Designation: E3276/E3276M – 21

Standard Test Method for Assessing Impact Energy and Precision of Direct-fire, Single-projectile Less Lethal Impact Rounds Used by Public Safety Officers[1]

This standard is issued under the fixed designation E3276/E3276M; 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 test method addresses direct-fire, single-projectile less lethal impact rounds used by public safety officers, including law enforcement, corrections, and others.

1.2 This test method addresses both blunt impact rounds and payload delivery rounds.

1.2.1 This test method is limited to direct-fire, single-projectile rounds and excludes skip-fire rounds or multiple-projectile rounds.

1.3 This test method is used to measure velocity and determine precision and impact energy for a round.

1.4 A specification is under development by ASTM that addresses the safety of targeted individuals during deployment of less lethal impact rounds. That specification will reference this test method.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.6 *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.*

1.7 *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]

E2771 Terminology for Homeland Security Applications

E3005 Terminology for Body Armor

E3062/E3062M Specification for Indoor Ballistic Test Ranges for Small Arms and Fragmentation Testing of Ballistic-resistant Items

F1494 Terminology Relating to Protective Clothing

2.2 *Other Documents:*

National Institute of Justice (NIJ) No. 236950, 2011 Test Methodologies for the Assessment of Less-lethal kinetic energy rounds[3]

Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) Glossary of Industry Terms. Newtown, CT[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *90 % circular error probable (CEP), n*—the diameter of a circle, centered about the mean X- and Y-impact values, whose boundary is predicted to include 90 % of the projectile impact locations for the same testing parameters and setup.

3.1.2 *caliber, n*—a term used to designate the specific cartridge(s) for which a firearm is chambered;

in firearms—the approximate diameter of the circle formed by the tops of the lands of a rifled barrel, often expressed in hundredths of an inch (".38 caliber") or millimeters ("7 mm caliber");

in ammunition—a numerical term included in a cartridge name to indicate a rough approximation of the bullet diameter. **SAAMI**

3.1.3 *cartridge, n*—a single assembled unit consisting of one or more projectiles, propellant, primer, and casing; synonymous with *round*. **Adapted from E3005**

[1] This test method is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.04 on Public Safety Equipment.

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

[3] Available from National Institute of Justice (NIJ), 810 7th St., NW, Washington, DC 20531, http://nij.gov.

[4] Available from Sporting Arms and Ammunition Manufacturers' Institute (SAAMI), http://www.saami.org.

3.1.3.1 *Discussion*—For less lethal impact devices, the cartridge or round contains a less lethal projectile instead of a bullet.

3.1.4 *controlled ambient, n*—conditions with temperature of 20 °C ± 5.5 °C [68 °F ± 10 °F] and 50 % ± 20 % relative humidity (RH). **E3005**

3.1.5 *direct-fire, adj*—designed to be fired directly at a specific target.

3.1.6 *laser boresight, n*—a laser pointer inserted into the firing system barrel and used to indicate the barrel aim point on a target.

3.1.7 *less lethal impact round, n*—a type of cartridge in which the projectile is intended to be less likely to be lethal than a bullet.

3.1.8 *model, n*—the supplier's design, with unique specifications and characteristics, of a particular item. **E2771**

3.1.9 *multi-launcher, n*—a launcher that has a cylinder or magazine system allowing multiple rounds to be fired.

3.1.10 *over and under, n*—firearms with two barrels placed one above the other. **SAAMI**

3.1.11 *precision, n*—a measure of how close the various impacts for a given round are to each other. **NIJ No. 236950**

3.1.12 *projectile, n*—an object launched by external force. **E3005**

3.1.13 *pump action, n*—an action in which a moveable fore-end is manually actuated in a motion generally parallel to the barrel; this motion is transmitted to a breech bolt assembly which performs all the functions for loading and extracting cartridges; this type of action is prevalent in shotguns and is found to a lesser extent in rifles. **SAAMI**

3.1.14 *round, n*—See *cartridge*.

