Functionality Examinations

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1 Introduction

Many manufactured devices function on the bases of well-established engineering and design criteria. Consequently, when a device fails to function as intended, it is usually possible to discern the cause of the failure by careful inspection of the device's components. The possible causes of a particular malfunction can be diagnosed by examining the subsystems of the device and determining which of them may be responsible for the observed problem. Correction of the problem indicates it has been appropriately diagnosed.

2 Scope

This document applies to case working personnel who perform metallurgy analyses. There are a wide variety of mechanisms, components, metals, treatments, conditions, types of damage, applications, environments, and combinations of these, as well as an unpredictable range of determinations that can be requested regarding the failure or damage sustained and exhibited, in any particular evidence submission. The following procedure outlines the basic analyses most commonly performed in functionality testing an item or assembly.

3 Principle

Generally, it is possible to establish whether a mechanism is operating correctly by supplying the appropriate energy source to it. These can include dry cell batteries, electrical power, wind, gasoline, sunlight, pressurized gas, or another source, depending upon the device's requirements.

When the device is a sensor, it is also necessary to supply its stimulating species in order to verify its proper function. For example, a smoke detector can be tested by exposing it to a smoke source. Similarly, a radiation detector can be tested using an appropriate radioactive source material.

When a device is not functioning, it is often possible to determine why by examining it closely. For example, a broken wire in an electrical device could prevent it from working as intended. If replacement of a failed component restores its function, it may be deduced that it was the cause of the malfunction, provided that it can also be demonstrated that another defective component did not contribute to the failure of an otherwise sound component.

4 Specimens

Nearly any mechanical device and many non-mechanical devices can be examined using this procedure.

5 Equipment

A list of items commonly used in this examination follows. Not every item is used for every investigation. The instrumentation and equipment used will depend on the configuration of the item or mechanism to be examined for functionality.

- Macro camera

- Stereomicroscope with a fiber optic light source and a magnification of at least four (4) diameters with camera
- Digital X-ray radiography unit*
- Miscellaneous hand tools
- Digital multimeter
- Variable power supply
- Manually operated gas pump
- Graduated cylinder (500 ml)
- Leak detecting solution (Snoop® or equivalent)
- Miscellaneous components for substitution of missing or damaged components
- Compressed non-reactive gases

* When an instrument marked with an asterisk is used, see the appropriate Chemistry Unit (CU) Metallurgy technical procedure for additional equipment.

6 STANDARDS AND CONTROLS

The standards and control samples to be employed in this procedure will depend on the specific analytic methods employed and the nature of the items under analysis. Exemplars for evidentiary items will be obtained as needed. Any instrument used in this procedure will employ such standards as are required under its specific technical procedure (see section 14 References).

7 PROCEDURE

A. Perform a preliminary examination and note any apparent shipping damage as well as any material transfer from shipping and/or handling. Record any dial/gauge readings and make an evaluation as to type of device including the nature of the input and output (e.g., gas, electrical power, fluid). Record any informative manufacturer's markings, visible or restorable.

B. Photograph the “as received condition” (ARC) of the specimen, noting the overall condition of the appliance or item, any damage exhibited, and the spatial relationship of the controls and components.

C. If appropriate, perform radiographic examination of the internal components of the device.

D. If feasible and appropriate, obtain a comparable, undamaged device (exemplar) for examination and comparison.

E. Conduct both visual and low power magnification examinations to assess the totality of the item and/or system, its integrity and the specific relative position(s) of controls, control components, and other functional components. Examine any exhibited damage, exogenous debris, material, or item not present by design and any post-production modifications. In addition, note any missing components and any other characteristic of interest or value.

F. Check electrical, flow, or other appropriate continuity with a multimeter, pump, or other appropriate detection device(s). Make note of any relevant circuit, system, and/or fluid behavior. If residue is present (e.g., lubricant or fuel), preserve the material in place or collect it using appropriate safety precautions.

