General Approach to Report Writing in Metallurgy

1 Introduction

The report issued by a metallurgy examiner is a summary of analytical findings and an explanation of the interpretations of these findings. As a result of the variety of requests and evidence received, this standard operating procedure is only a general guideline for report writing. Its intent is to assist examiners in formulating reports that are both factual and contain enough explanatory information to allow rational evaluation of the conclusions drawn and the limitations of the examinations performed. Further, the wording must be approved by an authorized reviewer during the technical review process.

2 Scope

This document applies to Chemistry Unit caseworking personnel who write *Laboratory Reports* that convey the results of metallurgy examinations and the interpretations and opinions that are based on these examinations.

3 Equipment/Materials/Reagents

Not applicable.

4 Standards and Controls

Not applicable.

5 Sampling or Sample Selection

Not applicable.

6 Procedure

Metallurgy *Laboratory Reports* will contain the administrative requirements set forth in the FBI Laboratory Operating Manual (LOM). Metallurgy *Laboratory Reports* will also comply with the language limitations detailed in the Chemistry Unit (CU), FBI Approved Standards for Scientific Testimony and Report Language for Metallurgy and the *Department of Justice Uniform Language for Testimony and Reports for the Forensic Metallurgy Discipline (Metallurgy ULTR)*

6.1 The Results of Examinations section will include a summary of the results of the metallurgy examinations conducted on each item of evidence examined and a succinct statement of any conclusion drawn from the examination results. Any pertinent limitations of the evidence that prevent forming conclusions related to the incoming request may be included in this section or may be deferred to the Methodology, Interpretation and Discussion section of the report if it is deemed to improve the clarity of the report.

6.2 For a comparative examination, the Results of Examinations section will indicate the general nature of any conclusion (e.g., 'fracture fit', 'inclusion', 'exclusion', or 'inconclusive'), the characteristics on which the conclusion is based, and an indication of the significance of the conclusion. An explanation of the significance of an 'inclusion' will describe the population of other materials that possess characteristics similar to those exhibited by the evidence. For example, when an 'inclusion' is made to a broad, general population of items or materials (such as mass-produced items), the report will explain that the chance of finding coincidentally indistinguishable materials may be high. For an 'inconclusive' comparison, the reason for the inconclusive result will be expressly stated (e.g., "Due to the small size of the particle, there is an insufficient quantity of observable characteristics to determine whether it originated from a bullet.")

6.3 Any quantitative result reported in the Results of Examinations will include an estimate of the uncertainty for the value that will be reported at 99.7% confidence or higher. The (estimated) confidence level will also be reported.

6.4 In addition to the Results of Examinations section, each metallurgy report will include a Methodology, Interpretation and Discussion section that specifies the instruments and procedures that were employed. This section may also provide additional information intended to help the reader understand the results of the examinations. To this end, the section may include:

- information on both the strengths and the limitations of the examinations performed
- explanations of the principles on which conclusions were based
- recommendations for remedial action to prevent future failures
- supplementary data and the sources of such data (e.g., externally managed databases like those maintained by the United States Patent and Trademark Office)
- details regarding the nature and strength of any associations
- other interpretations, opinions or predictions that can be inferred from the results of the examinations, and the bases for these opinions.

6.5 The Remarks section will contain a statement that incorporates the *Department of Justice Uniform Language for Testimony and Reports for the Forensic Metallurgy Discipline* into the *Laboratory Report* by reference. In addition, the following will be included in the Remarks section when applicable and appropriate and when this information may assist the reader of the report:

- a listing of evidence collected but not examined in metallurgy
- an explanation of how to properly collect, mark and preserve metallurgical evidence in the future
- any other information that will assist the reader that does not belong in another section of the report.

6.6 The language used to convey this information should be accurate, clear, unambiguous and objective. The composition will be decided upon by the metallurgy examiner and agreed to by the technical reviewer before the *Laboratory Report* is issued. Documentation of this agreement is maintained in the case record (e.g., Case Record Report, Case Record Reviews, Technical: "Completed", or initials on a hardcopy of expedited results.) Copies of metallurgy *Laboratory Reports* will be maintained in a central, designated area in order to facilitate consistency in language over time and among examiners.

