same number of pellets until a similar known weight is obtained.

5.1.3.3.3 Measuring Pellet Size

5.1.3.3.3.1 Choose the most intact or un-deformed specimen and measure the diameter using a calibrated measuring device.

5.1.3.3.3.2 Consult known shot sizes in Tables 1 and 2 of the Appendices Section of the AFTE Glossary (4th Edition).

5.1.3.4 Wads – the following may be utilized to determine the gauge of a fired wad. The condition of the wad shall determine which steps may be used.

5.1.3.4.1 Directly compare the evidence wad to known Laboratory standards of similar manufacture or composition by comparing the base of the evidence to the bases of the standards until a similar known size is obtained.

5.1.3.4.2 Measure the base diameter of the wad and compare these measurements to known measurements.

5.1.3.4.3 Manufacturer data may be determined by locating information stamped into the wad or by comparing the evidence wad to known Laboratory references.

5.1.4 Rifling Characteristics

5.1.4.1 For damaged bullets for which the total number of land and groove impressions cannot be visually determined, this number shall be calculated using the following formula:

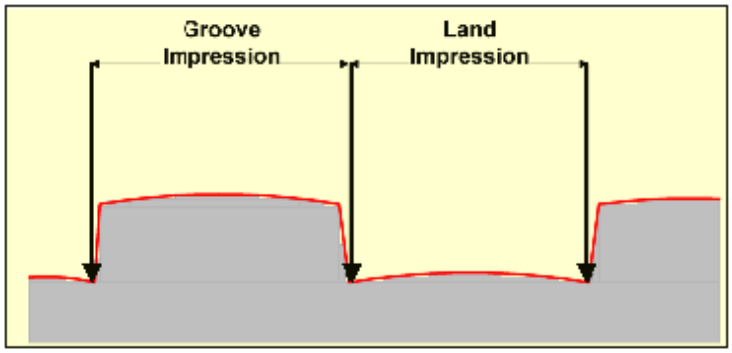
$$N = d\pi/(L+G)$$

where N = total number of lands and grooves
d = diameter of base of bullet
π = pi = 3.1416
L = width of one land impression
G = width of one groove impression

5.1.4.1.1 This formula is represented in Table 6 of the Appendices section of the AFTE Glossary, 4th edition and in an article from the AFTE Journal titled "Land and Groove Tabulation."

5.1.4.1.2 If this formula or the extrapolated chart is used to determine the total number of land and groove impressions, the AFTE Journal article shall be imported into the case file.

5.1.4.2 In measuring a fired bullet to determine the width of a land impression or a groove impression, it is paramount that the points used for beginning and ending a measurement comply with discipline-wide practice. This practice utilizes the anchor points shown below.



All suitable land and groove impressions shall be measured and their average measurement, recorded to the nearest thousandth of an inch, shall be recorded in the notes for each bullet. Methods may include the Leica Application Suite Measurement Module and the air gap method.

5.1.4.2.1 **Leica Application Software** - A comparison microscope equipped with the Leica Application Suite (LAS) Measurement Module may be used to make measurements.

5.1.4.2.2 **Air Gap Method**

5.1.4.2.2.1 The fired bullet is mounted on one stage of the comparison microscope. The measuring device, typically a micrometer, is mounted on the other stage.

5.1.4.2.2.2 Both stages shall use the same magnification level (objective setting) and be in focus.

5.1.4.2.2.3 Align the image of the land or groove impression with one of the anchor points corresponding with the anvil of the micrometer. Rotate the micrometer's spindle to the next anchor point of the land or groove impression and record the measurement gap (opening) of the micrometer to the nearest thousandth of an inch.

5.2 General Rifling Characteristics (GRC) File Protocol

5.2.1 If an evidence bullet is not identified to a particular firearm, a list of manufacturers of firearms of similar caliber and/or rifling class characteristics shall be compiled using the computerized General Rifling Characteristics File provided by the FBI.

5.2.2 A combination list generated using class characteristics of both fired bullets and cartridge cases shall not be produced.

5.2.3 Fill in the applicable fields at the bottom of the GRC Search page with the pertinent case information and the information obtained during the examination of the bullet, and run the computerized search of the database files.

