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An American National Standard

# Standard Test Methods for
# Measuring High-Speed Bat Performance[1]

This standard is issued under the fixed designation F2219; 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 ($\varepsilon$) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These test methods define a 1.1 A method for determining bat performance by measuring the bat-ball coefficient of restitution (BBCOR), deriving the ball exit speed ratio (BESR), and calculating a batted-ball speed (BBS). It is applicable to baseball and softball bats of any construction or material. The test methods provide quantitative measures of bat dynamic performance that may be used for comparison purposes.

1.2 The BBCOR, BESR, and BBS are each calculated from measurements taken in the laboratory on test equipment meeting the requirements defined in this specification. standard.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *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 to determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]
F1887 Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs
F1888 Test Method for Compression-Displacement of Baseballs and Softballs
F2398 Test Method for Measuring Moment of Inertia and Center of Percussion of a Baseball or Softball Bat

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *balance point (BP), n*—distance to the center of mass of a bat when measured from the distal end of the bat knob. bat.

3.1.2 *ball exit speed ($V_f$* ball exit speed ($v_r$) , n*—outbound speed of a ball following impact with a bat as defined in these test methods.

3.1.3 *ball exit speed ratio (BESR), n*—ratio of ball exit speed ($v_r$) to ball inbound speed ($v_i$) plus ½ , as determined by these test methods.

3.1.4 *ball inbound speed ($v_i$), n*—inbound speed of a ball prior to impact with a bat as defined in this test method.

3.1.5 *bat-ball coefficient of restitution (BBCOR)*—COR of a specific ball colliding with a bat as defined in these test methods. See *coefficient of restitution (COR).*

3.1.6 *center of percussion (COP), n—also known as the center of oscillation, the length of a simple pendulum with the same period as a physical pendulum, as in a bat oscillating on a pivot.*

3.1.7 *coefficient of restitution (COR), n*—measure of impact efficiency calculated as the relative speed of the objects after impact divided by the relative speed of the objects before impact.

3.1.8

3.1.7 *moment of inertia (MOI), n*—measure of mass distribution relative to an axis of rotation. It is the product of the mass multiplied by the square of the distance to the mass, summed over the entire bat.

## 4. Significance and Use

4.1 These test methods offer a laboratory measure of the performance of baseball and softball bats.

4.2 Use of these test methods can provide quantitative batted-ball speed and metrics of bat performance.

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## 5. Apparatus and Equipment

5.1 *Test Balls*—~~Official baseballs and softballs approved for use in the game of baseball or softball and tested in accordance with Table 1.~~—Baseballs or softballs as determined by those specifying the test requirements.

5.2 Balls specification values are to be recorded and traced to individual balls.

5.3 *Bat-Ball ~~COR~~ Test Apparatus*:

5.3.1 *Ball Cannon*—~~A device capable of shooting a softball at speeds at least up to 205.3 ft/s (62.6 m/s, approximately 140 mph) for Option 1 or a baseball at speeds at least up to 220 ft/s (67.1 m/s, approximately 150 mph) for Option 2, or both. Balls shall be oriented to impact the strike surface between the stitches. Typical pitching machines cannot yield the aiming accuracy required by these test methods. Cannon exhaust air must not cause motion of the bat in the absence of an impact.~~—A device capable of shooting a ball at speeds up to 220 ft/s (67.1 m/s, approximately 150 mph). Balls shall be oriented to impact the strike surface between the stitches. Typical pitching machines cannot yield the aiming accuracy required by these test methods. Cannon exhaust air must not cause motion of the bat in the absence of an impact.

5.3.2 *Ball Speed Gate*—~~A light trap device, or an equivalent, capable of measuring a softball traveling at speeds at least up to 205.3 ft/s (62.6 m/s, approximately 140 mph) for Option 1 or a baseball traveling at speeds at least up to 220 ft/s (67.1 m/s, approximately 150 mph) for Option 2, or both, with an accuracy of ±3 ft/s (0.89 m/s) or better. The device shall measure across a length of no less than half the ball diameter to avoid centering error. For example, the device shall sense an object across a 2.0 in. (50.8 mm) line. The first sensor shall trigger when the ball is no more than 18.0 in. (457.2 mm) from the bat surface. The second sensor shall trigger between 12 ± 0.03 in. (30 ± 0.08 cm) from the first sensor. The second sensor is located between the first sensor and the bat surface. The distance between sensors must be measured and maintained within ±0.005 in. (±0.13 mm) (see~~ —Light screens capable of measuring a ball traveling at speeds up to 220 ft/s (67.1 m/s, approximately 150 mph), with an accuracy of at least ±0.7 ft/s (0.2 m/s). The device shall measure across a length of no less than half the ball diameter to avoid centering error. The first sensor shall be located no more than 12.0 in. (304.8 mm) from the bat surface. The second sensor shall be located 6 ± 0.03 in. (152 ± 0.8 mm) after the first sensor (see Fig. 1~~). The device must be able to measure the ball exit speed. This requirement dictates that the device must reset and arm quickly enough to capture the ball traveling back through the speed gate.~~). The ball speed gate must measure the ball rebound speed.

