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# Standard Practice for Probability of Detection Analysis for Hit/Miss Data[1]

This standard is issued under the fixed designation E2862; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the procedure for performing a statistical analysis on nondestructive testing hit/miss data to determine the demonstrated probability of detection (POD) for a specific set of examination parameters. Topics covered include the standard hit/miss POD curve formulation, validation techniques, and correct interpretation of results.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E178 Practice for Dealing With Outlying Observations

E456 Terminology Relating to Quality and Statistics

E1316 Terminology for Nondestructive Examinations

E2586 Practice for Calculating and Using Basic Statistics

E3023 Practice for Probability of Detection Analysis for $\hat{a}$ Versus $a$ Data

E3080 Practice for Regression Analysis with a Single Predictor Variable

2.2 *Department of Defense Handbook:*

MIL-HDBK-1823A Nondestructive Evaluation System Reliability Assessment[3]

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *analyst, n*—the person responsible for performing a POD analysis on hit/miss data resulting from a POD examination.

3.2.2 *demonstrated probability of detection, n*—the calculated POD value resulting from the statistical analysis of the hit/miss data.

3.2.3 *false call, n*—the perceived detection of a discontinuity that is identified as a find during a POD examination when no discontinuity actually exists at the inspection site.

3.2.3.1 *Discussion*—A synonym for "false call" is "false positive."

3.2.4 *hit, n*—an existing discontinuity that is identified as a find during a POD demonstration examination.

3.2.5 *miss, n*—an existing discontinuity that is missed during a POD examination.

3.2.6 *probability of detection (POD), n*—the fraction of nominal discontinuity sizes expected to be found given their existence.

3.3 *Symbols:*

3.3.1 $a$—discontinuity size.

3.3.2 $a_p$—the discontinuity size that can be detected with probability $p$.

3.3.2.1 *Discussion*—Each discontinuity size has an independent probability of being detected and corresponding probability of being missed. For example, being able to detect a specific discontinuity size with probability $p$ does not guarantee that a larger size discontinuity will be found.

3.3.3 $a_{p/c}$—the discontinuity size that can be detected with probability $p$ with a statistical confidence level of $c$.

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.10 on Specialized NDT Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

3.3.3.1 *Discussion*—According to the formula in MIL-HDBK-1823A, $a_{p/c}$ is a one-sided upper confidence bound on $a_p$. $a_{p/c}$ represents how large the true $a_p$ could be given the statistical uncertainty associated with limited sample data. Hence $a_{p/c} > a_p$. Note that POD is equal to $p$ for both $a_{p/c}$ and $a_p$. $a_p$ is based solely on the hit/miss data resulting from the examination and represents a snapshot in time, whereas $a_{p/c}$ accounts for the uncertainty associated with limited sample data.

## 4. Summary of Practice

4.1 In general, the POD examination process is comprised of specimen set design, study design, examination administration, statistical analysis of examination data, documentation of analysis results, and specimen set maintenance. This practice is focused only on and describes step-by-step the process for analyzing nondestructive testing hit/miss data resulting from a POD examination and includes minimum requirements for validating the resulting POD curve and documenting the results.

4.2 This practice also includes definitions and discussions for results of interest (for example, $a_{90/95}$) to provide for correct interpretation of results.

4.3 Definitions of statistical terminology used in the body of this practice can be found in Annex A1.

4.4 A more general discussion of the POD analysis process can be found in Appendix X1.

4.5 An example POD analysis using simulated data can be found in Appendix X2.

4.6 A mathematical overview of the underlying model commonly used with hit/miss data resulting from a POD examination can be found in Appendix X3.

## 5. Significance and Use

5.1 The POD analysis method described herein is based on a well-known and well established statistical regression method. It shall be used to quantify the demonstrated POD for a specific set of examination parameters and known range of discontinuity sizes under the following conditions.

5.1.1 The initial response from a nondestructive evaluation inspection system is ultimately binary in nature (that is, hit or miss).

5.1.2 Discontinuity size is the predictor variable and can be accurately quantified.

5.1.3 A relationship between discontinuity size and POD exists and is best described by a generalized linear model with the appropriate link function for binary outcomes.

5.2 This practice does not limit the use of a generalized linear model with more than one predictor variable or other types of statistical models if justified as more appropriate for the hit/miss data.

5.3 If the initial response from a nondestructive evaluation inspection system is measurable and can be classified as a continuous variable (for example, data collected from an Eddy Current inspection system), then Practice E3023 may be more appropriate.

5.4 Prior to performing the analysis it is assumed that the discontinuity of interest is clearly defined; the number and distribution of induced discontinuity sizes in the POD specimen set is known and well-documented; discontinuities in the POD specimen set are unobstructed; and the POD examination administration procedure (including data collection method) is well-designed, well-defined, under control, and unbiased. The analysis results are only valid if convergence is achieved and the model adequately represents the data.

5.5 The POD analysis method described herein is consistent with the analysis method for binary data described in MIL-HDBK-1823A, and is included in several widely utilized POD software packages to perform a POD analysis on hit/miss data. It is also found in statistical software packages that have generalized linear modeling capability. This practice requires that the analyst has access to either POD software or other software with generalized linear modeling capability.

5.6 This practice does not apply to hit/miss data resulting from a POD examination based on the Point Estimate Method (PEM), also referred to as the "29 out of 29" method. (See X1.2.4.5 for more detail.)

## 6. Procedure

6.1 The POD analysis objective shall be clearly defined by the responsible engineer or by the customer.

6.2 The analyst shall obtain the hit/miss data resulting from the POD examination, which shall include at a minimum the documented known induced discontinuity sizes, whether or not the discontinuity was found, and any false calls.

6.3 The analyst shall also obtain specific information about the POD examination, which shall include at a minimum the specimen standard geometry (for example, flat panels), specimen standard material (for example, Nickel), examination date, number of inspectors, type of inspection method (for example, line-of-site Level 3 Sensitivity Fluorescent Penetrant Inspection), and pertinent comments from the inspector(s) and test administrator.

6.3.1 In general, the results of an experiment apply to the conditions under which the experiment was conducted. Hence, the POD analysis results apply to the conditions under which the POD examination was conducted.

6.4 Prior to performing the analysis, the analyst shall conduct a preliminary review of the POD examination procedure and resulting hit/miss data to identify any examination administration or data issues. The analyst shall identify and attempt to resolve any issues prior to conducting the POD analysis. Identified issues and their resolution shall be documented in the report. Examples of issues that could arise and possible resolutions are outlined in the following subsections:

6.4.1 If the examination procedure was poorly designed or executed, or both, the validity of the resulting data is questionable. In this case, the examination procedure design and execution should be reevaluated. For design guidelines see MIL-HDBK-1823A.