



Designation: G 73 – 98

Standard Practice for Liquid Impingement Erosion Testing¹

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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

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 Plastics²
- E 92 Test Method for Vickers Hardness of Metallic Materials³
- 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 Methods⁴

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials⁵

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens⁶

G 32 Test Method for Cavitation Erosion Using Vibratory Apparatus⁶

G 40 Terminology Relating to Wear and Erosion⁶

G 134 Test Method for Erosion of Solid Materials by a Cavitating Liquid Jet⁶

2.2 Military Standards:

MIL-C-83231 Coatings, Polyurethane, Rain Erosion Resistance for Exterior Aircraft and Missile Plastic Parts⁷

MIL-P-8184 Plastic Sheet, Acrylic, Modified⁷

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_0 , 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.

3.3.3.1 *Discussion*—In practice, it is usually found that the damaged area in repetitive impact tests is greater than the exposed area as defined above, but the above definition is adopted not only for simplicity but also for consistency between some of the other calculations for distributed and repetitive tests.

3.3.4 *impingement rate*, U_i [LT^{-1}]*—*the volume of liquid impinging per unit time on a unit area of exposed surface; for a plane target surface it is given by $\psi V \cos \theta$.

3.3.5 *incubation impingement*, H_0 [L]*—*the mean cumulative impingement corresponding to the incubation period; hence, impingement rate times incubation time.

3.3.6 *incubation resistance number*, NOR*—*the normalized incubation 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 incubation resistance (3.3.14).

3.3.7 *incubation specific impacts*, N_0 *—*same as rationalized incubation period.

3.3.8 *mean cumulative impingement*, H [L]*—*the cumulative volume of liquid impinged per unit area of exposed surface; impingement rate times exposure time.

3.3.9 *rationalized erosion rate*, R_e *—*See 3.2.

3.3.10 *rationalized incubation period*, N_0 *—*the duration of the incubation period expressed in dimensionless terms as the number of specific impacts; hence, the specific impact frequency times incubation time. (Also referred to as "incubation specific impacts.")

3.3.11 *reference erosion resistance*, S_{er} *—*a normalized erosion resistance, based on interlaboratory test results, assigned to a specified reference material in this practice so as to constitute a bench-mark in the "erosion resistance number" scale. The value of unity is assigned to 316 stainless steel of hardness 155 to 170 HV.

3.3.12 *reference incubation resistance*, S_{or} *—*a normalized incubation resistance, based on interlaboratory test results, assigned to a specific reference material in this practice so as to constitute a bench-mark in the "incubation resistance number" scale. The value of unity is assigned to 316 stainless steel of hardness 155 to 170 HV.

3.3.13 *specific impacts*, N *—*the number of impact stress cycles of damaging magnitude experienced by a typical point on the exposed surface, or an approximation thereof as estimated on the basis of simplified assumptions as described in this practice. (This concept has sometimes been termed "impacts per site.")

3.3.14 *specific impact frequency*, f_i [T^{-1}]*—*the number of specific impacts experienced per unit time, given by $(a/b) U_i$.

3.3.15 *volume concentration*, ψ *—*the ratio of the volume of liquid to the total volume in the path traversed or swept out by the exposed area of the specimen.

3.3.16 *volume mean diameter* [L]*—*in a population of drops of different sizes, the diameter of a sphere whose volume equals the total volume of all drops divided by the total number of drops.

3.4 Symbols: Symbols:

A	= exposed area of specimen, m^2 ,
a	= projected area of impinging drop or jet, m^2 ,
b	= volume of impinging drop or jet, m^3 ,

