



# Standard Test Method for Drop Weight Impact Sensitivity of Solid-Phase Hazardous Materials<sup>1</sup>

This standard is issued under the fixed designation E680; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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<sup>ε1</sup> NOTE—Editorial corrections were made to the format of the Warning notes in August 2011.

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## INTRODUCTION

This test method is one of several test methods being developed by ASTM Committee E27 on Hazard Potential of Chemicals. This test method is to be used in conjunction with other tests to characterize the hazard potential of chemicals.

### 1. Scope

1.1 This test method<sup>2, 3</sup> is designed to determine the relative sensitivities of solid-phase hazardous materials to drop weight impact stimulus. For liquid-phase materials refer to Test Method **D2540**.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

- 2.1 *ASTM Standards*:<sup>4</sup>  
**D2540 Test Method for Drop-Weight Sensitivity of Liquid Monopropellants** (Withdrawn 2003)<sup>5</sup>

### 3. Summary of Test Method

3.1 Restrictions are placed upon the ranges of impact tool masses and striking surface diameters that may be used, and a

standard sample thickness is prescribed for all tests.<sup>6</sup> In addition, procedures for sample preparation and treatment, as well as procedures for detecting reactions through the use of the human senses, are outlined.

3.2 Drop-weight impact tests are to be performed using the well-known Bruceton up-and-down method.<sup>7, 8</sup>

3.3 Outlined is a method for normalizing data generated on different impact apparatus.

### 4. Significance and Use

4.1 This test method does not require an overall rigid standardization of the apparatus. Samples are tested either unconfined or confined in confinement cups. For confined tests, some of the important cup parameters, such as cup material, cup wall thickness, and fit between the cup and the striking pin, are standardized. Data generated from unconfined and confined tests will not, in general, exhibit the same relative scale of sensitivities, and must be identified as confined or unconfined data and compared separately.

4.2 This test method applies to all testing where the intent is to establish a relative sensitivity scale for hazardous materials. It is not intended to prohibit testing process-thickness samples nor prohibit the use of other than standard tool masses and striking diameters to generate data for special purposes or for

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<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.02 on Thermal Stability and Condensed Phases.

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<sup>2</sup> This test method is a modification of and contains concepts proposed by Hercules, Inc. personnel at Allegheny Ballistics Laboratory. The method was outlined by personnel of Pittsburgh Mining and Safety Research Center, Bureau of Mines, Pittsburgh, Pa. For additional information see Footnote 3.

<sup>3</sup> Smith, D., and Richardson, R.H., "Interpretation of Impact Sensitivity Test Data," *Pyrodynamics*, PYDYA, Vol 6, 1968, pp. 159–178.

<sup>4</sup> 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.

<sup>5</sup> The last approved version of this historical standard is referenced on www.astm.org.

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<sup>6</sup> Becker, K.R., and Watson, R.W., "A Critique for Drop Weight Impact Testing," Proceedings of the Conference on the Standardization of Safety and Performance Tests for Energetic Materials, Vol 1, September 1977, pp. 415–430. Publication ARLCD-SP-77004, U. S. Army Armament Research and Development Command, Dover, N.J.

<sup>7</sup> Dixon, W. J., and Massey, F. J. Jr., *Introduction to Statistical Analysis*, McGraw-Hill Book Co., Inc., 1957, pp. 319–327.

<sup>8</sup> Statistical Research Group, Princeton University, "Statistical Analysis for a New Procedure in Sensitivity Experiments," AMP Report No. 101.1R, SRG-P, No. 40, Submitted to Applied Mathematics Panel, National Defense Research Committee, July 1944, p. 58.

in-house comparisons. In addition, the test method is not intended to restrict the generation of results at other than the  $H_{50}$  point as may be desirable for hazard analysis techniques.

4.3 The normalized data will serve as a measure of the relative sensitivities of hazardous materials at the 50 % probability of reaction level. The normalized  $H_{50}$  values can also be used in conjunction with additional data relating to other probability of reaction levels (not a part of this test method) to assess hazards associated with the manufacture, transportation, storage, and use of hazardous materials.

## 5. Definitions

5.1  $H_{50}$  value—a drop height with a 50 % probability of reaction, as determined experimentally by the Bruceton up-and-down method.