3.1.15 *single shot, n*—a firearm with no means in the mechanism for storing or loading more than a single cartridge housed in the chamber of the barrel. **SAAMI**

3.1.16 *skip-fire, adj*—designed to be fired into a surface in front of the target, such that the projectile loses energy and ricochets into the target; synonymous with *indirect fire*.

3.1.17 *supplier, n*—the entity that directs and controls the following: conformant product design, conformant product manufacturing, conformant product quality assurance; or the entity that assumes the liability for the conformant product or provides the warranty for the conformant product. **E2771**

3.1.18 *test item, n*—a single article intended for testing. **E3005**

4. Significance and Use

4.1 The purpose of this test method is to provide a test method for the evaluation of less lethal impact rounds used by law enforcement, corrections, and other public safety officers.

4.2 This test method may be used by suppliers, certification bodies, testing laboratories, research and development organizations, and others assessing the performance of less lethal impact rounds.

4.3 This test method may be used by purchasers in their evaluation of products to meet their needs and requirements.

5. Hazards

5.1 The tests described in this test method have inherent hazards. Adequate safeguards for personnel and property shall be employed when conducting these tests.

6. Test Item Requirements

6.1 At least 65 test items (rounds) are required.

NOTE 1—It is recommended that spare test items be provided.

6.1.1 50 test items are required for testing to achieve the required shots at two distances:

6.1.1.1 Supplier-specified test distance at which a 90 % circular error probable (CEP) of 15.2 cm [6 in.] or less can be achieved. (See Annex A1 for calculation of 90 % CEP.)

NOTE 2—The velocity at the supplier-declared minimum distance will be measured during this test.

6.1.1.2 Supplier-declared maximum distance.

6.1.2 Ten test items are required for confirming the alignment prior to testing.

6.1.3 Five test items are required for determining the mass of the projectiles.

6.1.4 Additional test items are required if an outlier occurs during testing.

6.1.5 For pneumatic launching systems with variable inputs (for example, velocity, bore size), additional test items are required for dialing in the settings specified by the supplier.

6.2 The supplier shall declare the type of delivery system (and relevant details) for the round being tested, addressing each item below:

6.2.1 Universal receiver or proprietary launcher;

6.2.1.1 When the supplier specifies a launcher with variable settings, the supplier shall specify the settings for the round being tested.

6.2.2 Single shot, over and under, multi-launcher, pump action; and

6.2.3 Barrel length and whether barrel is rifled or smooth bore.

6.2.4 The supplier shall declare details below for the round being tested:

6.2.4.1 Type, materials, and average mass;

6.2.4.2 Propellant (black powder, smokeless powder, or compressed air/gas);

6.2.4.3 Deployment range (that is, supplier-declared minimum distance to supplier-declared maximum distance); and

6.2.4.4 Test distance at which a 90 % CEP of 15.2 cm [6 in.] or less can be achieved.

6.3 The test items shall be conditioned at controlled ambient for at least 24 h prior to performance testing.

7. Test Requirements

7.1 Testing may be performed by the supplier (in-house) or by an independent test laboratory.

7.2 Test item performance shall be assessed in groups of 25 rounds for each procedure.

7.3 *Test Range:*

7.3.1 Testing shall be performed on an indoor test range, unless an indoor range of appropriate length is not available.

7.3.1.1 The indoor test range shall meet the requirements of Specification E3062/E3062M with respect to requirements for the temperature and humidity, firing system, and instrumentation.

(1) The launcher used for testing shall be a universal receiver, unless the round is intended to be fired from a specific launcher. In that case, the supplier shall provide the specific launcher which shall be used for testing (instead of a universal receiver).

(2) Muzzle to test item distance requirements of Specification E3062/E3062M are not applicable.

(3) Sections 8.1.3, 8.1.4, 8.1.5, and 8.2 from Specification E3062/E3062M shall not apply.

(4) "Test item reference plane" is replaced by "test target reference plane."

(5) The test item shall be fired from a supported position or mechanical fixture to minimize movement of the firing system's barrel in the X-, Y-, and Z-directions.

