Designation: G 73 – 98

Standard Practice for Liquid Impingement Erosion Testing[1]

This standard is issued under the fixed designation G 73; 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 concerns tests in which solid specimens are eroded or otherwise damaged by repeated discrete impacts of liquid drops or jets. Among the collateral forms of damage considered are degradation of optical properties of window materials, and penetration, separation, or destruction of coatings. The objective of the tests may be to determine the resistance to erosion or other damage of the materials or coatings under test, or to investigate the damage mechanisms and the effect of test variables. Because of the specialized nature of these tests and the desire in many cases to simulate to some degree the expected service environment, the promulgation of a method is not deemed practicable. This practice gives guidance in setting up a test, and specifies test and analysis procedures and reporting requirements that can be followed even with quite widely differing materials, test facilities, and test conditions. It also provides a standardized scale of erosion resistance numbers applicable to metals and other structural materials.

1.2 The values stated in SI units are to be regarded as standard. The inch-pound units in parentheses are provided for information.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[2]

E 92 Test Method for Vickers Hardness of Metallic Materials[3]

E 140 Hardness Conversion Tables for Metals (Relationship Between Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, and Knoop Hardness)[3]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[4]

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials[5]

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens[6]

G 32 Test Method for Cavitation Erosion Using Vibratory Apparatus[6]

G 40 Terminology Relating to Wear and Erosion[6]

G 134 Test Method for Erosion of Solid Materials by a Cavitating Liquid Jet[6]

2.2 *Military Standards:*

MIL-C-83231 Coatings, Polyurethane, Rain Erosion Resistance for Exterior Aircraft and Missile Plastic Parts[7]

MIL-P-8184 Plastic Sheet, Acrylic, Modified[7]

3. Terminology

3.1 See Terminology G 40 for definitions of terms relating to erosion by liquids and solids. Important terms used in this practice, or that might be used in a test report following this practice, are defined in either 3.2 or 3.3. Definitions of selected terms quoted from Terminology G 40 are listed in 3.2. Definitions of terms specific to this practice are presented in 3.3.

3.2 *Definitions*—All definitions listed below are quoted from Terminology G 40 – 98.

3.2.1 *acceleration period*, *n*— *in cavitation and liquid impingement erosion*, the stage following the incubation period, during which the erosion rate increases from near zero to a maximum value. (See also *erosion rate-time*.)

3.2.2 *angle of incidence*, *n*— *in impingement erosion*, the angle between the direction of motion of an impinging liquid or solid particle and the normal to the surface at the point of impact.

[1] This practice is under the jurisdiction of ASTM Committee G-2 on Wear and Erosion and is the direct responsibility of Subcommittee G02.10 on Erosion by Solids and Liquids.

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[2] *Annual Book of ASTM Standards,* Vol 08.01.

[3] *Annual Book of ASTM Standards,* Vol 03.01.

[4] *Annual Book of ASTM Standards,* Vol 14.02.

[5] *Annual Book of ASTM Standards,* Vol 06.01.

[6] *Annual Book of ASTM Standards,* Vol 03.02.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.2.3 *attenuation period*, *n— in cavitation and liquid impingement erosion*, a less-preferred term for *deceleration period.*

3.2.4 *catastrophic period*, *n— in cavitation or liquid impingement erosion*, a stage during which the erosion rate increases so drastically that continued exposure threatens or causes gross disintegration of the exposed surface. This stage is not inevitable; it is observed most commonly with some brittle materials. When it does occur, it may begin during any stage of the more common erosion rate-time pattern.

3.2.5 *cumulative erosion*, *n— in cavitation and impingement erosion*, the total amount of material lost from a solid surface during all exposure periods since it was first exposed to cavitation or impingement as a newly finished surface. (More specific terms that may be used are *cumulative mass loss*, *cumulative volume loss*, or *cumulative mean depth of erosion*. See also *cumulative erosion-time curve*.)

3.2.5.1 *Discussion*—Unless otherwise indicated by the context, it is implied that the conditions of cavitation or impingement have remained the same throughout all exposure periods, with no intermediate refinishing of the surface.

3.2.6 *cumulative erosion-time curve*, *n—in cavitation and impingement erosion*, a plot of cumulative erosion versus cumulative exposure duration, usually determined by periodic interruption of the test and weighing of the specimen. This is the primary record of an erosion test. Most other characteristics, such as the incubation period, maximum erosion rate, terminal erosion rate, and erosion rate-time curve, are derived from it.

3.2.7 *damage*, *n—in cavitation or impingement*, any effect on a solid body resulting from its exposure to these phenomena. This may include loss of material, surface deformation, or any other changes in microstructure, properties, or appearance.