6.7 Exemplar reports illustrating the basic document layout to be employed in writing metallurgy *Laboratory Reports* are contained in Appendix 1.

7 Calculations

Not applicable.

8 Measurement Uncertainty

Not applicable

9 Limitations

Not every metallurgy examination scenario can be anticipated. This document provides guidelines for the structure of metallurgy *Laboratory Reports*, but is not intended to limit the report author to any specific vocabulary, scope or amount of detail.

10 Safety

Not applicable.

11 References

FBI Laboratory Operations Manual, Federal Bureau of Investigation, Laboratory Division, latest revision

FBI Approved Standards for Scientific Testimony and Report Language for Metallurgy, Metallurgy Manual Metal 901, Chemistry Unit, latest revision

Department of Justice Uniform Language for Testimony and Reports for the Forensic Metallurgy Discipline, latest revision

Rev. #	Issue Date	History
0	06/08/2010	New document.
1	01/29/2019	Renumbered Metallurgy SOP Manual documents. This document was formerly Metal 22 and is now designated Metal 900. Changed title and removed references to metallurgy "discipline" throughout. Revised Section 2 Scope. Removed specific titles of LOM documents. Revised Section 6 Procedure by incorporating relevant documents by reference and adding and revising language to correspond to the relevant documents. Clarified documentation of technical reviewer agreement with report language. Also added documents to Section 11 References. Revised examples in Appendix 1.
2	02/18/2020	Changed the description of the technical reviewer qualification to "authorized" to conform with LOM language in sections 1 and 6.6. In section 1, changed "inferences" to "conclusions" to avoid confusion with sampling requirements. Added descriptive headings, increased specificity of Example 2 results and added Example 4 to the Appendix.

Approval

Redacted - Signatures on File

Metallurgy Technical Leader: Date: 02/13/2020

Chemistry Unit Chief: Date: 02/13/2020

Appendix 1: Examples of the Types of Content to be included in a Metallurgy Report

In the examples below, comments regarding the report language are enclosed in { } and are not part of the sample text.

Example 1: Comparison

Results of Examinations:

Items 1, 7 and 10 are sections of red-insulated wire. Each has a single-strand copper conductor. The diameters of the wire sections compare favorably with AWG 22 wire.

The Item 2-5 assembly contains one length of red-insulated, two-conductor cord. Each conductor is a single strand of copper that compares favorably to AWG 22 wire.

The Item 32 assembly contains two lengths of red-insulated, two-conductor cord. Each conductor is a single strand of copper that compares favorably to AWG 22 wire.

Based on metallurgical examinations of the insulated copper wires in Items 1 and 7, it was concluded that these were manufactured with the same fabrication tooling (extrusion die) as one of the wires attached to an electrical plug from Item 32. The observed characteristics indicate that the Item 1 and 7 wires were either cut from the same item as one wire in Item 32 or from some other length of wire produced using the same extrusion die. [*Inclusion*] {This statement explains that Items 1 and 7 could also have originated from another length of wire that did not include Item 32.} Due to large production runs, a substantial amount of wire would be expected to bear the same observable characteristics. {This paragraph explains the potential source population.}

Metallurgical examinations of the Item 10 insulated copper wire determined it to have the same manufacturer's information printed on its surfaces as the section from Item 2-5 and one of the sections from Item 32. The observed characteristics indicate that Item 10, the section from Item 2-5 and the section from Item 32 were either cut from the same length of wire or from similar lengths of wire bearing the same manufacturer's information. [*Inclusion*]

Further, the contents of the printed markings on the wire from Item 2-5, Item 10 and one wire from Item 32 differ slightly from those printed on the wires in Items 1, 7 and the other wire from Item 32. This means that at least two distinguishable sources of physically similar, insulated wires are represented within the items. [*Exclusion*] {The two types of wire differ from each other.}

Methodology, Interpretation and Discussion:

The items were examined for association/origin by visual inspections, dimensional measurements of the wire insulation and the internal conductors, x-ray fluorescence spectrometry (XRF) of the metal conductors and microscopic comparisons of the fabrication marks on the wire insulation.

{Include a list of Metallurgy SOPs used.}

Because wire producers commonly have many extrusion dies of the same size, the presence of extrusion marks on the wire insulation can be used to distinguish wire produced with a particular die from wire of the same size, color and type produced using a different die.