5.2 *impact tools*—the drop weight, intermediate weight, and anvil.

5.3 *drop weight*—that weight which is raised to a selected height and released. This weight does not impact the sample directly; rather it strikes another stationary weight that is in contact with the sample.

5.4 *intermediate weight*—the stationary weight in contact with the sample.

5.5 *anvil*—the smooth, hardened surface upon which the test sample or cup containing the sample rests.

5.6 *unconfined test*—a test in which the test sample is placed directly upon the anvil with no lateral confinement.

5.7 *confined test*—a test in which the test sample is contained within a confinement cup (sample container), and the confinement cup is then placed upon the anvil.

5.8 *confinement cup*—the metal sample container used in confined tests.

5.9 *guide bushing*—the steel bushing that surrounds, aligns, and holds the stationary intermediate weight in place.

5.10 *guide system*—the rails, wires, and shaft that guide the drop weight during its fall.

5.11 *striking surface*—the hardened, smooth, circular bottom surface of the intermediate tool that is in contact with the test sample.

5.12 *impact apparatus or machine*—the total apparatus including the foundation parts, guide rails, electromagnet lift, winch, and tools.

## 6. Apparatus

6.1 A complete impact apparatus is the specialized apparatus necessary for this test method.

6.2 The masses of the drop weight ( $m_1$ ) and intermediate weight ( $m_2$ ) should, preferably, be equal. However, the intermediate weight mass may be less than that of the drop weight mass so long as the mass ratio  $m_2/m_1$  is 0.6 or greater. This ensures that the force-time stimulus a test sample is subjected to will be nonoscillatory in nature, and ensures that the transfer of energy from the drop weight to the intermediate weight does not vary significantly.

6.3 The mass of the drop weight should be between 1.0 to 3.5 kg.

6.4 The hardness of all tooling surfaces involved in the impact (drop weight, intermediate weight, and anvil) should have a Rockwell C Hardness of 55 to 59 HRC.

6.5 The diameter of the striking surface of the intermediate weight shall be 9.52 to 19.05 mm ( $\frac{3}{8}$  to  $\frac{3}{4}$  in.). These limits were determined simply on the basis that data have been successfully normalized for tool diameters in this range.

6.6 The finish on the striking surface of the intermediate weight and of the anvil, though not highly critical in tests with solid explosives, should be a No. 8 grind (8  $\mu$ in.) or finer. If substantially different surface finishes are used, the data obtained should be accompanied by a footnote specifying the finish used.

6.7 In confined tests, the confinement cup shall be fabricated from Type 302 stainless steel. The cup base thickness shall range from 0.13 to 0.15 mm (0.005 to 0.006 in.). The outer periphery of the striking pin shall be in contact with a small portion of the arc joining the side and bottom of the cup. Although this permits greater energy losses in working the metal inside the cup than if the whole striking surface engaged only the flat portion of the metal in the base of the cup, it does ensure better confinement with less flow of test material up the sides of the striking pin and cup. A typical confinement cup is shown in Fig. 1. This, together with the striking pin dimensions shown in Fig. 2, provide some insight on a suitable mating between the striking pin and cup.

6.8 Experience has shown that an appreciable difference in the behavior of the apparatus can result from the manner in which it is mounted. Thus, the machine should be mounted on, and firmly attached to, a solid concrete foundation, preferably anchored to the foundation of a building (see Test Method D2540).

6.9 Fig. 3 illustrates a typical impact apparatus, and Figs. 4 and 1 are detailed drawings of a drop weight, an intermediate weight, and a confinement cup. Helpful notes on construction

