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An American National Standard

Standard Test Method for Measuring Softball Bat Performance Factor[1]

This standard is issued under the fixed designation F 1890; 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 specification defines a method for determining bat performance by measuring the Bat-Ball Coefficient of Restitution (BBCOR), deriving the Bat Performance Factor (BPF) and calculating a Batted Ball Speed (BBS). It is applicable to softball bats of any construction or material. The method provides a quantitative measure of bat dynamic performance that may be used for comparison purposes.

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

1.3 The values stated in English units are to be regarded as the 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 determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

F 1887 Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs

F 1888 Test Method for Compression-Displacement of Baseballs and Softballs

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

3.1.2 *bat-ball coefficient of restitution (BBCOR)*, *n*—the COR of a specific ball colliding with a bat as defined in this test method. See *coefficient of restitution (COR).*

3.1.3 *bat performance factor (BPF)*, *n*—the ratio of BBCOR to ball COR as defined in this test method.

3.1.4 *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. Forces and impacts at this location will not induce axial reactions at the pivot point.

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

3.1.6 *cycle*—one complete performance of the oscillation of the bat, specifically, one full swing of the bat.

3.1.7 *moment of inertia (MOI)*, *n*—a 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.

3.1.8 *period*, *n*—the time required for a pendulum to oscillate through one complete cycle.

4. Significance and Use

4.1 This test method offers a laboratory means to compare the performance of a softball bat.

4.2 Use of this test method can provide sports governing bodies a means to compare calculated batted-ball speed and other physical properties of the bat for the purposes of controlling the game.

5. Apparatus

5.1 *Bat COP Test Apparatus*:

5.1.1 *Ruler*, suitable for measuring lengths up to 42 in. (1067 mm) to the nearest 0.0031 in. (0.79 mm).

5.1.2 *Weight Scale*, suitable for measuring weight up to 48 oz (1360 g) to the nearest 0.0035 oz (0.1 g).

5.1.3 *Electronic Timer*, suitable device for measuring time to the nearest one microsecond (0.000001 s).

5.1.4 *MOI Stand*—A frame with a pivoting bat collar-clamp large enough to allow a bat held in a vertical position to swing freely (see Fig. 1).

5.1.5 *Bat Collar-Clamp*—A part of the MOI stand that allows quick accurate mounting of the bat without a variable MOI effect due to the clamp with a maximum MOI of 4 oz-in.^{2} (0.8 kg-cm^2) measured about the bat pivot location. A

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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.

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FIG. 1 MOI Fixture

lightweight clamp or collar that can hold the weight of a bat and provide a fixed pivot location. Collar shall be rotationally balanced (see Fig. 1).

5.2 *Test Balls*—Official softballs approved for play and tested in accordance with the following procedures.

5.2.1 *Compression*—350 to 375 lb at 0.25 in. deflection (1557 to 1668 N at 6.4 mm deflection) as determined per Test Method F 1888. Balls to be labeled with compression value.

5.2.2 *Weight*—6.25 to 6.75 oz (170.1 to 198.4 g). Balls to be labeled with weight value.

5.2.3 *Size*—12.00 to 12.25 in. circumference. (304.8 to 311.1 mm). Balls to be labeled with size value.

5.2.4 *Core Material*—Polyurethane.

5.2.5 *Ball COR*—0.450 to 0.470 as determined per Test Method F 1887. Balls to be labeled with COR and test speed in fps.

5.3 *Bat-Ball COR Test Apparatus*:

5.3.1 *Ball Cannon*—A device capable of shooting a ball at a speed of 88 ft/s. The ball shall not have a spin rate in excess of 10 rpm. Typical pitching machines cannot yield the aiming accuracy required by this test method. Cannon exhaust air must not cause motion of the bat in the absence of an impact.. The ball cannon can be any distance from impact location, as long as it can meet the ball aim requirements and provide six valid impacts in 12 shots or less.