3.2.7.1 *Discussion*—This term as here defined should normally be used with the appropriate modifier, for example, "cavitation damage," "liquid impingement damage," "single-impact damage," and so forth.

3.2.8 *deceleration period*, *n— in cavitation or liquid impingement erosion*, the stage following the acceleration period or the maximum rate period (if any), during which the erosion rate has an overall decreasing trend although fluctuations may be superimposed on it. (See also *erosion rate—time pattern*.)

3.2.9 *distributed impact test*, *n— in impingement erosion testing*, an apparatus or method that produces a spatial distribution of impacts by liquid or solid bodies over an exposed surface of a specimen.

3.2.9.1 *Discussion*—Examples of such tests are those employing liquid sprays or simulated rainfields. If the impacts are distributed uniformly over the surface, the term "uniformly distributed impact test" may be used. (Contrast with *repetitive impact erosion test*.)

3.2.10 *erosion*, *n—in tribology*, progressive loss of original material from a solid surface due to mechanical interaction between that surface and a fluid, a multicomponent fluid, or impinging liquid or solid particles.

3.2.10.1 *Discussion*—Because of the broad scope of this term, it is recommended that it normally be qualified to indicate the relevant mechanism or context, for example, cavitation erosion, liquid impingement erosion, solid impingement erosion, beach erosion, etc.

3.2.11 *erosion rate*, *n*—any determination of the rate of loss of material (erosion) with exposure duration. (See also *rationalized erosion rate.*)

3.2.11.1 *Discussion*—Erosion rate is usually determined as a slope on the cumulative erosion-time curve. Since in cavitation or liquid impingement this curve is generally not a straight line, it is necessary to specify how any particular numerical value was determined from this curve. The following more explicit terms may be used: average erosion rate, instantaneous erosion rate, interval erosion rate, maximum erosion rate, and terminal erosion rate. See individual definitions of these terms.

3.2.12 *erosion rate-time curve*, *n*—a plot of instantaneous erosion rate versus exposure duration, usually obtained by numerical or graphical differentiation of the cumulative erosion-time curve. (See also *erosion rate-time pattern*.)

3.2.13 *erosion rate-time pattern*, *n*—any qualitative description of the shape of the erosion rate-time curve, in terms of the several stages of which it may be composed.

3.2.13.1 *Discussion*—In cavitation and liquid impingement erosion, a typical pattern may be composed of all or some of the following "periods" or "stages": *incubation period, acceleration period, maximum-rate period, deceleration period, terminal period,* and occasionally *catastrophic period.* The generic term" period" is recommended when associated with quantitative measures of its duration, etc.; for purely qualitative descriptions the term "stage" is preferred.

3.2.14 *exposure duration*, *n— in erosion or wear*, exposure time, or any other appropriate measure of the accumulation of exposure to an erosion or wear environment.

3.2.14.1 *Discussion*—For impingement erosion, some alternative duration parameters are the number of impacts that have occurred on a given point, or the mass or volume of particles that have impinged on a unit area of exposed surface. For wear, it may be the distance traveled.

3.2.15 *impact velocity*, *n— in impingement erosion*, the relative velocity between the surface of a solid body and an impinging liquid or solid particle.

3.2.15.1 *Discussion*—To describe this velocity completely, it is necessary to specify the direction of motion of the particle relative to the solid surface in addition to the magnitude of the velocity. The following related terms are also in use:

(1) absolute impact velocity—the magnitude of the impact velocity.

(2) normal impact velocity—the component of the impact velocity that is perpendicular to the surface of the test solid at the point of impact.

3.2.16 *impingement*, *n— in tribology*, a process resulting in a continuing succession of impacts between (liquid or solid) particles and a solid surface.

3.2.16.1 *Discussion*—In preferred usage, "impingement" also connotes that the impacting particles are smaller than the solid surface, and that the impacts are distributed over that surface or a portion of it. If all impacts are superimposed on the same point or zone, then the term" repeated impact" is preferred.

3.2.16.2 *Discussion*—In other contexts, the term "impingement" sometimes has different meanings, as in the steady-state impingement of a liquid stream against a solid body, or in "impingement corrosion." The definition given here applies in the context of Committee G-2's scope.

3.2.17 *impingement corrosion*, *n*—a form of erosion-corrosion generally associated with the impingement of a high-velocity, flowing liquid containing air bubbles against a solid surface.

3.2.18 *incubation period*, *n— in cavitation and impingement erosion*, the initial stage of the erosion rate-time pattern during which the erosion rate is zero or negligible compared to later stages. Also, the exposure duration associated with this stage. (Quantitatively it is sometimes defined as the intercept on the time or exposure axis, of a straight line extension of the maximum-slope portion of the cumulative erosion-time curve.)

3.2.19 *instantaneous erosion rate*, *n*—the slope of a tangent to the cumulative erosion-time curve at a specified point on that curve.