d	= diameter of impinging drop or jet, m,
F_0	= apparatus severity factor for incubation,
F_e	= apparatus severity factor for erosion rate,
f_i	= specific impact frequency, s^{-1} ,
H	= mean cumulative impingement, m,
H_0	= incubation impingement, m,
N_0	= number of specific impacts for incubation, or "rationalized, incubation period," dimensionless,
NER	= erosion resistance number,
NOR	= incubation resistance number,
n	= number of jets or drops impacting on exposed surface of specimen in one revolution,
Q_e	= volumetric erosion rate, m^3/s ,
R_e	= "rationalized erosion rate," (dY/dH) , dimensionless,
S_e	= normalized erosion resistance (relative to a specified reference material),
S_{er}	= reference erosion resistance,
S_0	= normalized incubation resistance (relative to a specified reference material),
S_{or}	= reference incubation resistance,
t	= exposure time, s,
t_0	= incubation time, s,
U_e	= linear erosion rate (dY/dt) , $\text{m/s} = Q_e/A$,
U_i	= impingement rate (dH/dt) , m/s ,
U_r	= rainfall rate, m/s ,
U_t	= terminal velocity of drops in falling rainfield, m/s ,
V	= impact velocity of drop or jet relative to specimen, m/s ,
V_n	= component of impact velocity normal to specimen surface, m/s ,
Y	= mean depth of erosion, m,
θ	= angle of incidence of impacts (see 3.2),
ψ	= volume concentration of liquid in rainfield or in space swept through by specimen, and
Ω	= rotational speed of specimens, rev/s .

3.5 Except in equations where different units are expressly specified, the use of SI units listed in 3.4—or any other coherent system of units—will make equations correct without the need of additional numerical factors. When referring to quantities in text, tables, or figures, suitable multiples or submultiples of these units may, of course, be used.

4. Summary of Practice

4.1 Liquid impingement tests are usually, but not always, conducted by attaching specimens to a rotating disk or arm, such that in their circular path they repeatedly pass through and impact against liquid sprays or jets (Sections 6 and 7). Standard reference materials (Section 8) should be used to calibrate the apparatus and included in all test programs.

4.2 Data analysis begins by establishing a cumulative erosion-time curve from measurements of mass loss (or other damage manifestation) periodically during the tests (Section 9). These curves are then characterized by specified attributes such as the incubation time and the maximum erosion rate (Section 10).

4.3 For comparative materials evaluations, the results are normalized (Section 10) with respect to the standard reference materials included in the test program. A standardized scale of "erosion resistance numbers" is provided for structural bulk materials and coatings (10.4.3). For more in-depth analysis of the results, the incubation times or erosion rates are expressed in dimensionless "rationalized" forms that are based on more physically meaningful exposure duration variables than clock time as such (Section 11).

4.4 The information to be given in the report depends on the objectives of the test (Section 12).

5. Significance and Use

5.1 Erosion Environments—This practice may be used for evaluating the erosion resistance of materials for service environments where solid surfaces are subjected to repeated impacts by liquid drops or jets, or are exposed to a cavitating liquid. The practice is *not* intended nor applicable for evaluating or predicting the resistance of materials against erosion due to solid particle impingement, due to “impingement corrosion” in bubbly flows, due to liquids or slurries “washing” over a surface, or due to continuous high-velocity liquid jets aimed at a surface. For background on various forms of erosion and erosion tests, see Refs (1) through (7).⁸ Reference (6) is an excellent comprehensive treatise.

5.2 Discussion of Erosion Resistance— Liquid impingement erosion and cavitation erosion are, broadly speaking, similar processes and the relative resistance of materials to them is similar. In both, the damage is associated with repeated, small-scale, high-intensity pressure pulses acting on the solid surface. The precise failure mechanisms in the solid have been shown to differ depending on the material, and on the detailed nature, scale, and intensity of the fluid-solid interactions (Note 1). Thus, “erosion resistance” should not be regarded as one precisely-definable property of a material, but rather as a complex of properties whose relative importance may differ depending on the variables just mentioned. (It has not yet been possible to successfully correlate erosion resistance with any independently measurable material property.) For these reasons, the consistency between relative erosion resistance as measured in different facilities or under different conditions is not very good. Differences between two materials of say 20 % or less are probably not significant: another test might well show them ranked in reverse order. For bulk materials such as metals and structural plastics, the range of erosion resistances is much greater than that of typical strength properties: On a normalized scale on which Type 316 stainless steel is given a value of unity, the most resistant materials (some Stellites and tool steels) may have values greater than 10, and the least resistant (soft aluminum, some plastics) values less than 0.1 (see Refs (7) and (8)).

NOTE 1—On failure mechanisms in particular, see in Ref (6) under “The Mechanics of Liquid Impact” by W. F. Adler, “Erosion of Solid Surfaces by the Impact of Liquid Drops” by J. H. Brunton and M. C. Rochester, and “Cavitation Erosion” by C. M. Preece.