5.3.2 *Bat Speed Gate*—A light trap device, or an equivalent, capable of measuring an edge traveling at speeds of between 5 and 15 feet per second with a resolution of one hundreth of a foot per second (0.01 ft/s)with an accuracy of at least ±1 % when the distance between the first and second sensor is between 3 in. (76.2 mm) and 3.6 in. (94.1 mm). The first sensor shall trigger when the bat rotates no less than 25° and no more than 30° from its start position. It is suggested the second trigger be 3 in. (76.2 mm) away from the first and must not be any further than 3.6 in. (91.4 mm) away on a 6-in. (15.24-cm) radius.

5.3.3 *Ball Speed Gate*—A light trap device, or an equivalent, capable of measuring a sphere traveling at speeds in excess of 88 ft/s (26.8 m/s) with an accuracy of 0.5 ft/s or better (0.2 m/s)The device shall measure across a length of no less than half the ball diameter to avoid centering error. For example, when testing softballs, 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 12 in. (30.5 cm) from the bat surface. The second sensor shall trigger between 3.6 in. (91.4 mm) and 8 in. (203.2 mm) from the first sensor.

5.3.4 *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 a radius no 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 in a pair of ball bearings (see Fig. 2). The polar MOI for the clamp turntable assembly shall not exceed 192 oz-in.^{2} (35117 g-cm^2). The actual MOI of the clamp turntable assembly shall be determined and used in the performance calculations.

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.

6.2 *Calibration Rod*—A calibration rod tested at two different pivot locations shall be used to determine if the MOI Stand is capable of accurately measuring the MOI of a bat. The rod shall be a 1 in. (25.4 mm) diameter by 24 in. (609. 6 mm) long steel rod weighing 85.65 oz (2.43 kg). The MOI of this rod measured with the pivot location at 8 in. (20.32 cm) should be 5487 oz-in.^{2} (1003 kg-cm^2) and at a pivot location of 2 in. (50. 8 mm) should be 12 682 oz-in.^{2} (2319.5 kg-cm^2). Deviations more than 50 oz-in.^{2} (9.15 kg-cm^2), after accounting for the MOI of the clamp fixture, shall be rectified before bats are tested.

6.3 *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*:

7.1.1 Balls shall be stored at the environmental conditions in 7.1.2 and 7.1.3 until their weight change over 24 h is less than 0.1 %. 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 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 is to be maintained at 50 ± 10 %.

7.1.4 Ball and bat tests should be completed within 1 h of removal from controlled area.

7.2 *Test Room Conditions*:

7.2.1 The test room shall be controlled environmentally.

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

7.2.3 Relative humidity is to be maintained between 20 and 60 %.

[redacted]

FIG. 2 Bat Testing Machine

8. Procedure

8.1 *Determination of Bat Features and Test Location*:

8.1.1 *Balance Point*—Measure and record the overall bat length to the nearest 0.0625 in. (1.58 mm) Place bat on level balance point stand as shown in Fig. 3. Record the weight measured by the 6 in. (Wt_6) and the 24 in. (Wt_{24}) scales to the nearest 0.035 oz (1.0 g). Eq 1 calculates the balance point relative to the distal end of the bat knob:

$$BP = \left[\frac{(6Wt_6) + (24\ Wt_{24})}{(Wt_6 + Wt_{24})}\right] \tag{1}$$

where:

BP = balance point from distal end of the bat knob,
Wt_6 = weight of the bat measured 6 in. from the knob,
Wt_{24} = weight of the bat measured 24 in. from the knob, and
Wt = Wt_6+ Wt_{24}= total weight of the bat.

8.1.2 *Bat MOI Set-Up*—Apply MOI clamp to bat handle so that the pivot location (point of the vee on underside of the clamp) is 6 in. ± 0.031 in. (152.4 mm ± 0.8 mm) from the distal end of the bat knob. Hang bat in MOI stand making sure the bat hangs vertically and can swing freely about the pivots. If the bat does not hang vertically, correct by centering the bat to the pivots.