5.3.3 *Bat Pivot Support*—A turntable, rotating in the horizontal plane, with clamps to support and align the bat in the path of the ball. The ~~clamp surfaces shall be a 45° Vee clamp with no radii greater than 2.0 in. (50.8 mm). The~~ rotating clamp and shaft assembly shall not weigh more than 6 lb (2.7 kg) and shall spin freely via ball bearings (see Fig. 1). The actual MOI of the clamp turntable assembly shall be determined, recorded, and used in the performance calculations. The polar MOI for the clamp turntable assembly shall not exceed ~~192~~300 oz-in.$^2$ ~~(35 117 g-cm~~$^{(5498 \text{ kg-mm}^2)}$).

5.4 *Bat Speed Sensor*—Device to measure bat rotational speed for at least 100° after impact. Device shall read speeds up to 3000°/s with an accuracy of at least 1°/s (found to be achievable using an optical encoder). Bat speed is taken from the slope of the linear least-squares fit to the bat rotation versus time data between 5° and 95° after impact.
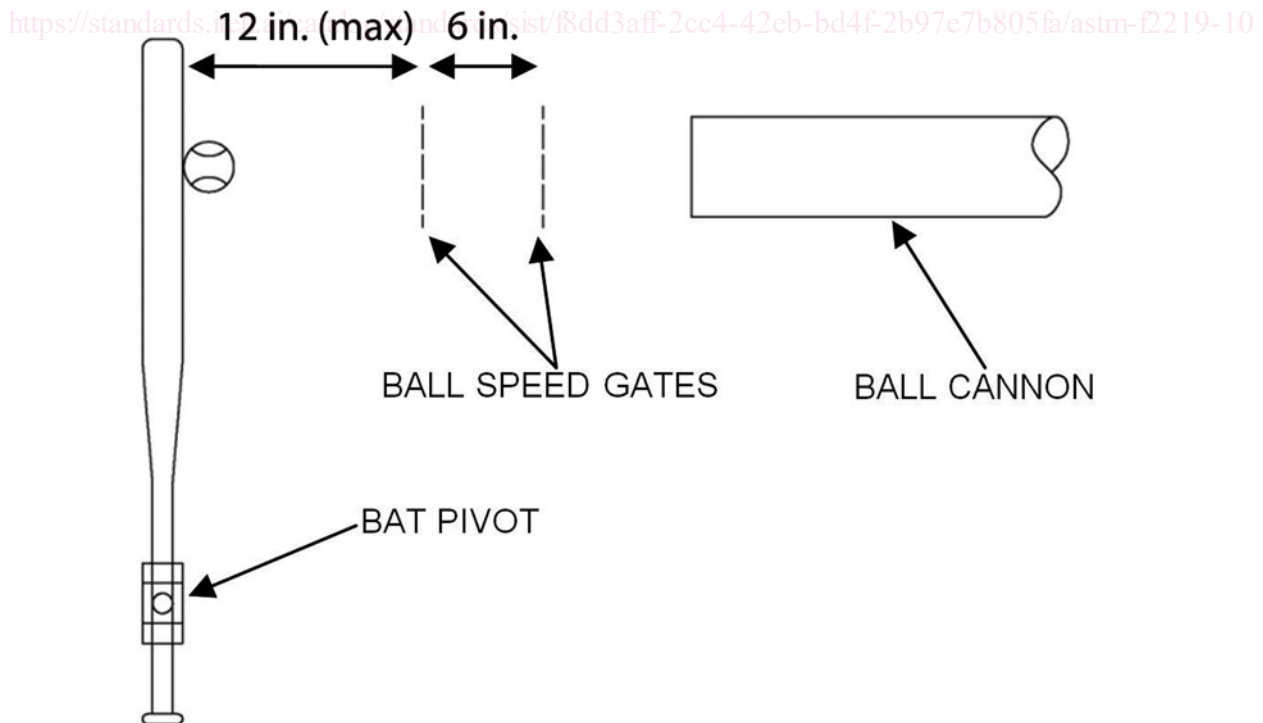


**FIG. 1 Bat Testing Machine**

## 6. Calibration and Standardization

6.1 *Ball Speed Gate*—~~The distances between the sensors of the speed gates must be known and recorded to the stated tolerances. The accuracy of the timers used in the velocity sensors must be adequate to provide the stated velocity accuracy at maximum stated speeds. The timers used shall be calibrated on at least a yearly basis.~~ The distance between the sensors of the speed gates should be measured and recorded. The timers used for speed measurements should be calibrated on at least a yearly basis.