G. If the device is electrically activated, gradually apply input voltage until device activation or full-rated power is reached. Observe voltmeter, ammeter, and/or ohmmeter at various locations in circuits as necessary. Note the threshold voltage of activation if testing an audible alarm device.

H. If the device is flow-activated, pass gas through the device to detect any sources of leakage. Leakage in the pressurized device may be detected by submersion, audibly, or by spraying the pressurized portions of the item with soapy water[1] or other leak detection solution (e.g., Snoop®).

    1. If leakage is detected, measure the volume of escaping gas and note duration of collection (elapsed time). One method of doing this involves using a graduated cylinder which has been submerged then inverted over the leak.

    2. If no leak is detected, pressurize the system to its rated pressure and observe for leak(s) and/or proper functioning.

I. Summarize findings based on all collected data of value.

8 INSTRUMENTAL CONDITIONS

A. The instrumental conditions of optical and radiographic imaging systems are generally adjusted by the operator to achieve sufficient resolution for analysis.

B. Macro- and micro-photographs will contain a reference scale whenever feasible, however these are included for general reference and measurements will not be taken from the images.

9 ACCEPTANCE CRITERIA

9.1 Instrument Performance

Adequate function of any test or inspection equipment used will be demonstrated and recorded in the case notes.

9.2 Qualitative Evaluations

The conclusions derived from this procedure are based on careful interpretation of all of the information gathered from testing and investigation. A valid conclusion is one which reasonably explains the observations made during the various stages of examination. When more than one scenario may explain the observations, this will be noted in the report. In some cases, the

[1] The use of soap solutions may tend to remove any residues which may be present on the surfaces of the device.

proper functioning of a device is self-evident. In other instances, it is possible to infer the functioning (or malfunctioning) of a device based on an analysis of its physical remains. The uncertainty associated with such an analysis will depend strongly on the nature of the evidence submitted and the available factual information.

9.3 Quantitative Evaluations

When this procedure is used to assess a numerical limit associated with functionality, the technique used to detect the limit will be validated and measurement uncertainty will be estimated. When certified reference materials are not available for such determinations, the performance of commercial products can provide information to assess the adequacy of the procedure. Limitations will be recorded in the case notes and included in the *Laboratory Report*.

10 LIMITATIONS

The limitations of a particular functionality test are determined by the device condition and type, the available background information, and numerous other factors specific to the situation under consideration. Although specific limitations cannot be predicted within this procedure, any limitations encountered during functionality examinations will be recorded in the case notes, and, if appropriate, included in the *Laboratory Report*.

11 SAFETY

A. Wear an x-ray film badge or dosimeter when operating instruments that generate x-rays. The instruments have protective enclosures and internal safety interlocks to prevent inadvertent x-ray radiation exposure. Never bypass or disable safety interlocks on instruments.

B. Wear personal protective gear and use engineering controls that are appropriate for the task being performed (e.g., safety glasses when cutting and chemical fume hood when etching). Electrical or mechanical hazards may require special precautions (e.g., grounding to prevent electric shock or wearing a face guard to prevent impact from flying debris.) Review instrument technical procedures and pertinent material Safety Data Sheets (SDS) prior to conducting examinations. If additional guidance is required, contact the Laboratory Health and Safety Group.

12 REFERENCES

- Wolf, S., *Guide to Electronic Measurements and Laboratory Practice*, 2nd edition, Prentice-Hall, Inc. 1983
- Scatler, N., *Mechanisms and Mechanical Devices Sourcebook*, McGraw-Hill 2011
- Parmley, R. O., *Machine Devices and Components Illustrated Sourcebook*, McGraw-Hill 2004
- Oberg, E., Jones, F. D., Horton, H. L., and Ryffell, H. H., *Machinery's Handbook*, 25th Edition, Industrial Press Inc., 1996

13 REVISION HISTORY

Revision	Issued	Changes
06	09/15/2022	Revised to comply with new formatting requirements. Expanded description of acceptance criteria.