NOTE 3—With respect to the test target, the X-direction is left-right, the Y-direction is up-down, and the Z-direction is barrel-target.

7.3.2 When an indoor range of appropriate length and height is not available, testing may be performed on an outdoor range during mild weather conditions meeting the requirements below:

7.3.2.1 The temperature shall be between 12 °C and 30 °C [54 °F and 86 °F];

7.3.2.2 The relative humidity shall be between 30 % and 70 %;

7.3.2.3 Wind parallel and transverse to the line of fire shall not exceed 4.5 m⁄s [10 mph] or vary by more than 2.2 m⁄s [5 mph];

7.3.2.4 Firing shall not be done when wind gusts are present;

7.3.2.5 Firing shall not be done when precipitation exists (for example, rain, hail, mist, or fog); and

7.3.2.6 The meteorological conditions shall be recorded.

7.4 *Test Targets:*

7.4.1 The test target shall register the impact location of the test round, shall be of appropriate dimensions to capture the impacts, and shall be located in the test target reference plane.

7.4.1.1 The test target shall be either an electronic target or a physical target (for example, cardboard) that distinctly identifies each projectile impact location and size.

NOTE 4—When using physical targets, the impact location can be identified as an impression/mark or a through hole. The through hole size should be near to the caliber of the projectile. Placing backing material behind the test target is allowed if it improves the ability to locate the impact center.

7.4.1.2 The test target shall be mounted so that it does not move during the test event.

7.4.1.3 The test target shall have markings or other capability to indicate the test target center point and 25 mm [1-in.] increments from center in both the X- and Y-directions.

7.4.1.4 The test target shall be oriented vertically with respect to the floor and normal to the firing system barrel's longitudinal axis in the X-direction.

7.5 *Velocity Measurement:*

7.5.1 A velocity measuring system(s) shall be used and shall be capable of capturing the velocity of the test item both at 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the muzzle and at 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the test target, with an accuracy of ±0.1 m/s [0.33 ft/s].

7.6 *Firing System:*

7.6.1 The alignment of the firing system and the test target in the X-, Y-, and Z-directions shall be verified, and the barrel aim point shall be denoted as (0,0). The following steps shall be used to indicate the theoretical aimpoint at each distance.

7.6.1.1 Place a physical target at a distance of approximately 3 m [10 ft] (Z) from the muzzle.

7.6.1.2 Level the firing system and measure the distance from the floor to the center of the barrel. Record the height (Y) to the closest millimeter [⅛ in.].

7.6.1.3 Fire five shots at the test target. Average the left/right (X) locations to determine the center to the closest millimeter [⅛ in.]. Using the left/right average (X) and the previously recorded height from the floor (Y), indicate the theoretical aimpoint. Insert a laser boresight into the firing system barrel and adjust so that it aligns with the theoretical aimpoint (0,0).

7.6.1.4 Place the test target at the appropriate distance and determine the center as indicated by the laser boresight. If a physical test target is used, mark the theoretical center. If an electronic test target is used, record the location of the theoretical center.

(1) If a physical test target is used and needs to be replaced during a sequence of shots, the boresight shall be realigned prior to replacing the test target. If possible, use the previously marked theoretical aimpoint. If not possible, 7.6.1.1 – 7.6.1.4 shall be repeated.

7.6.2 For testing at distances for which projectile drop is expected, the barrel aim point shall be raised by an amount specified by the supplier. This occurrence and the amount shall be documented, and the new barrel aim point shall be set as (0,0) for this test.

7.7 *Addressing Outliers in Testing Data:*

7.7.1 When all of the required 25 projectiles for a test hit the test target, the analysis described in Annex A2 shall be done to assess whether there is an outlier.

7.7.1.1 When an outlier is identified, that occurrence shall be documented, and the test procedure of Section 8 shall be repeated for another group of 25 rounds at the appropriate distance.

NOTE 5—It is the supplier's decision as to whether to repeat the test or stop testing. If a repeated test results in an outlier, it is recommended that an analysis be conducted to determine the cause of the outliers (for example, movement of launching platform or target, inconsistency in impact rounds).