3.2.20 *liquid impingement erosion*, *n*—progressive loss of original material from a solid surface due to continued exposure to impacts by liquid drops or jets.

3.2.21 *liquid jet*, *n*—a body of liquid projected into motion, usually of approximately cylindrical shape, such as could be produced by discharging the liquid through an orifice. In liquid impingement testing two kinds of liquid jet are used:

3.2.21.1 *continuous jet*—a continuous flow of liquid in the form of a jet.

3.2.21.2 *slug, or jet segment*—a body of liquid projected into motion, in the form approximately of a finite cylinder whose length is usually no more than several times its diameter and which moves in a direction approximately parallel to its length.

3.2.22 *maximum erosion rate*, *n— in cavitation and liquid impingement*, the maximum instantaneous erosion rate in a test that exhibits such a maximum followed by decreasing erosion rates. (See also *erosion rate–time pattern*.)

3.2.22.1 *Discussion*—Occurrence of such a maximum is typical of many cavitation and liquid impingement tests. In some instances it occurs as an instantaneous maximum, in others as a steady-state maximum which persists for some time.

3.2.23 *maximum rate period*, *n— in cavitation and liquid impingement erosion*, a stage following the acceleration period, during which the erosion rate remains constant (or nearly so) at its maximum value. (See also *erosion rate–time pattern*.)

3.2.24 *mean depth of erosion*, *n— in cavitation and impingement erosion*, the average thickness of material eroded from a specified surface area, usually calculated by dividing the measured mass loss by the density of the material to obtain the volume loss and dividing that by the area of the specified surface. (Also known as *mean depth of penetration* or *MDP*. Since that might be taken to denote the average value of the depths of individual pits, it is a less-preferred term.)

3.2.25 *normal impact velocity*—See *impact velocity.*

3.2.26 *normalized erosion resistance,* N_e, *n*—the volume loss rate of a test material, divided into the volume loss rate of a specified reference material similarly tested and similarly analyzed. By "similarly analyzed" is meant that the two erosion rates must be determined for corresponding portions of the erosion rate-time pattern; for instance, the maximum erosion rate or the terminal erosion rate.

3.2.26.1 *Discussion*—A recommended complete wording has the form, "The normalized erosion resistance of (test material) relative to (reference material) based on (criterion of data analysis) is (numerical value)."

3.2.27 *normalized incubation resistance,* N_0, *n—in cavitation and liquid impingement erosion*, the incubation period of a test material, divided by the incubation period of a specified reference material similarly tested and similarly analyzed. (See also *normalized erosion resistance*.)

3.2.28 *rationalized erosion rate*, *n*—an erosion rate for impingement tests expressed in dimensionless form as follows: the volume of material lost per unit volume of (liquid or solid) particles impinging, both determined for the same area.

3.2.29 *repetitive impact erosion test*, *n—in impingement erosion testing*, an apparatus or method that produces a controlled or countable number of impacts by liquid or solid particles, of uniform size, shape, and impact velocity, all on the same location of the test specimen. One example of such a test is the "wheel-and-jet" type of liquid impact apparatus.

3.2.30 *terminal erosion rate*, *n— in cavitation or liquid impingement*, the final steady-state erosion rate that is reached (or appears to be approached asymptotically) after the erosion rate has declined from its maximum value. (See also *terminal period* and *erosion rate–time pattern*.)

3.2.31 *terminal period*, *n— in cavitation or liquid impingement erosion*, a stage following the deceleration period, during which the erosion rate has levelled off and remains approximately constant (sometimes with superimposed fluctuations) at a value substantially lower than the maximum rate attained earlier. This occurs in some, but not all, cavitation and liquid impingement tests. (See also *erosion rate–time pattern*.)

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *apparatus severity factor, F*—an empirical factor that accounts for the systematic differences between rationalized erosion rates (or rationalized incubation periods) as determined for the same material and impact velocity in different facilities. It reflects variations in test conditions not accounted for by the data reduction procedures of this practice.

3.3.2 *erosion resistance number,* NER—the normalized erosion resistance of a test material relative to a standardized scale, calculated from test results with one or more designated reference materials as described in this practice. See also reference erosion resistance (3.3.13).

3.3.3 *exposed surface (or area)*—that surface (or area) on the specimen nominally subjected to liquid impingement.

(1) For "distributed impact tests," it is generally to be taken as the projected area of the exposed surface of the specimen on a plane perpendicular to the direction of impingement. However, if a plane specimen surface is deliberately oriented so as to obtain impingement at an oblique angle, then the actual plane area is used.

(2) For "repetitive impact tests," it is to be taken as the projected area of the impinging liquid bodies on the specimen, the projection being taken in the direction of relative motion.