



Designation: E1245 – 03 (Reapproved 2023)

Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis¹

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INTRODUCTION

This practice may be used to produce stereological measurements that describe the amount, number, size, and spacing of the indigenous inclusions (sulfides and oxides) in steels. The method may also be applied to assess inclusions in other metals or to assess any discrete second-phase constituent in any material.

1. Scope

1.1 This practice describes a procedure for obtaining stereological measurements that describe basic characteristics of the morphology of indigenous inclusions in steels and other metals using automatic image analysis. The practice can be applied to provide such data for any discrete second phase.

NOTE 1—Stereological measurement methods are used in this practice to assess the average characteristics of inclusions or other second-phase particles on a longitudinal plane-of-polish. This information, by itself, does not produce a three-dimensional description of these constituents in space as deformation processes cause rotation and alignment of these constituents in a preferred manner. Development of such information requires measurements on three orthogonal planes and is beyond the scope of this practice.

1.2 This practice specifically addresses the problem of producing stereological data when the features of the constituents to be measured make attainment of statistically reliable data difficult.

1.3 This practice deals only with the recommended test methods and nothing in it should be construed as defining or establishing limits of acceptability.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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 This practice is under the jurisdiction of ASTM Committee E04 on Metallography and is the direct responsibility of Subcommittee E04.14 on Quantitative Metallography.

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1.6 *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

E3 Guide for Preparation of Metallographic Specimens

E7 Terminology Relating to Metallography

E45 Test Methods for Determining the Inclusion Content of Steel

E768 Guide for Preparing and Evaluating Specimens for Automatic Inclusion Assessment of Steel

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this practice, see Terminology E7.

3.2 Symbols:

$\bar{A}$	= the average area of inclusions or particles, μm^2 .
A_A	= the area fraction of the inclusion or constituent.
A_i	= the area of the detected feature.
A_T	= the measurement area (field area, mm^2).
H_T	= the total projected length in the hot-working direction of the inclusion or constituent in the field, μm .
$\bar{L}$	= the average length in the hot-working direction of the inclusion or constituent, μm .

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.

L_T	= the true length of scan lines, pixel lines, or grid lines (number of lines times the length of the lines divided by the magnification), mm.
n	= the number of fields measured.
N_A	= the number of inclusions or constituents of a given type per unit area, mm ² .
N_i	= the number of inclusions or constituent particles or the number of feature interceptions, in the field.
N_L	= the number of interceptions of inclusions or constituent particles per unit length (mm) of scan lines, pixel lines, or grid lines.
PP_i	= the number of detected picture points.
PP_T	= the total number of picture points in the field area.
s	= the standard deviation.
t	= a multiplier related to the number of fields examined and used in conjunction with the standard deviation of the measurements to determine the 95 % CI
V_V	= the volume fraction.
$\bar{X}$	= the mean of a measurement.
X_i	= an individual measurement.
λ	= the mean free path (μm) of the inclusion or constituent type perpendicular to the hot-working direction.
$\sum X$	= the sum of all of a particular measurement over n fields.
$\sum X^2$	= the sum of all of the squares of a particular measurement over n fields.
95 % CI	= the 95 % confidence interval.
% RA	= the relative accuracy, %.

4. Summary of Practice

4.1 The indigenous inclusions or second-phase constituents in steels and other metals are viewed with a light microscope or a scanning electron microscope using a suitably prepared metallographic specimen. The image is detected using a television-type scanner tube (solid-state or tube camera) and displayed on a high resolution video monitor. Inclusions are detected and discriminated based on their gray-level intensity differences compared to each other and the unetched matrix. Measurements are made based on the nature of the discriminated picture point elements in the image.³ These measurements are made on each field of view selected. Statistical evaluation of the measurement data is based on the field-to-field or feature-to-feature variability of the measurements.

5. Significance and Use

5.1 This practice is used to assess the indigenous inclusions or second-phase constituents of metals using basic stereological procedures performed by automatic image analyzers.

5.2 This practice is not suitable for assessing the exogenous inclusions in steels and other metals. Because of the sporadic, unpredictable nature of the distribution of exogenous inclusions, other methods involving complete inspection, for

example, ultrasonics, must be used to locate their presence. The exact nature of the exogenous material can then be determined by sectioning into the suspect region followed by serial, step-wise grinding to expose the exogenous matter for identification and individual measurement. Direct size measurement rather than application of stereological methods is employed.

5.3 Because the characteristics of the indigenous inclusion population vary within a given lot of material due to the influence of compositional fluctuations, solidification conditions and processing, the lot must be sampled statistically to assess its inclusion content. The largest lot sampled is the heat lot but smaller lots, for example, the product of an ingot, within the heat may be sampled as a separate lot. The sampling of a given lot must be adequate for the lot size and characteristics.

5.4 The practice is suitable for assessment of the indigenous inclusions in any steel (or other metal) product regardless of its size or shape as long as enough different fields can be measured to obtain reasonable statistical confidence in the data. Because the specifics of the manufacture of the product do influence the morphological characteristics of the inclusions, the report should state the relevant manufacturing details, that is, data regarding the deformation history of the product.

5.5 To compare the inclusion measurement results from different lots of the same or similar types of steels, or other metals, a standard sampling scheme should be adopted such as described in Test Methods E45.

5.6 The test measurement procedures are based on the statistically exact mathematical relationships of stereology⁴ for planar surfaces through a three-dimensional object examined using reflected light (see Note 1).

5.7 The orientation of the sectioning plane relative to the hot-working axis of the product will influence test results. In general, a longitudinally oriented test specimen surface is employed in order to assess the degree of elongation of the malleable (that is, deformable) inclusions.

5.8 Oxide inclusion measurements for cast metals, or for wrought sections that are not fully consolidated, may be biased by partial or complete detection of fine porosity or microshrinkage cavities and are not recommended. Sulfides can be discriminated from such voids in most instances and such measurements may be performed.

5.9 Results of such measurements may be used to qualify material for shipment according to agreed upon guidelines between purchaser and manufacturer, for comparison of different manufacturing processes or process variations, or to provide data for structure-property-behavior studies.

6. Interferences

6.1 Voids in the metal due to solidification, limited hot ductility, or improper hot working practices may be detected as oxides because their gray level range is similar to that of oxides.

³ Vander Voort, G. F., "Image Analysis," Vol 10, 9th ed., *Metals Handbook: Materials Characterization*, ASM, Metals Park, OH, 1986, pp. 309–322.

⁴ Underwood, E. E., *Quantitative Stereology*, Addison-Wesley Publishing Co., Reading, MA, 1970.