7.7.2 When one projectile out of the required 25 projectiles for a test misses the test target, that occurrence shall be documented. The test may be stopped upon this occurrence,

and the test procedure of Section 8 shall be repeated for another group of 25 rounds at the appropriate distance.

8. Test Procedure at Required Distances

8.1 This test procedure shall be performed with 25 shots at each of two distances from the muzzle to the test target reference plane:

(1) Supplier-specified test distance at which a 90 % CEP of 15.2 cm [6 in.] or less can be achieved; and

(2) Supplier-declared maximum distance.

8.1.1 A graphic of the test setups is shown in Annex A3.

8.2 Remove the projectiles from five spare rounds (to use in calculating energy) and weigh each projectile. Report all the masses and calculate the average and standard deviation.

8.3 Set the distance from the muzzle to the test target reference plane and document the distance.

8.4 Clean the firing system barrel (per manufacturer cleaning instructions).

8.5 If a physical target is being used, install a fresh test target initially and at least after every five shots. Mark the physical target appropriately to indicate the round being tested.

NOTE 6—The physical test target may be replaced more frequently if necessary to distinguish impacts.

8.5.1 If two or more impacts create a hole in the target that a subsequent projectile could pass through, install a fresh target.

8.6 Verify the alignment of the firing system and the test target in the X- and Y-directions and ensure that the barrel aim point is correct.

8.7 When testing at the 15.2 cm [6 in.] 90 % CEP distance, fire the round, measuring the velocity at three locations:

(1) 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the muzzle;

(2) 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the test target; and

(3) At the supplier-declared minimum distance.

8.8 When testing at the supplier-declared maximum distance, fire the round, measuring the velocity at two locations:

(1) 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the muzzle; and

(2) 1 m ± 0.01 m [39.4 in. ± 0.4 in.] from the test target.

8.9 For each projectile, perform the following:

8.9.1 Document velocity for each projectile;

8.9.2 Calculate the impact energy, using Eq 1 and the average mass;

$$\text{Impact Energy} = \frac{1}{2}(\text{mass}) \times (\text{velocity})^2 \qquad (1)$$

8.9.3 After each shot, measure the vertical distance between the X-axis and the impact center and the horizontal distance between the Y-axis and the impact center. Measurements shall be taken to the nearest 0.6 cm [0.25 in.];

NOTE 7—When using physical targets, ensure that the targets are not moved during measurements.

8.9.3.1 When using physical targets and the shot results in an impact area that overlaps that of a previous shot, this occurrence and the impact center (X-Y coordinates) shall be documented.

NOTE 8—For a shot that apparently overlaps a previous one, it should be verified that the projectile is registered by the target. It is recommended that one of the following methods be used:

(1) Use a soft backing material, such as a blanket or rubber mat, behind the target to "catch" the projectiles;

(2) Use a firm backing material, such as a foam board, that is sufficiently larger than the target to capture the impacts that miss the target;

(3) Review Doppler radar velocity data for each shot. A projectile that completely misses the target will typically have a different velocity profile than projectiles that hit the target; or

(4) Use a high-speed video camera to capture the trajectory of projectiles.

8.9.4 Document the X-Y coordinates; and

8.9.5 When using physical targets, photograph the test target to show impacts.

8.10 Repeat the steps in 8.5 – 8.9.5 until the required 25 shots have been taken.

8.11 Analyze the data to determine if there is an outlier as described in Annex A2 and take the appropriate next step according to 7.7.

8.12 Using the calculation provided in Annex A1, determine the 90 % CEP and shot group center (in X-Y coordinates) from barrel aim point.

8.13 Document the firing system details (including manufacturer, model, caliber, smooth bore or rifled, and barrel length), distance to test target, measured values, and calculated values.