5.2.3.1 The search parameters for land and groove impression widths shall include a tolerance of +/- 0.003 inch. This tolerance may be increased due to damage, deformity, poor rifling, etc. at the discretion of the Forensic Scientist in accordance with accepted industry and forensic laboratory standards and based on the analyst's training and experience.

5.2.3.2 Based on the Forensic Scientist's training and experience, the list may be filtered based on characteristics of the bullet that may indicate or exclude a particular caliber or type of firearm.

5.2.3.3 If multiple evidence bullets have been identified to each other, one list of possible firearm manufacturers shall be compiled. The land and groove impression measurements for each bullet shall be incorporated in the search parameters. For example, if two bullets have land impression widths of 0.057 and 0.058 inch with a tolerance of +/- 0.003 inch, the minimum and maximum land impression width search parameters should be 0.054 and 0.061 inch, respectively.

5.2.4 Record this information in the case notes and import the search results generated by the General Rifling Characteristics File into the case file.

5.2.5 Report the list of possible manufacturers in the main body of the Report.

5.2.5.1 Always include a disclaimer notifying the submitting agency that the list may not be all inclusive and should not be used to eliminate any suspect firearm.

5.2.6 If the list consists of more than twenty (20) possible firearm manufacturers, the complete list shall be imported into the Case Record Object Repository and the report shall contain a statement that the list of firearms that may have fired the evidence bullet(s) was too numerous to be of investigative value.

5.3 Comparison Microscope Protocol

5.3.1 The following is an illustration of an approved method of performing a comparison microscope examination of test and/or evidence bullets. Forensic Scientists may develop an individual routine for this type of examination; however, they shall incorporate all the general underlined points mentioned below.

5.3.1.1 Select the correct objective (magnification) setting and ensure that the objectives are locked in place. Low magnification (10X - 15X) is typically used to examine the entire bearing surface looking for areas with the most obvious individual characteristics. Higher magnification (20X or greater) is typically used to verify the correspondence of finer striations.

5.3.1.2 The illumination (lights) used shall be properly adjusted. Oblique lighting is usually preferred.

5.3.1.3 Mount a bullet on each stage of the comparison microscope with the noses facing to the left. If the comparison is performed with the noses toward the right, the notes shall reflect this orientation.

5.3.1.4 If a firearm was submitted for comparison to evidence bullets, first compare the test bullets fired from this firearm to each other to determine which microscopic characteristics are reproducing. If the test bullets cannot be matched to each other (the agreement is not sufficient), more test bullets may be fired and inter-compared. If the test fired bullets still cannot be matched, the Forensic Scientist may reach the conclusion that the firearm barrel in question does not reproduce its individual characteristics very well or that the firearm barrel does not produce sufficient individual marks to reach a positive conclusion.

5.3.1.4.1 If the test bullets can be matched to each other, the area of best agreement or the area with the most obvious striae shall be indexed with an indelible marker.

5.3.1.5 Compare unknown fired bullet(s) to either another unknown fired bullet or a test fired bullet.

5.3.1.5.1 The Forensic Scientist can ascertain at this point if the class characteristics agree by noting whether the direction of twist is the same and whether the widths of both land and groove impressions are the same on both bullets.

5.3.1.5.1.1 If the class characteristics are different and this difference is not attributed to distortion or deformation due to a damaged evidence bullet or to damage to the barrel after the firing of the evidence bullet, the Forensic Scientist may conclude that the evidence bullet was not fired from the evidence firearm or that the evidence bullets were not fired from the same firearm.

5.3.1.5.2 In the case of comparison to a test fired bullet, attempt to locate the area on the evidence bullet that corresponds to the previously indexed area of the test bullet.

5.3.1.5.3 When comparing evidence bullets to each other, an area with obvious individual characteristics may be noted on one bullet. The other bullet may then be examined in an attempt to locate the corresponding area.

5.3.1.5.4 When and if this area is found, align the edges of the corresponding land or groove impression. These examinations shall be made with the bullets in phase. This means that the edges of the land or groove impressions of both bullets align with each other and the relationship of the other land and groove impressions visible in the viewing area is the same.