Modern fabrication tooling can produce an unknown but very large quantity of insulated wire having identical fabrication marks and printed manufacturer's information. Although many manufacturers worldwide make a myriad of types, sizes and colors of wire, large concentrations of a particular product in a limited geographic area can and do sometimes occur. Consequently, it is extremely difficult to estimate the number of individuals who might possess seemingly identical products within a limited geographic area at any given time. {This paragraph contains details regarding the limited significance of the *Inclusions* presented in the Results section.}

Example 2: Identification and Comparison

Results of Examinations:

The Item 1-1, 1-2 and 1-3 pipe fragments and the largest metal fragment from Item 6-1 were analyzed and determined to be fabricated from galvanized, plain carbon steel. Based on the similarities in the compositions and physical characteristics of the four fragments, metallurgy examinations determined that they either all originated from the same length of pipe or from multiple pipes fabricated from identical grades of steel having highly similar physical dimensions, chemistries, and plating layers. [*Inclusion*] {This paragraph includes the bases for the *Inclusion* conclusion.}

In addition to the fragment analyzed, Item 6-1 contains four additional, smaller fragments. These fragments appear to have originated from a source such as an endcap based upon the visual and microscopic visual examinations of them. No compositional analysis of these fragments was conducted.

Methodology, Interpretation and Discussion:

Items 1-1, 1-2 and 1-3 and the largest fragment from Item 6-1 were analyzed for association/origin with a binocular microscope, physical examinations, x-ray fluorescence spectrometry (XRF) and spark-discharge-in-argon optical emission spectrometry (SDAR-OES). {Include a list of Metallurgy SOPs used.}

The binocular microscopy, XRF and mechanical measurements served primarily as evaluations of the class characteristics of the fragments to include: the general alloy class, the type of surface plating, wall thickness, shape, and surface finish. Because of the damaged nature of the fragments, such evaluations are primarily qualitative in character. {This paragraph explains limitation of the examinations.}

Sections were cut from Items 1-1, 1-2, 1-3, and the largest fragment from Item 6, and the galvanized coating was ground off of one surface of each section. Quantitative compositional comparisons of the sections were performed using SDAR-OES. Commonly, carbon steel samples contain fifteen or more elements above the limits of detection of the instrument. Statistical comparisons of the measured compositions of two steel samples are made using a Bonferroni corrected, Student's t-test with a null hypothesis that the steels have identical compositions. Using this scheme, the comparison of two steel samples that actually have identical compositions will result in a failure to associate them approximately 5% of the time.

The likelihood of incorrectly associating two steel samples that actually have different elemental compositions is more complicated to calculate. Thousands of different compositional specifications exist which govern the production of the many different types of steel. Moreover, there is considerable compositional variation between individual heats of steel produced to the same specification. Consequently, the number of potentially distinguishable compositions of steel that could be encountered is very large but it is not unlimited. Logically, it follows that there is a possibility of encountering steel components that cannot be distinguished from each other but which are from different manufactured sources.

Because a single heat of steel commonly exceeds one hundred tons in weight, many thousands of pipes having indistinguishable compositions can potentially be produced from a single heat. Also, large concentrations of a particular product in a limited geographic area can and do sometimes occur. Consequently, it is extremely difficult to estimate the number of individuals who might possess seemingly identical products within a limited geographic area at any given time. {The above paragraphs explain the limitations of the significance of the *Inclusion* conclusion.}

Example 3: Identification of Material

Results of Examinations:

Based on microstructural evaluations of the Item 1 copper disc, it was concluded that the cone is unlikely to have been fabricated from an oxygen free grade of copper. [*Exclusion*] This conclusion is supported by compositional analysis of microscopic inclusions. The Item 1 material contains significantly more oxygen-bearing microscopic inclusions than would be expected in oxygen free copper.