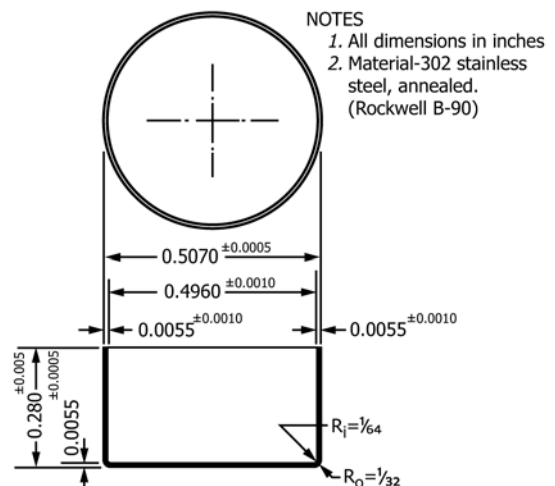


FIG. 1 Confinement Cup Used as a Sample Container in Confined Tests

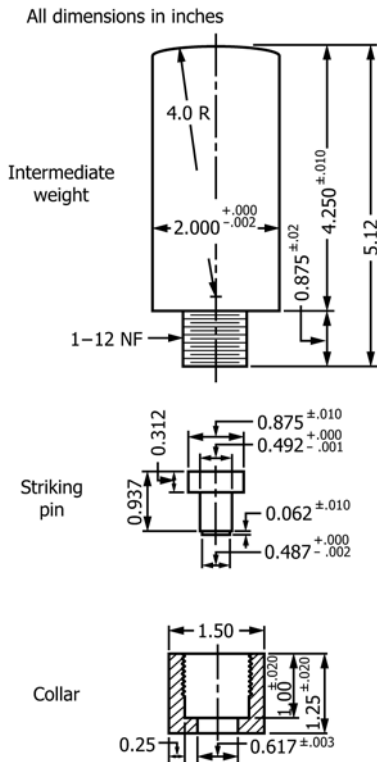


FIG. 2 Intermediate Weight Assembly

of the tools are found in the Appendix. These tools and apparatus are in use at the U. S. Bureau of Mines, Bruceton, Pa., but are not necessarily the only acceptable designs. All designs, however, should incorporate a device that captures the drop weight after it rebounds to prevent further interactions with the intermediate weight.

## 7. Test Sample

7.1 Sample thickness must be the same for all tests. This is achieved by using a constant volume per unit area sample spread uniformly over that area. The standard is 31.5 mm<sup>3</sup>/cm<sup>2</sup>. This provides a distributed thickness of 0.315 mm (12.4 mils) and ensures the same energy input per unit mass of a given test material no matter what the diameter of the striking surface area is. Thus, for a sample diameter of 12.7 mm (0.50 in.), 40 mm<sup>3</sup> of sample volume would be used. Proportionately larger or smaller sample volumes, varying in direct proportion to the sample, may be used so long as the sample volume per unit area is 31.5 mm<sup>3</sup>/cm<sup>2</sup>. Errors in sample volume may be ±10 %, and sample measuring spoons having the appropriate volume can be machined or drilled for this purpose. In cases where it is desirable to test process thickness samples that differ from the standard, simply indicate the thickness used, especially if the  $H_{50}$  values appear in the same tables together with  $H_{50}$  values obtained using standard thickness samples.

7.1.1 In some cases, the sample consistency may prohibit the sample from being measured in a measuring spoon. In these instances, the proper sample size can be determined by its mass;  $M = \rho V$ , where  $V$  is the proper volume for a given sample area, and  $\rho$  is the loose-packing density of the sample. The density may have to be determined if it has not been specified.