5.3.1.5.5 The entire unknown shall be considered. Rotate both bullets simultaneously, examining and comparing each land impression and each groove impression from base to nose until the Forensic Scientist concludes there is sufficient agreement to match or there is not sufficient agreement to match.

5.3.1.5.6 If the bullets can be matched to each other, the area of best agreement or the area with the most obvious striae shall be indexed with an indelible marker.

5.3.1.5.6.1 The evidence bullet may be damaged or deformed in the area of the index. It may be necessary to use other areas of the indexed bullet to compare to the undamaged areas of the evidence bullet.

5.3.1.5.6.2 If the evidence bullet is missing the indexed area or if it is just a portion of a bullet, the evidence shall be indexed at the best area on the evidence bullet with a different color index mark. The previously indexed bullet(s) shall then be indexed again at this area of agreement with the same color index mark (different color than already present).

5.3.1.5.7 If an identification is not initially made, the Forensic Scientist may consider the following possible reasons for the lack of sufficient agreement:

5.3.1.5.7.1 The evidence bullet and test bullets were fired from different firearms.

5.3.1.5.7.2 The firearm was damaged between firing the evidence bullet and the test bullets.

5.3.1.5.7.3 The test ammunition available is significantly different from the evidence causing a difference in the way the bullet is marked.

5.3.1.5.7.4 Misalignment occurs between chamber and barrel causing marks to differ on bullets fired from different chambers.

5.3.1.5.7.5 Extreme leading or corrosion is/was present in the barrel, either prior to firing the evidence bullet or occurring since the evidence bullet was fired.

5.3.1.5.7.6 Damage occurred to the evidence bullet causing distortion, deformation or the elimination of microscopic detail.

5.3.1.5.7.7 The evidence bullet was fired from a firearm of an incorrect caliber.

5.3.1.5.7.8 Other reasons may exist and may be considered and tested if appropriate at the discretion of the Forensic Scientist based on his/her training and experience.

5.3.2 Similar microscopic protocols may be used for the comparison of individual markings found on slugs and wadding material.

5.4 Range of Conclusions

5.4.1 The suggested report wording listed below may be modified at the Forensic Scientist's discretion to reflect more accurately his/her conclusions. Any such modifications to report wording shall be reviewed and approved with the technical review.

5.4.2 Identification

5.4.2.1 There is agreement of all discernible class characteristics and sufficient agreement of individual characteristics to constitute a match.

- "The Q-1 bullet was fired from the K-1 firearm."
- "The Q-1 and Q-2 bullets were fired from the same firearm."

5.4.3 Inconclusive

5.4.3.1 There is agreement of all discernible class characteristics and some agreement of individual characteristics, but insufficient for an identification; or

There is agreement of all discernible class characteristics without agreement or disagreement of individual characteristics due to an absence, insufficiency, or lack of reproducibility; or

There is agreement of all discernible class characteristics and some disagreement of individual characteristics, but insufficient for elimination.

- "There is agreement of all discernible class characteristics between the Q-1 fired bullet and test bullets fired from the K-1 pistol; however, the comparison of individual characteristics was inconclusive. Therefore, the Q-1 bullet could not be identified or eliminated as having been fired from the K-1 pistol."
- "There is agreement of all discernible class characteristics between the Q-1 and Q-2 fired bullets; however, the comparison of individual characteristics was inconclusive. Therefore, the Q-1 and Q-2 bullets could not be identified or eliminated as having been fired from the same firearm."

5.4.4 Elimination

5.4.4.1 There is significant disagreement of discernible class characteristics and/or individual characteristics.

- "The Q-1 bullet was not fired from the K-1 firearm."
- "The Q-1 and Q-2 bullets were not fired from the same firearm."

5.4.5 Unsuitable

5.4.5.1 The fired evidence in question is not suitable for comparison purposes. E.g. small lead fragments and/or bullet jacket fragments that exhibit no class characteristics and/or individual characteristics.

- "The Q-1 lead fragment contains no marks of comparison value for forensic firearms identification."