8.1.3 *COP Test*—Rotate the bat about the pivots to an angle of 5° from vertical. Release bat and allow to swing freely. Allow bat to swing through 5 cycles and to settle into simple pendulum oscillation. Start the electronic timer when the bat reaches the bottom of the swing cycle. Stop the timer once the bat has completed 10 full cycles. The timer shall be triggered by a light beam broken by the path of the bat at the bottom of the pendulum arc. Repeat test five times to minimize timing errors. Do not use these results if the standard deviation of the five measurements is greater than 0.5 % of the mean. Instead, repeat the five measurements after repeating section 8.1.2. Determine and record the average period for the bat, using Eq 2:

$$average\ period = \left(\frac{\frac{time_1}{no.\ cycles_1} + \frac{time_2}{no.\ cycles_2} + \frac{time_3}{no.\ cycles_3} + \frac{time_4}{no.\ cycles_4} + \frac{time_5}{no.\ cycles_5} +}{number\ of\ tests\ (5)}\right) \tag{2}$$

8.1.4 *COP Location*—Calculate and record bat COP relative to pivot location stated in 8.1.2 using Eq 3:

$$COP = \left(\frac{(Avg.\ Period)^2\ g}{4\pi^2}\right) \tag{3}$$

where:

COP, in. = (average period)^2 (9.779)(in./s^2),
COP, cm = (average period)^2 (24.839)(cm/s^2), and
g = acceleration due to gravity, 32.17 ft/s^2 (9.806 m/s^2).

8.1.5 *Moment of Inertia, MOI*—Calculate and record the moment of inertia (MOI) of the bat to the nearest 0.1 oz-in.^{2} (182.7 g-cm^2) using Eq 4:

$$I = \left(\frac{(average\ period)^2\ gW_t a}{4\pi^2}\right) \tag{4}$$

where:

W_t = Total weight of the bat,
a = distance from pivot point to balance point, BP, thus *a* = BP – 6 in. (15.24 cm),
I, oz-in.^{2} = (average period)^2 (9.779)(Wt (BP – 6 in.)), and
I, cm-in.^{2} = (average period)^2 (24.839)(Wt (BP – 15.24 cm)).

8.2 *Bat Test Procedure*:

8.2.1 Ready and calibrate ball and bat speed light trap in accordance with the manufacturer's instructions.

8.2.2 Select a test ball meeting requirement of 5.2 and record the actual values of compression, weight, size, and COR of the ball per 5.2.

8.2.3 Set Ball Cannon to fire the ball at the desired impact speed of 88 ft/s (26.8 m/s). Valid test speeds must be done within ±3 ft/s (0.9 m/s).

8.2.4 Mount bat in the clamps on the Bat Pivot Support. The distal end of the bat knob must be 6 in. (152.4 mm) from the axis of rotation of the turntable assembly.

8.2.5 Center the bat barrel to the impact reference pin by rotating the bat about the handle in the clamps. The ball impact must be on centered vertically and horizontally on the bat diameter at the desired impact location per 8.2.

8.2.6 Position the bat against the start position reference which must place the bat axis perpendicular to the ball line of travel. (see Fig. 2).

8.2.7 Verify that all speed traps are reset and ready to take data.

8.2.8 Shoot ball at the bat observing the necessary safety precautions.

8.2.9 Load selected test ball in Ball Cannon. Attempt to load test ball so that its impact with the bat will be between the stitches of the ball.

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

8.2.11 Record ball inbound speed and bat rebound speed. Do not use data where the ball inbound speed deviates by more than the tolerances stated in 8.2.3 from the targeted test speed.

8.2.12 Continue testing for six valid impact readings or for 12 total impacts. Rotate the ball in the cannon so that the impact area of the ball is different for each impact. If six valid impacts are not achieved prior to 12 total impacts, fix the set-up to alleviate cause of invalid impacts. Verify support system for the bat, timer, or cannon are rigid. Retest using a new test ball.

9. Calculation of Results

9.1 Calculate the bat-ball coefficient of restitution (BBCOR) for each valid impact using Eq 5:

$$Bat\text{–}Ball\ COR = \left(1 + \frac{I}{wR^2}\right)\left(\frac{DRt}{drT}\right) - 1 \tag{5}$$

[redacted]

FIG. 3 Balance Point Fixture

where:

D = distance between bat speed sensors, in. (cm),
d = distance between ball speed sensors, in. (cm),
I = moment of inertia (MOI) of bat, oz-in.^{2}, (g-cm^2)
R = center of percussion distance (COP), in. (cm),
r = radius to bat speed sensors, in. (cm),
T = time for bat to travel through bat speed sensors, s,
t = time for ball to travel through ball speed sensors, s, and
w = weight of the ball used in each event, oz (g).