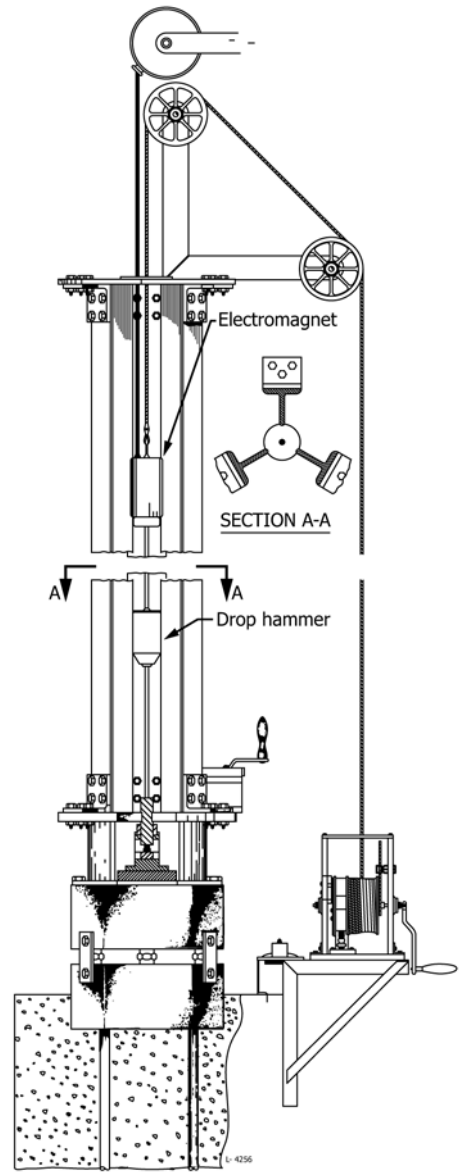


FIG. 3 Bureau of Mines Impact Apparatus

7.2 Specifications of sample diameters to be used in conjunction with different diameter tools are as follows: (a) in confined tests, specifically, a test where the sample is confined in a cylindrical cup, the sample diameter will be the same as the inside diameter of the cup. Hence, calculate a sample volume or mass based upon the inside diameter of the confinement cup, and (b) for unconfined tests, specifically, a test where the sample is spread directly upon the anvil, use about a 0.33-mm (13-mil) thick template made from plastic, metal, or tape having a circular hole cut in it. Place the template on the anvil, pile the sample in the hole, and scrape level with a spatula or straight edge. The hole diameter should, in all cases, be somewhat larger than the tool contact surface diameter. Leave the template in place during the impact trial. The larger size will make it easy to miss striking the periphery of the template hole during impact. The template also serves as an excellent means for keeping the sample inbounds. The recommended template hole for a 12.7-mm (½-in.) diameter

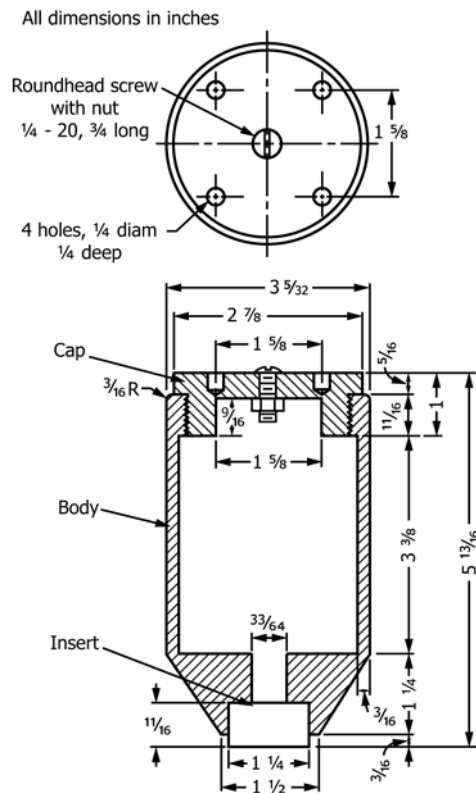


FIG. 4 Drop Weight Assembly

tool is 15.9 mm ( $\frac{5}{8}$  in.), but it may be 19.1 mm ( $\frac{3}{4}$  in.) or larger, as long as a proportionally larger sample is used. Here, it is important to remember that the sample volume or mass used to obtain constant-thickness samples is based upon the template diameter, not the tool diameter.

7.2.1 In no case should the sample diameter be less than that of the tool. The normalization method cannot be applied if this is the case. Furthermore, the normalization method cannot be applied to mixed data from confined and unconfined tests. It is generally applicable in the unconfined case. Information is limited on applicability to the confined case. However, it is believed that data from confined trials could be normalized provided the confinement parameters are reasonably alike. The important cup parameters that were standardized were given in 6.7.

## 8. Preparation of Apparatus

8.1 Inspection checks of the apparatus are an important part of the test procedure. This includes the physical condition of certain parts, alignment, and cleanliness.

8.1.1 *Physical Condition of Equipment*—Inspect the guide rails, or wires, or shafts periodically for evidence of nicks, frays, dirt, or other physical impairments, and eliminate any defects that might impede the drop weight in its fall. Inspect the drop weight, intermediate weight, and anvil, making especially sure that all metal surfaces that are involved in the collision process are free from defects. Make sure that the intermediate weight slides through and rotates freely in the guide bushing without significant side play. Recondition or replace the bottom surface (striking surface) of the intermedi-

ate weight or top surface of the anvil if they show any evidence of wear. Use a new, clean confinement cup each trial in confined tests if confinement cups (sample containers) are used.