5.4.6 Forensic Scientists shall include in their notes all conclusions reached from the microscopic comparison of evidence bullets and/or test fired ammunition components. Forensic Scientists shall also explain their reasons for reaching these conclusions. The reasons shall be clear and succinct and shall be able to be understood by another competent forensic firearms scientist. The Forensic Scientist shall include the position and type of index marks used and which of the test fires (if an evidence firearm was fired) was used or if more than one test fire was used to reach the conclusions.

5.5 Standards and Controls – N/A

5.6 Calibration – For comparison microscope, balance, caliper, and micrometer calibration information, see the Firearms Unit Technical Procedure for Instrument Calibration and Maintenance.

5.7 Maintenance – For comparison microscope, stereomicroscope, balance, caliper, and micrometer maintenance information, see the Firearms Unit Technical Procedure for Instrument Calibration and Maintenance.

5.8 Sampling – N/A

5.9 Calculations

- For calculating the total number of lands and grooves, see 5.1.4.1.
- For calculating the nominal caliber, see 5.1.3.1.3.

5.10 Uncertainty of Measurement – N/A

6.0 Limitations – N/A

7.0 Safety – Examinations performed in the Firearms Unit are inherently dangerous. These procedures involve hazardous chemicals, firearms, ammunition, and potential biohazards. All hazardous procedures shall be performed in compliance with the State Crime Laboratory Safety Manual. If the examination involves a biohazard, the Forensic Scientist shall use proper personal protective equipment, such as eye protection, a lab coat, and/or gloves.

8.0 References

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9.0 Records

- FA Worksheets
- GRC File Search Results

10.0 Attachments – N/A

Revision History		
Effective Date	Version Number	Reason
09/17/2012	1	Original Document
02/15/2013	2	Removed Raleigh from the header; **5.1.2.2.2** – added type of rifling; created new **5.1.3.1.3.1**, **5.1.3.1.3.2**, and **5.1.3.1.3.2.1**; **5.1.4.2** – second paragraph reworded to reflect that the average width of all suitable land and groove impressions is recorded in notes
09/06/2013	3	**5.4.3.3** – added "some" to the paragraph and to the two examples of report wording
11/15/2013	4	Added issuing authority to header
09/05/2014	5	**Header and various subsections** – corrected to reflect organizational change; added magnet to Equipment list; two sentences added to **5.2.3.2.1**
12/11/2015	6	**5.1.1.1** – reworded 1st sentence, removed 2nd Removed old **5.1.1.1.1, 5.1.1.1.2, 5.1.1.1.3, 5.1.1.2** **5.1.1.3** – changed shall to may Removed old **5.1.1.7.1, 5.1.1.7.2** **5.1.2.1** – replaced bullet worksheet with entry; removed last sentence Removed old **5.1.2.3** Old **5.1.3.1.3.1** – combined with **5.1.3.1.3** **5.1.3.1.3.2** – removed last sentence; changed CROR to case file; decreased indent by one level Old **5.1.3.3.1.1 -** combined with **5.1.3.3.1** Old **5.1.4.1.1.1** – decreased indent by one level (now **5.1.4.1.2**), replaced CROR with case file, removed last sentence **5.1.4.2.2.1 –** reworded **5.1.4.3 –** indented two levels (now **5.1.4.2.2.3**) **5.2.3** – removed specific list **5.2.3.2** – reworded Removed old **5.2.3.3** **5.2.3.2.1** – decreased indent one level (now **5.2.3.3**) **5.2.4** – removed specific worksheet and CROR to case file/notes **5.3.1.3** – removed preference/nature of detail **5.3.1.6 – 5.3.1.9.8** – increased indent one level (now **5.3.1.5.4-5.3.1.5.7.8)** Removed quotation marks from all conclusions **5.9** – added nominal caliber calculation **9.0** – removed specific worksheets
07/01/2016	7	Combined old **5.4.3.2** and **5.4.3.3** into **5.4.3.1** and added new bullets; **5.1.3.1.3.1** – changed "titles" to "titled"; corrected revision history entry for 12/11/2015 (entry for **5.1.3.1.3** changed to

		5.1.3.1.3.2).