8.14 Repeat the steps in 8.3 – 8.13 until testing at the two required distances is complete.

9. Test Report

9.1 The test report shall include at least the following:

9.1.1 Name and contact information of the organization performing the testing;

9.1.2 Title and unique identifier for test report (that is, report number) and of each page, and the total number of pages;

9.1.3 Supplier or organization requesting the testing (name, address, and phone);

9.1.4 Model designation;

9.1.5 Test results, measurements with specified units of measure, calculations, photographs, and observations; and

9.1.6 Name, function, and signature of the person(s) authorizing the test report.

9.2 An example test report format is provided in Appendix X1.

10. Precision and Bias

10.1 *Precision*—The precision of test results in this test method requires data to be collected which cannot be done until the test method has been published.

10.1.1 In the interim, a simulation using the data in A1.2.2 (see Table A1.1) was performed to reflect 90 % CEP results when the impact location center measurements are off by up to

1.27 cm [0.5 in.] in any direction from the theoretical true value. In that simulation, the 90 % CEP varied from 17.09 cm [6.73 in.] to 18.36 cm [7.23 in.] for 25 trials when the true value was 17.48 cm [6.88 in.]. The shot group center location varied by less than 0.51 cm [0.20 in.] in both the X- and Y-directions. This simulates 25 measurements on the target in A1.2.2 by 25 different people.

10.1.2 The precision of the velocity measurements depends on the instrumentation being used and is described in other standards. The velocity measurement affects the calculation of energy.

10.2 *Bias*—Sources of potential bias include systematic errors in electronic instrumentation and physical measurements. Bias cannot be determined until test method is published and put into practice.

11. Keywords

11.1 impact; kinetic energy; less lethal; less lethal impact round

ANNEXES

(Mandatory Information)

A1. METHOD FOR DETERMINING 90 % CEP AND CENTER OF SHOT GROUP

A1.1 *Calculation of 90 % CEP*:

A1.1.1 Tabulate the (X, Y) values and determine the mean for both X and Y.

A1.1.2 Calculate the distance from 0,0 to shot group center using Eq A1.1:

$$\text{Distance} = \sqrt{x_{avg}{}^2 + y_{avg}{}^2} \quad \text{(A1.1)}$$

where:

x_{avg} = mean of x values, and
y_{avg} = mean of y values.

A1.1.3 Calculate the sample standard deviation in X and Y using the following equation:

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n - 1}} \quad \text{(A1.2)}$$

where:

s = x or y sample standard deviation,
n = size of the data set (for example, 25 for a 25-shot data set),
x_i = each value from the impact coordinates in either x or y, and
$\bar{x}$ = mean of either x or y.

A1.1.4 After calculating s_x and s_y, use the following equation to calculate the 90 % CEP:

$$90\ \%\ \ \text{CEP} = 4.2919 \times \sqrt{(s_x{}^2 + s_y{}^2)/2} \quad \text{(A1.3)}$$

where:

4.2919 = ±2.14595 standard deviations about the mean of a 2-dimensional circular normal distribution, which is equal to 90 % of the area under the distribution curve (2 × 2.14595 = 4.2919),
s_x = standard deviation of drift among a group of projectile impacts, and
s_y = standard deviation of drop among a group of projectile impacts.

A1.2 *Example of 90 % CEP Calculation for a 25-shot Data Set*:

A1.2.1 See Fig. A1.1 for an X-Y plot of a 25-shot data set.

A1.2.2 The X-Y coordinates for the data set are shown in Table A1.1.

A1.2.3 The calculated values using Eq A1.1, Eq A1.2, and Eq A1.3 are given below:

x_{avg} = -0.177
y_{avg} = 0.134
s_x = 1.843
s_y = 1.322
90 % CEP = 6.88 in.

A1.2.4 This means that for the data set shown in Table A1.1, a 6.88-in. diameter circle, centered about the coordinates (-0.117, 0.134) referenced from (0, 0), will predict 90 % of a projectile's impact locations for the same testing parameters and setup. A graphical summary of this is shown in Fig. A1.2.

NOTE A1.1—The data used for this example does not meet the 90 % CEP requirement of 6.0 in.