8.1.2 *Alignment*—Align the guide system, allowing the drop weight to fall along a path perpendicular to the plane of the earth within  $\pm 0.25$  deg. Misalignments of this magnitude can easily be detected using a plumb line, since a 0.25-deg misalignment amounts to a 13-mm displacement over a 3000-mm length.

8.1.2.1 Align the bottom face (striking surface) of the intermediate weight and the top surface of the anvil. These surfaces must be both plane and parallel. A convenient way to check this is with Prussian blue dye. Place a small amount of the dye on a piece of paper and insert the paper between the intermediate tool striking surface and anvil. By hand lower the intermediate tool onto the area of the paper containing the dye. Lift the intermediate tool and insert a clean piece of paper. Lower and raise the tool a number of times on different areas of the clean paper, making many different imprints. Be careful not to make a judgment solely on the basis of the first or second imprint, since an excess of dye might smear and cover up defects. If the two surfaces are not parallel, a portion of one side of the circle will be missing. A convex tool striking surface will produce a circle having a diameter less than that of the tool striking surface, whereas a concave tool will produce a normal diameter circle with the bare spot centrally located. If any of these defects or others are noted, take proper steps to eliminate them.

8.1.3 *Cleanliness*—Keep all surfaces of the weights, guides, and interior of the guide bushing reasonably clean at all times. Clean especially the intermediate tool striking surface and top of the anvil for each trial. All traces of explosive or residue from reactions must be removed with a tissue wet with acetone, and then wiped with clean, dry tissue. Clean the bottom surface of the drop weight and top surface of the intermediate weight several times during an up-and-down test.

## 9. Procedures

9.1 Avoid testing hygroscopic materials under high humidity conditions, if climate control is not available. Sample conditioning and certain test procedures can be implemented to minimize humidity effects.

9.2 For materials that have been stored under unknown or high humidity conditions, vacuum dry the samples for 2 h at 90°C. For test samples thermally sensitive to 90°C vacuum dry for 8 h at 50°C.

9.3 After drying, place the material in a tightly sealed container and store in a desiccator. The materials should be tested within several days after drying.

9.4 Transfer a sample amount sufficiently large for a complete  $H_{50}$  run to a smaller, dry container and work out of the small container for the up-and-down test, closing up the small container between trials.

9.5 Some materials should not be dried, specifically, those that would lose volatile constituents. These, of necessity,



should be sealed in air-tight containers until ready for use. It is advisable to transfer a suitable amount to a smaller container for the  $H_{50}$  test.

9.6 The test results may vary depending on particle size distribution. Some crystalline materials contain several crystal forms. One form may be, for example, larger in dimensions and more sensitive to impact. Screening may concentrate or remove the more sensitive crystal forms. In general, comparisons are valid only if the particle size distributions are the same. No rigid guidelines for screening all samples in a like manner are given here because some samples cannot be screened, and it may be desirable in many cases to test samples in the “as received” particle size distribution.

9.6.1 In some cases, the size of the sample particles may be inordinately large and the proper test sample thickness cannot be maintained without some reduction (crushing) of particle size. Therefore, with the exception of cases where it is desirable to test process size particles, crush the particles to an extent so that the sample can be distributed uniformly over the template hole area or cup base area with little or no metal visible between sample particles. (**Warning**—Where particle size reduction by grinding is necessary, the user of the method should determine if the material is dangerous, and use remote grinding methods if in doubt. It should also be pointed out that the proper volume of sample to be used for a test should be measured out from the crushed sample.)

9.7 For unconfined tests, center a template upon the anvil beneath the intermediate tool striking surface, fasten with tape, and with a small spatula distribute the proper volume of sample (see 7.1 and 7.2) uniformly over the entire template hole area with as few ridges and valleys as possible. Do not press down or tamp the sample unduly. Lower the intermediate tool gently upon the sample without a twisting motion.

9.8 Use the same procedure for the confined test, except distribute the proper size sample in the bottom of the cup, making sure that the cup and sample remain level while positioning the cup on the anvil. Do not twist the tool after insertion in the cup.