Methodology, Interpretation and Discussion:

The microstructure of the disc was evaluated by cutting and polishing copper sections to a less than 0.1 micron surface roughness using metallographic diamond polishing compounds containing known particle sizes. Some of the inclusions contained in the copper from the Item 1 specimen were analyzed by scanning electron microscopy with energy dispersive spectrometry (SEM/EDS) to determine their elemental compositions.
{Include a list of Metallurgy SOPs used.}

Oxygen is not highly soluble in copper and its presence can be seen in the form of inclusions having a different color and reflectivity under microscopic examination than the polished metal surface surrounding them. Comparison of such polished surfaces with the published images of polished copper available in standard references was used to investigate the types of inclusions present in the Item 1 sample. Based on such comparisons, the sample from Item 1 contains numerous inclusions which closely resemble the oxide inclusions known to be present in oxygen bearing grades of copper. Oxygen free grades of copper commonly contain less than 10 parts per million oxygen by weight. As a consequence of this, oxide particles are not readily observed in oxygen free grades of copper.

Several chemically distinct types of inclusions can occur in copper. These may include sulfides, phosphides, and oxides, as well as other types. Since the chemistry of the inclusions affects their shapes and colors, it is usually possible to distinguish among different inclusion types based on visual microscopic examinations. The elemental composition of these inclusions can be evaluated by SEM/EDS.

Some extreme service conditions are capable of changing the microstructural characteristics of materials. For example, heating an oxygen free grade of copper at high temperature in air for a very prolonged period would permit the diffusion of oxygen into the sample. However, it is highly probable this would result in a much higher density of oxide particles near the surface than in the sample core unless extensive, additional thermal and mechanical processing of the sample was subsequently undertaken. No such gradient of oxide particles was observed in Item 1. {This paragraph describes limitations of the examination.}

Example 4: Lamp Examination

Results of Examination:

Metallurgical examinations of the damaged Item 3 headlight lamp determined that some of its observable characteristics almost certainly resulted from the lamp sustaining a severe impact while its low beam filament was illuminated. Notably, the filament of Item 3 was extensively stretched out.

The remains of the Item 1, Item 2 and Item 4 lamps were too limited to determine if any of these lamps were incandescent at the time of the reported collision. {This paragraph explicitly states the reason the examination of these items was *Inconclusive*.}

Methodology, Interpretation and Discussion:

Lamp examinations consist of evaluations of the characteristics that distinguish whether a lamp was exposed to impact and/or air while at either high temperature or at ambient temperature. The lamps in this case were examined visually and with a binocular microscope for physical changes which would indicate their operating condition at the time of the reported collision. The Item 3 lamp was also checked with an ohmmeter to verify its electrical continuity.

The forensic examination of automotive lamps is based on the knowledge that the tungsten metal used to produce lamp filaments has dramatically different chemical and physical properties at room temperature and at the elevated temperatures that characterize an incandescent filament. Tungsten is typically brittle at room temperature but capable of highly ductile behavior at elevated temperatures. Consequently, extensive stretching of a lamp filament usually indicates that the filament was deformed while at elevated temperature.

It is frequently not possible for these examinations to determine when a particular lamp became damaged. In some instances, the observed changes in a lamp could have occurred in an incident prior to that under investigation since some damaged lamps can continue to function.

When slight apparent filament deformation is present, it is not always possible to unambiguously determine its cause. For example, unused (new) filaments can exhibit slight ductility when cold. In addition, automotive lamps are occasionally manufactured with filaments that have a slight bow in them. Similarly, long, fine gauge filaments may stretch downward somewhat during prolonged normal operation due to the effects of gravity. This phenomenon is known as "age sag". Despite the possible occurrence of such characteristics, it is usually possible to identify the damage induced by a severe impact on an incandescent filament.

The stretching of the Item 3 filament is not typical of deformation resulting from age sag, cold deformation of a new filament or with as-manufactured characteristics. Rather, it is more typical of the deformation that occurs during a severe impact while a filament is at elevated temperature.

Example 4: Characterization of Product

Results of Examination:

Metallurgy examinations determined that the Item 1 collection contains ten coins marked “silver”. Compositional analysis determined that the exterior of each coin is unalloyed silver. One of the coins, Item 1-1, was sectioned and the composition was analyzed through the thickness of the coin. The composition through the entire thickness of the sectioned coin is unalloyed silver.”

{Avoid attributing characteristics determined by analysis to items (or locations on items) that were not analyzed. Do not express results that may be misconstrued as describing ALL of the pieces, such as, “The Item 1 collection contains silver coins.”}