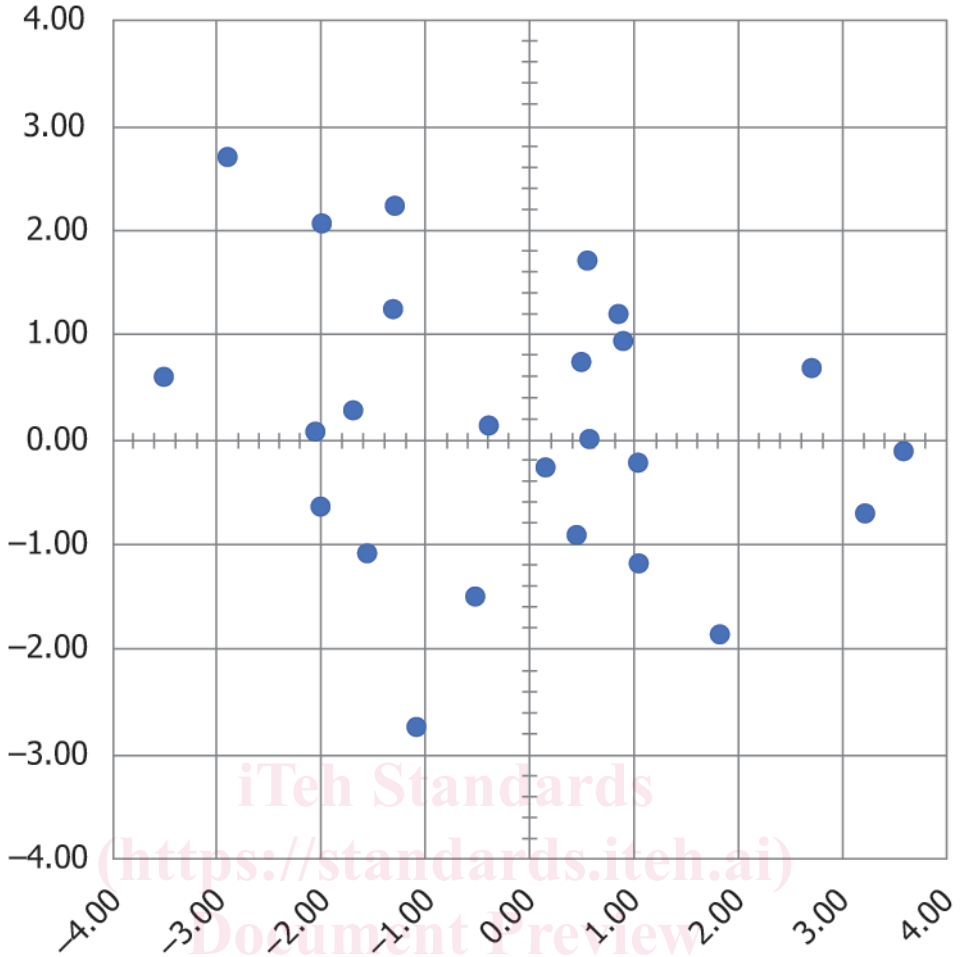

FIG. A1.1 X-Y Plot of 25-shot Data Set

TABLE A1.1 (X, Y) Coordinates for Each Shot

Shot #	X (in.)	Y (in.)
1	0.152	-0.259
2	1.040	-0.225
3	-0.527	-1.500
4	1.820	-1.860
5	-2.020	-0.637
6	-2.000	2.060
7	1.050	-1.180
8	-1.080	-2.740
9	3.590	-0.112
10	-0.385	0.128
11	-1.310	1.250
12	-2.900	2.700
13	2.710	0.675
14	0.569	0.006
15	3.210	-0.703
16	0.846	1.210
17	-1.690	0.279
18	-2.050	0.066
19	0.887	0.928
20	0.554	1.700
21	-3.510	0.599
22	0.499	0.746
23	0.452	-0.923
24	-1.550	-1.080
25	-1.290	2.230