9.9 Proceed with the Bruceton up-and-down method as described in Dixon and Massey<sup>7</sup> in which the next trial after a “go” is performed at one test level lower; while after a “no-go,” the next test is performed at one higher test level. The minimum number of tests recommended is 21. (**Warning**—The operator performing the test should wear safety glasses with side shields in all preparations prior to the release of the drop weight, and should be positioned behind a shield or in a remote location when the drop weight is released.)

9.10 Suggested test heights are given in Table 1. They are based upon equal log intervals and are quite suitable for the errors normally encountered in impact testing. If these intervals are not suitable, similar tables having more closely or more widely spaced intervals may be constructed. Equally spaced “real height” intervals will also produce satisfactory  $H_{50}$  values and may be used. A rule of thumb is to choose an interval that is about 20 to 25 % as large as the “guessed”  $H_{50}$  value.

**TABLE 1 Suggested Scale of Normalized Heights**

Log Increment	Corresponding Height (mm)	Test Height <sup>A</sup> (nearest 5 mm)
1.705	50.7	50
1.805	63.8	65
1.905	80.4	80
2.005	101.0	100
2.105	127.0	125
2.205	160.0	160
2.305	202.0	200
2.405	254.0	255
2.505	320.0	320
2.605	403.0	405
2.705	507.0	505
2.805	638.0	640
2.905	804.0	805
3.005	1012.0	1010
3.105	1274.0	1275
3.205	1603.0	1605
3.305	2018.0	2020
3.405	2541.0	2540
3.505	3199.0	3200

<sup>A</sup> Test heights have been rounded off to nearest 5 mm because the apparatus in question is adjustable in 5-mm increments.

## 10. Reaction Detection

10.1 This is one of the more troublesome areas in sensitivity testing that can significantly alter test results. Guidelines that establish a cut-off point between a reaction and a nonreaction are mandatory, no matter how arbitrary they may appear to be. A reaction (go) is defined as an impact that produces one or more of the following phenomena: (a) audible report, (b) flame or visible light, (c) definite evidence of smoke (not to be confused with a dust cloud of dispersed sample), and (d) definite evidence of discoloration of the sample due to decomposition. The main concern is with reactions that have no distinguishable audible report, no flame, and little sample consumption. The cut-off point in these cases is based primarily upon the appearance of the sample after the test. The impact in most cases will compress the sample into a thin wafer. Portions of the wafer may adhere to the striking tool surface, the anvil, or both. Inspect the tool and anvil surfaces and look for voids (missing wafer parts). Look for discoloration due to decomposition in areas where voids occur. If there is discoloration from decomposition, specify the trial as a reaction. If there are small voids and no discoloration, specify the trial a nonreaction. If doubt exists whether or not discoloration is present, specify the trial a nonreaction. If the only evidence is a slight odor or a small amount of smoke, which may be a dust cloud from dispersed sample, consider the trial a nonreaction.

## 11. Calculation

11.1 Table 2 and Fig. 5 show the individual trial results in the order in which they were performed, as well as a summary of data and calculations needed for a typical up-and-down test. The various test heights in this case were based on equal log intervals (see Table 1). Estimates of the mean ( $m$ ) and standard deviation ( $S$ ) are computed on a log basis. The antilog of  $m$  is the  $H_{50}$  value in real-height terms. If equally-spaced test intervals had been used, the values of  $m$  and  $S$  could have been computed directly in real-height terms.

NOTE 1—Consult Dixon and Massey or any other suitable source for a

**TABLE 2 Calculations for Up-and-Down Test**

Mean ( <i>m</i> )	Standard Deviation ( <i>S</i> )
$m = c + d \left( \frac{A}{N} + \frac{1}{2} \right)$	$S = 1.62 d \left( \frac{NB - A^2}{N^2} + 0.029 \right)$
$= 1.5051 + 0.1 \left( \frac{10}{10} + \frac{1}{2} \right)$	$= 1.62 \left[ \frac{(10)(14) - 100}{100} + 0.029 \right]$
$= 1.6551$ ; antilog $m = 45.2$ cm	$= 0.070$

where:  
*c* = log of lowest test level on which the less frequent event occurred; for example log 32,  
*d* = interval between levels,  
*n* = number of “go” or “no go” at a particular height level,  
*N* = total number of “go” or “no go” in complete up-and-down test,  
*i* = multiplier index, for example, *i* = 0 for *c*, *i* = 1 for *c* + *d*,  
*A* =  $\sum in$ , *N* =  $\sum n$ , and  
*B* =  $\sum i^2 n$

See Footnotes 3 and 6 for any additional details.