6.2 *Reference Standards and Blanks*—A standard bat and ball shall be used for reference purposes to verify proper machine operation.

## 7. Conditioning

7.1 *Ball and Bat Conditioning and Test Room Conditions*:

7.1.1 Test balls shall be stored in an environmentally controlled space for at least 14 days immediately before testing. Wood bats shall be stored at these environmental conditions for at least 24 h prior to testing. Non-wood bats shall be stored at these test environmental conditions for at least 2 h prior to testing.

7.1.2 Temperature is to be maintained at 72 ± 4°F (22 ± 2°C).

7.1.3 Relative humidity (RH) is to be maintained between 40 and 60 %.

7.1.4 Temperature and relative humidity are to be measured and recorded hourly within ±0.5°F (±0.3°C) and ±2 % RH over the conditioning and test duration.

## 8. Procedure

8.1 *Determination of Bat Features and Test Location*—Determine bat balance point ~~(BP), bat MOI,~~ (BP) and bat ~~COP~~MOI in accordance with Test Method F2398.

~~8.2 *Impact Locations*—Three methods for testing are described herein for evaluating the performance of a bat. These methodologies provide alternatives for determining the impact location of the bat-ball collision prescribed by these test methods.~~

~~8.2.1 *Method A*—Impact location is 6 in. from the barrel end of the bat.~~

~~8.2.2 *Method B*—Impact location is at the COP.~~

~~8.2.3 *Method C*—Multiple impact locations for identifying the maximum value of the performance variable in question.~~

~~8.2.3.1 Select a performance variable (BBCOR, BESR, or BBS) to calculate. The choice of performance variable is left to those specifying the test requirements.~~

~~8.2.3.2 Test at an initial impact location 5.0, 6.0, or 7.0 in. (127, 152.4, or 177.8 mm) from the barrel end of the bat. Repeat testing at 1.0-in. (25.4-mm) intervals in either direction from the initial impact location until a local maximum is found, then converge on the maximum performance location in 0.5-in. (12.7-mm) increments.~~

~~8.2.3.3 The maximum value to the nearest 0.5-in. (12.7-mm) interval is the impact location to be used under Method C (that is, if local maxima are found at 4.0 in. (101.6 mm) and 5.0 in. (127.0 mm), the test is then done at 4.5 in. (114.3 mm). The max performance location is the one associated with the maximum of the test results obtained from these three impact locations of 4.0 in. (101.6 mm), 4.5 in. (114.3 mm), and 5.0 in. (127.0 mm)).~~

8.2 Select a performance variable (BBCOR, BESR, or BBS) to calculate. The choice of performance variable is left to those specifying the test requirements.

8.3 *Bat Test Procedure*:

8.3.1 Ready and calibrate ball speed gates in accordance with the manufacturer's instructions.

8.3.2 Select six test balls meeting requirement of 5.1, and record the actual values of compression, weight, size, and COR of the ball.

~~8.3.3 Set ball cannon to fire the ball per Table 1 at the desired impact speed as noted in Table 2 for Option 1 (softball) and Eq 1 for Option 2 which determines the nominal impact speed which varies with the desired impact point selected in accordance with 8.2. Valid test speeds are considered to be those within tolerance noted in Table 2 and Eq 1.~~

8.3.3 Set ball cannon to fire the ball at the desired test speed (60 to 150 mph) as determined by those specifying the test requirements.

8.3.4 Mount the bat in the clamps of the bat pivot support. Locate the bat pivot to provide a ball impact near the maximum performance location (often 6 in. from the distal end of the bat).

8.3.5 The ball impact must be centered vertically and horizontally on the bat diameter at the desired impact location.

8.3.6 Locate the bat against the start position reference to obtain a ball rebound perpendicular to the inbound ball line of travel (see Fig. 1).

8.3.7 Verify that all ball speed gates are reset and ready to take data.

8.3.8 Load the selected test ball in ball cannon. Load the test ball so that its impact with the bat will occur between the stitches of the ball.

8.3.9 Shoot the ball at the bat, observing the necessary safety precautions.

8.3.10 Verify proper bat alignment by observing the rebound path of the ball after impact with the bat. The ball rebound angle immediately after impact should be within ±5° of the inbound path. At slow ball rebound speeds the effects of gravity can be large, as shown in Fig. 2. Thus, the spatial limits for a valid rebound are speed-dependent.

8.3.11 Record the ball inbound speed, ball rebound speed, and the bat rebound speed. For inbound speeds below 120 mph, the