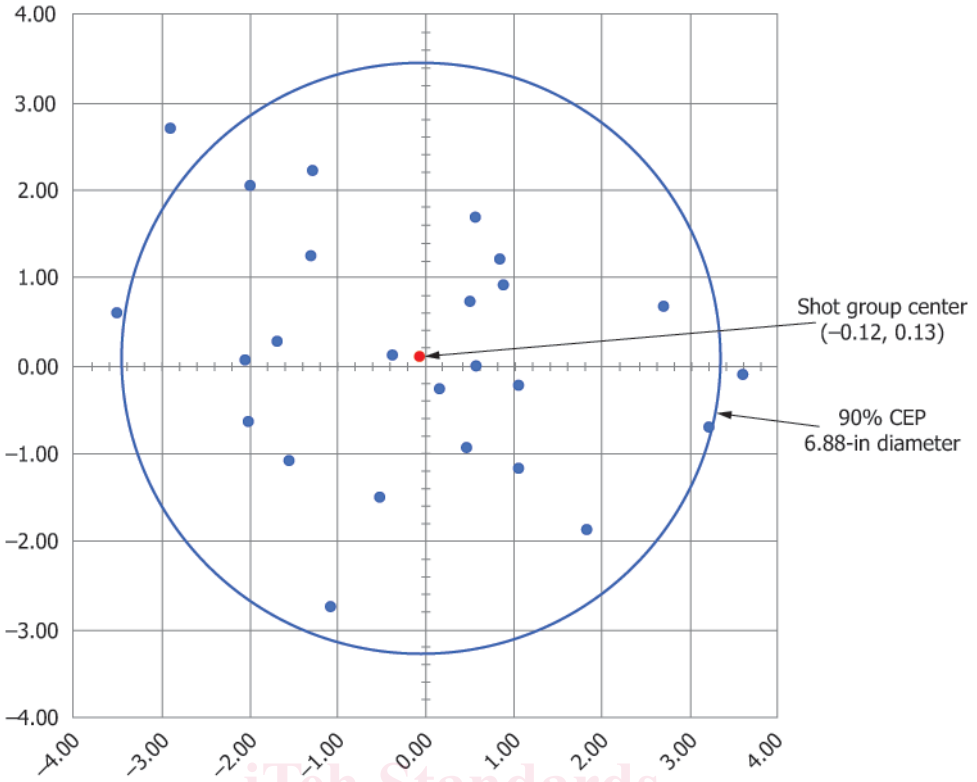

FIG. A1.2 90 % CEP and Center for a 25-shot Data Set

A2. ANALYSIS OF TEST DATA TO IDENTIFY AN OUTLIER

A2.1 *Steps for Identifying Outliers are Provided Below*:

NOTE A2.1—It is recommended that Microsoft Excel[5] or a similar software be used to perform the required calculations.

Calculate the average of the X values (x_{avg}) and the average of the Y values (y_{avg}).

A2.3 For the 25-projectile data set of X-Y coordinates, calculate the distance from the shot group center (x_{avg}, y_{avg}) to each impact location using Eq A2.1.

$$\text{Distance} = \sqrt{(x_{avg} - x_i)^2 + (y_{avg} - y_i)^2} \quad \text{(A2.1)}$$

A2.4 Arrange the 25 distance values in ascending order.

A2.5 *Identify the Following*:

A2.5.1 *First Quartile (1Q)*—The 7th value in the list of distance values.

A2.5.2 *Third Quartile (3Q)*—The 19th value in the list of distance values.

Calculate the interquartile range (IQR) and the upper bound (UB) using the equations below:

$$\text{IQR} = 3\text{Q} - 1\text{Q} \quad \text{(A2.2)}$$

$$\text{UB} = 3\text{Q} + \text{IQR} \times 1.5 \quad \text{(A2.3)}$$

A2.7 Compare the largest distance value to UB. If that distance value is greater than UB, that value is an outlier.

NOTE A2.2—The lower bound is not of concern for less lethal rounds; only impacts outside the upper bound are of concern.

[5] Microsoft Excel is a trademark of the Microsoft Corporation, One Microsoft Way, Redmond, WA, 98052-6399.