Drop height, cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
101.0																					
80.5																					
64.0													x					x			
50.5	x		x						x		o		x		x		o		x		x
40.5		o		x		x		o		o					o		o				o
32.0						o		o													
25.5																					

(a) Results for individual trials.

Drop height, cm	$\sum n$ (go)	$\sum n$ (no go)	<i>i</i>	$\sum in$	$\sum i^2 n$
64.0	2	0	3	0	0
50.5	7	2	2	4	8
40.5	2	6	1	6	6
32.0	0	2	0	0	0
T	11	10		10	14
				A	B

(b) Organization of pertinent quantities for calculations. For identification of quantities see Table 2.

**FIG. 5 Example of Data Organization for Up-and-Down Test**

more complete treatment of the up-and-down method if needed.

11.2 Important data that should be recorded together with the up-and-down test results are as follows:

11.2.1 Drop and intermediate weight masses and tool striking surface diameter;

11.2.2 Confined or unconfined test;

11.2.3 Volume (or mass and density) of sample used in a test;

11.2.4 Diameter or area of sample in unconfined tests, or the interior diameter of the sample cup in confined tests;

11.2.5 Sample treatment (drying or screening), if any; and

11.2.6 Any other departures from standard procedure outlined in this method.

11.3 The information in 11.2.1 is needed to normalize the  $H_{50}$  value for comparison with another normalized  $H_{50}$  value. The information in 11.2.2 – 11.2.6 contains a number of important test parameters that should be the same (or correct) in order that valid comparisons can be made.

11.4 Statistical testing for the equivalence of means is outside the scope of this method and is discussed in the literature previously cited. A good rule of thumb for making decisions is to subtract the two normalized  $H_{50}$  values. Then simply compare this difference with the larger of the two normalized standard deviations (the standard deviations are normalized by mass per unit area (*M/A*) in the same manner as the  $H_{50}$  values are (see 11.5). If the difference is less than the normalized standard deviation, then the  $H_{50}$  values would quite probably also not be found to be different at the 95 % level of significance in the statistical test procedure described in the reference cited. The statistical test or rule of thumb method must be performed in log terms if equal log intervals determined the height test levels, or be performed with real-height quantities ( $H_{50}$  and *S*) if equal interval heights were used.

11.5 The procedure for normalizing data obtained for a given material on two different drop weight impact testers, utilizing different mass and striking diameter tools, may be accomplished in two ways: (a) apply normalizing factors to one  $H_{50}$  value to put it on a comparable basis with the other, or (b) apply normalizing factors, *M/A*, to both  $H_{50}$  values, producing comparable normalized  $H_{50}$  values that are unlike either initial  $H_{50}$  value.

11.5.1 The methods are described as follows:

*Apparatus A:*

drop weight mass = 2.0 kg,

intermediate tool striking diameter = 12.7 mm (½ in.),

intermediate tool striking area = 1.27 cm<sup>2</sup>, and

$H_{50}$  = 500 mm (for explosive XX).

*Apparatus B:*

drop weight mass = 3.0 kg,

intermediate tool striking diameter = 9.52 mm (⅜ in.),

intermediate tool striking area = 0.712 cm<sup>2</sup>, and

$H_{50}$  = 187 mm (for explosive XX).

11.5.2 *Method 1*—The effects from the larger drop weight mass and smaller intermediate tool striking diameter associated with apparatus B are to produce lower  $H_{50}$  values relative to that obtained from apparatus A. Two normalizing factors, both greater than unity, representing the mass and diameter (or area) effects must be applied to the  $H_{50}$  value obtained with apparatus B to put it on a comparable basis with that from apparatus A.