5.3 Significance of the Variation of Erosion Rate with Time:

5.3.1 The rate of erosion due to liquid impact or cavitation is not constant with time, but exhibits one of several “erosion rate-time patterns” discussed more fully in 10.3.3. The most common pattern consists of an “incubation period” during which material loss is slight or absent, followed by an acceleration of erosion rate to a maximum value, in turn followed by a declining erosion rate which may or may not tend to a “terminal” steady-state rate. The significance of the various stages in this history can differ according to the intended service applications of the materials being tested. In

almost no case, however, are significant results obtained by simply testing all materials for the same length of time and comparing their cumulative mass loss.

5.3.2 The “incubation period” may be the most significant test result for window materials, coatings, and other applications for which the useful service life is terminated by initial surface damage even though mass loss is slight.

5.3.3 For bulk materials, this practice provides for determination of the “incubation period” as well as the “maximum erosion rate,” and material ratings based on each. Empirical relationships are given in Annex A2 by which the incubation period and the maximum erosion rate can then be estimated for any liquid impingement conditions in which the principal impingement variables are known. It must be emphasized, however, that because of the previously described variation of erosion rate with exposure time, the above-mentioned parameters do not suffice to predict erosion for long exposure durations. Extrapolation based on the maximum erosion rate could over-estimate the absolute magnitude of long-term cumulative erosion by a factor exceeding an order of magnitude. In addition, it could incorrectly predict the relative difference between long-term results for different materials.

5.3.4 Because of these considerations, some experimenters concerned with long-life components may wish to base material ratings not on the maximum erosion rate, but on the lower “terminal erosion rate” if such is exhibited in the tests. This can be done while still following this practice in many respects, but it should be recognized that the terminal erosion rate is probably more strongly affected by secondary variables such as test specimen shape, “repetitive” versus “distributed” impact conditions, drop size distributions, etc., than is the maximum erosion rate. Thus, between-laboratories variability may be even poorer for results based on terminal erosion rate, and the test time required will be much greater.

5.4 This practice is applicable for impact velocities ranging roughly from 60 m/s to 600 m/s; it should not be assumed that results obtained in that range are valid at much higher or lower velocities. At very low impact velocities, corrosion effects become increasingly important. At very high velocities the material removal processes can change markedly, and specimen temperature may also become a significant factor; testing should then be done *at* the velocities corresponding to the service environment.

5.5 Related Test Methods—Since the resistances of materials to liquid impingement erosion and to cavitation erosion have been considered related properties, cavitation erosion Test Methods G 32 and G 134 may be considered as alternative tests to this practice for some applications. For metals, the relative results from Test Method G 32 or G 134 should be similar but not necessarily identical to those from a liquid impact test (see 5.2). Either Test Method G 32 or G 134 may be less expensive than an impingement test, and provides for standardized specimens and test conditions, but may not match the characteristics of the impingement environment to be simulated. The advantages of a liquid impingement test are that droplet or jet sizes and impact velocities can be selected and it can simulate more closely a specific liquid impingement environment. A well-designed liquid impingement test is to be preferred for

⁸ The boldface numbers in parentheses refer to the list of references at the end of this practice.

elastomers, coatings, and brittle materials, for which size effects may be quite important.

6. Apparatus

6.1 This practice is applicable principally to those erosion test devices in which one or more specimens are attached to the periphery of a rotating disk or arm, and their circular path passes through one or more liquid jets or sprays, causing discrete impacts between the specimen and the droplets or the cylindrical surface of the jets (Note 2). Fig. 1 and Fig. 2 show two representative devices of very different size and speed. Considerations relating to the specimens and their attachment are covered in Section 7.

NOTE 2—Some representative rotating apparatus are described in Ref (2) by Ripken (pp. 3–21) and Hoff et al (pp. 42–69); in Ref. (3) by Elliott et al (pp. 127–161) and Thiruvengadam (pp. 249–287); and by A. A. Fyall in “Radome Engineering Handbook,” J. D. Walton, editor, Marcel Dekker, Inc., New York, NY, 1970, pp. 461–572.

6.2 A distinction is made between “distributed impact tests” and “repetitive impact tests.” Devices using sprays or simulated rainfields fall into the first category, and most using jets into the second.