9.2 *Calibration*—Determine the value of the combinations (D/dr) as follows. Place a large calibration mass (MOI) ≥ 30 000 oz-in.^{2} in the bat position on the pivoting stage. Measure its MOI and COR as described above. Shoot a ball of known COR and weight (w). Measure t and T. Determine (D/dr) from ball COR as follows:

$$\frac{D}{dr} = \frac{1 + Ball\ COR}{\left(1 + \frac{I}{wR^2}\right)\left(\frac{Rt}{T}\right)} \tag{6}$$

9.3 Calculate the Bat Performance Factor (BPF) for each valid impact using Eq 7:

$$BPF = \frac{BBCOR}{Ball\ COR} = \frac{\left(\left(1 + \frac{I}{wR^2}\right)\left(\frac{D}{dr}\right)\left(\frac{Rt}{T}\right) - 1\right)}{Ball\ COR} \tag{7}$$

9.4 Calculate the bat average BPF for the test bat from the six valid impacts using Eq 8. When different balls are used to test the same bat, always be sure to calculate the BBCOR and BPF using the actual size, weight, compression and COR of the ball used in each of the six valid impacts:

$$BPF_{avg} = \frac{((BPF)_1 + (BPF)_2 + ... + (BPF)_6)}{6} \tag{8}$$

9.5 Calculate Batted Ball Speed (BBS) value of the test bat using Eq 9 and 10:

$$k = \left(\frac{w}{W}\right) + \left(\frac{w(R-a)^2}{(I - Wa^2)}\right) \tag{9}$$

$$BBS = \frac{V(1 + e) + v(e - k)}{(1 + k)} \tag{10}$$

where:

V = bat swing speed (mph) at the COP,
v = pitch speed (mph), the horizontal speed of the ball incoming to the batter,
W = bat weight, oz,
e = BPF × (SB COR ÷ TB COR),
a = distance from pivot to center of mass (balance point),
R = COP,
k = ball-bat inertia ratio,
$SBCOR$ = 0.46, and
$TBCOR$ = the measured COR of the test ball.

10. Report

10.1 Report the following information:

10.1.1 Name of the test facility and test operator,

10.1.2 Test date,

10.1.3 Test conditions,

10.1.3.1 Humidity and temperature of test room,

10.1.3.2 Humidity and temperature of the ball and bat conditioning environment,

10.1.3.3 Number of hours ball and bat were in conditioning environment,

10.1.4 Test equipment used for this test method,

10.1.5 Test Ball Information as per 5.2 including the compression, weight, size, and COR of the test ball,

10.1.6 Bat model, length, weight tested and any other pertinent data, such as condition of the bat or modification to the bat,

10.1.7 Bat MOI and COP, and MOI of the bat pivot support,

10.1.8 For each impact (including invalid impacts) ball inbound speed, bat rebound speed, BBCOR and BPF,

10.1.9 *Final Average Bat Performance Factor*—Assuming current ball COR measurement variations are ±0.01, the bat-ball COR uncertainty is currently ±0.02. This results in a BPF uncertainty of ±0.05. To reflect this uncertainty, the BPF assigned to each bat will be the measured average BPF reduced by the 0.05 uncertainty. Expected future improvements in measurement equipment and product control will reduce the above uncertainty,

10.1.10 Any and all unique observations including, but not exclusively, any damage to the bat, misdirected ball impacts, and any odd noises or vibrations, and

10.1.11 Calibration certificate numbers for measurement devices and velocity timers.

11. Precision and Bias

11.1 Precision and bias evaluations have not been conducted for this test method. When such data are available, a precision and bias section will be added.

12. Keywords

12.1 baseball bats; bat performance; BBCOR; BBS; BPF; COR; softball bats; softballs