*Mass factor:* 3 kg/2 kg = 1.50

*Diameter factor:* (12.7 mm/9.52 mm)<sup>2</sup> = 1.78

or

*Area factor:* (1.27 cm<sup>2</sup>/0.712 cm<sup>2</sup>) = 1.78

*Total factor:* = 2.68

*Normalizing*  $H_{50}^B \rightarrow H_{50}^A \cdot (2.68)(H_{50}^B) = (2.68)(187 \text{ mm}) = 500 \text{ mm}$

11.5.3 *Method 2*—Both  $H_{50}$  values are multiplied by their respective *M/A* values,

$M_i/A_i H_{50}^i = \text{constant.}$

$M_A/A_A H_{50}^A = (2.0/1.27)(500 \text{ mm}) = 790 \text{ mm}$

$$M_B/A_B H_{50}^B = (3.0/0.712)(187 \text{ mm}) = 790 \text{ mm}$$

11.5.4 Both methods accomplish the desired objective, that is, normalizing out the effects from differences in tool mass and striking area. The standard deviations  $S$  may be normalized in a similar manner if the up-and-down test was performed initially using equal real (not log) height intervals and a statistical test for equivalence of means may be performed in real-height terms. However, it should be mentioned that a peculiar characteristic of the Bruceton up-and-down method is that if equal-spaced log intervals are used,  $S$  cannot be transformed on a real-height basis (by taking the antilog), as may be done with the mean. If a statistical test for equivalence of means is desired, the whole procedure for normalizing data and the statistical test must be performed in log terms.

## 12. Precision and Accuracy

12.1 The precision of the test is limited by the drop height interval ( $d$ ) used. The standard deviation estimate ( $S$ ) must be comparable in magnitude to the interval.

12.2 The acceptance or rejection of test results are governed by the following rule; accept the test if  $1/2d \leq S \leq 2d$ . Otherwise, repeat the test using an appropriately larger or smaller interval.

12.3 Based upon  $H_{50}$  tests performed at one establishment, the average ratio of the standard deviations ( $S$ ) to the mean values obtained ( $m$ ) from many explosive tests was approximately 0.20 (20 %). This average ratio was obtained from data having real height (not log) values, and provides additional insight on the precision that may be expected from the test. It is on this basis that the original choice of an interval is recommended to be about 20 to 25 % of the “guessed” mean.

## APPENDIX

### (Nonmandatory Information)

#### X1. CONSTRUCTION NOTES ON DROP WEIGHT TOOLS

##### X1.1 Intermediate Weight Assembly

X1.1.1 Material for intermediate weight and striking pins must be of a type steel that can be hardened to 55 to 59 HRC on the Rockwell C scale. The collar may be cold, rolled steel.

X1.1.2 With the exception of the bottom surface of striking pins, all sharp edges and corners on hardened parts should be broken as much as is consistent for the proper mating of parts. The purpose of this is to eliminate stress points and possible crack formation.

X1.1.3 It would be convenient if collar were made of “hex” stock. If made of round stock, grind flat areas (180 deg apart) on exterior surface so that the collar can be tightened with a wrench.

X1.1.4 Total mass of the three parts must be  $2.00 \pm 0.04$  kg. To meet this condition, the length of the intermediate weight is altered as necessary. Check the mass prior to hardening.

X1.1.5 After hardening, grind top and bottom surfaces of intermediate weight and striking pins to a No. 8-grind finish or finer.


X1.1.6 The details of the base of the striking pin, that is, the 0.492-in. shaft diameter and 0.487-in. relieved diameter are compatible with a good fit into a standard stainless steel cup used by the Bureau of Mines as a sample cup in confined tests.

##### X1.2 Drop Weight

X1.2.1 Total mass of drop weight (cap, body, and insert) must be  $2.00 \pm 0.04$  kg. Dimensions as given will result in a slight overweight. Trim inside surfaces of body to reduce mass.

X1.2.2 The insert (the element that strikes the intermediate weight in a drop test) should be made of a type of steel that can be hardened to 55 to 59 HRC on the Rockwell C scale. The fit of the insert into the main body should be a metal-to-metal press fit. The main body may be heated and insert chilled to facilitate pressing.

X1.2.3 The purpose of a machine screw-in cap is to facilitate seating of the drop weight in an electromagnetic pick-up head used by the Bureau of Mines to raise the drop weight to a desired drop height. This detail may be altered to suit individual needs.

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