NOTE 3—Repetitive impact tests, as compared to distributed impact tests, generally provide much higher specific impact frequencies and have higher severity factors (see 6.5), thus producing erosion more rapidly at equal impact velocities. However, because the damage is localized at a line or point on the specimen, the topography and progress of damage differs somewhat from that in distributed impact tests or under most typical service conditions.

6.3 Test devices of the types described above have been built for peripheral velocities (and hence impact velocities) from about 50 m/s to as high as 1000 m/s. The higher velocities pose considerable difficulties relating to power requirements,

aerodynamic heating and noise, and balancing. Partial evacuation of the test chamber may be required. At the intended operating speeds it should be possible to maintain the speed steady within 0.5 %, and to measure it within 0.1 %.

6.4 Droplet or jet diameters have ranged from around 0.1 mm to about 5 mm. Droplets may be generated by spray nozzles, vibrating hollow needles, or rotating disks with water fed onto their surface. The typical droplet or jet diameter, and the volume of liquid actually impacting the specimen per unit time, should be determined within 10 %. For jets, the diameter can usually be assumed to equal the nozzle diameter. However, photographic verification is desirable since jets may exhibit instabilities under some conditions. With drops, there will usually be a size distribution, and in most cases it will be necessary to determine that distribution by photography and analysis of the photographs. Some dropgenerating techniques, such as vibrating needles, provide more uniform drop sizes than sprays. For a single-number characterization, the *volume mean diameter* should be used, so as to obtain the correct relationship between total volume and total number of drops. Ideally, the apparatus should be characterized by the drop population per unit volume in the path traversed by the specimen, and the repeatability thereof, as a function of test settings. From this, the impingement rate and specific impact frequency, needed for Section 11, can then be readily determined.

6.5 Even when erosion test results are “rationalized” (see Section 11) by taking into account the amount of liquid impacting the specimen, there will still be systematic differences from one apparatus to another. These are represented by the “apparatus severity factors,” which can be calculated from test results by equations given in 11.5, and can be estimated in the design stage as shown in Annex A2. This can help in

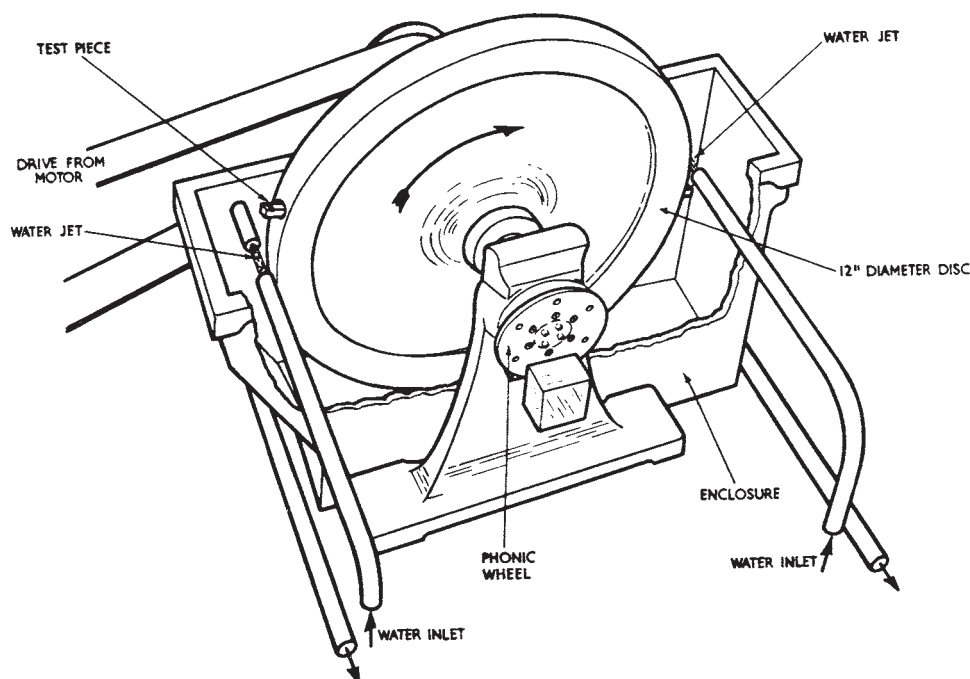


FIG. 1 An Example of a Small, Relatively Low-Speed, Rotating Disk-and-Jet Repetitive Impact Apparatus (Courtesy of National Engineering Laboratory, East Kilbride, Scotland, UK)