Designation: F 1890 – ~~98~~01

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 coefficient of restitution (COR) of the bat-ball collision using a ball with a known COR then deriving a bat performance factor.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

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:*

[1] This test method is under the jurisdiction of ASTM Committee F-08 on Sports Equipment and Facilities and is the direct responsibility of Subcommittee F08.26 on Baseball and Softball Equipment and Facilities.

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F 1887 Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs[2]
F 1888 Test Method for Compression-Displacement of Baseballs and Softballs[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*
3.1.1 *balance point, n*—the distance to the center of mass measured from the outermost edge of the knob end of the bat.
3.1.2 *bat-ball coefficient of restitution (COR), n*—the COR of a specific ball colliding with a stationary bat as defined in this test method. See *coefficient of restitution (COR).*
3.1.3 *bat performance factor (BPF), n*—the ratio of performance change a bat introduces to a ball collision, compared to a ball colliding with a solid wall as in Test Method F 1887.
3.1.4 *ball cover, n*—the leather or equivalent material used to cover the ball core.
3.1.5 *center of percussion (COP), n*—also known as the center of oscillation, the length of a simple pendulum with the same period. Forces and impacts at this location will not induce reactions at the pivot point.
3.1.6 *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.
3.1.7 *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 overall performance of a bat as it relates to batted balls speeds.
4.2 Use of this test method can provide sports governing bodies a means to compare the anticipated batted ball speed, thus batted ball distance for the purposes of controlling the game and safety.
4.3 Batted ball speed can be related to bat performance factor (BPF) using the following formulae:
4.3.1 *V = bat swing speed, mph*—speed measured at the point of impact, at the sweet spot of the bat, otherwise specified as the COP. Impacts as the COP offer essentially the highest batted ball speeds due to the optimization of momentum transfer. The BPF value has been measured at this point and represents the maximum performance of the bat; therefore, the following calculations are correct only when the bat swing speed at the point impact are used. The swing speed at the COP can be as much as 20 % slower than bat speeds measured at the end of the bat. Typical adult values are 60 mph for average players and 70 mph for top level non-super major softball players. It is recognized that a players swing speed varies depending on skill level, conditioning, and bat swing weight (MOI).
4.3.2 *v = pitch speed, mph*—horizontal speed of the ball incoming to the batter. Typical slow pitch values are 10 mph while fast pitch speeds vary significantly with the level of play.
4.3.3 *W = bat weight, oz.*
4.3.4 *w = ball weight, oz.*
4.3.5 *II = MOI, oz-in.[2]—typical value for an average bat is 9000.* .
4.3.6 *e = bat-ball COR* = BPF × ball COR. One must choose a ball (SB COR to determine the batted ball speed. ÷ TB COR).
4.3.7 *a* = distance from pivot to center of mass (balance point); typical value is 14 in. point).
4.3.8 *R* = COP, the radius of rotation. Typical value for an average bat is 22 in. rotation.
4.3.9 *k* = ball-bat inertia ratio, a convenient means to collect terms. Typical value for the average bat is 0.35.

$$k = \left(\frac{w}{W}\right) + \left(\frac{w(R-a)^2}{(I - Wa^2)}\right) \tag{1}$$

4.3.10 Batted ball speed = $\frac{V(1 + e) + v(e - k)}{(1 + k)}$
4.3.11 Table 1 offers sample calculations to show
4.3.11 Bat-Ball COR = a value determined using the test method from the formula seti forth ins 7.14.
4.3.12 SBCOR = .46.
4.3.13 TBCOR = The measured coeffipcient of BPF and ball COR. restitution of the softball actually used in the test.

5. Apparatus

5.1 *Bat Center of Percussion Test Apparatus*:
5.1.1 *Ruler*, suitable for measuring lengths up to 42 in. to the nearest 0.10625 in. (3 (1.588 mm).
5.1.2 *Scale*, suitable for measuring weight up to 48 oz (1360 g) to the nearest 0.01 oz (20.28 g).
5.1.3 *Stop watchTachometer*, or other suitable device for measuring time to the nearest tehousandth of a second (0.001 s).
5.1.4 *Stand*—A frame large enough to allow a bat held in a vertical position to swing freely (see Fig. 1).

[2] *Annual Book of ASTM Standards*, Vol 15.07.

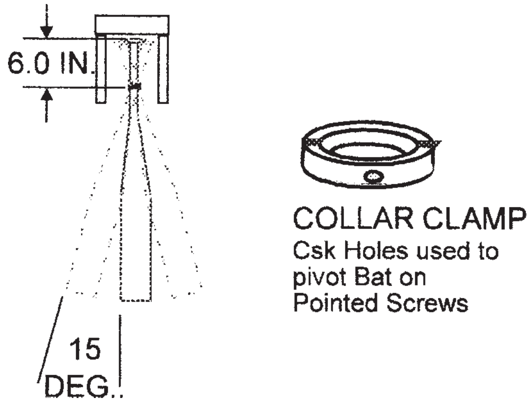


FIG. 1 MOI Fixture

5.1.5 *Collar-Clamp*— A light weight clamp or collar, which can hold the weight of a bat and provide a fixed pivot location. Collar shall be balanced rotationally (see Fig. 1). A simple hook-loop band used with sharp pointed screw may be used as a pivot.

5.2 *Bat-Ball COR Test Apparatus* :

5.2.1 *Test Balls*—Official softballs approved for play, individually tested in accordance with ~~ASTM standards TBD~~ Test Methods F 1887 and F 1888 and marked with their resulting COR and compression-displacement values. Balls may be used without the cover material to reduce variations in the test data. In this case, the ball COR must be tested in accordance with ~~ASTM Standard TBD~~ Test Methods F 1887 and F 1888 without the cover material. Test balls must meet the following specifications.

5.2.1.1 *Compression*— 350 to 375 lb at ¼-in. deflection (1557 to 1668 N).

5.2.1.2 *Weight*—6.5 ± 0.5 oz (185 ± 15 g).

5.2.1.3 *Size*—12.125 ± 0.125 in. circumference.

5.2.1.4 *Core Material*— Polyurethane.

5.2.1.5 *COR*—0.4~~7~~6 ± 0.010~~5~~ (0.4~~6~~5 to 0.47~~5~~).

5.2.2 *Ball Cannon*— A device capable of shooting a ball at a speed of 88 ft/s with a maximum aiming error of ± 0.125 in. ~~(6~~ (3.18 mm) at the point of impact. Ball shall not have a spin rate in excess of ~~50~~ 10 rpm. Typical pitching machines cannot yield the aiming accuracy required by this test method. Cannon exhaust air must not be allowed to pass to the bat. Cannon shall not blow out a match located in the impact location when cannon is dry fired (fired without a ball). ~~B~~ Aperture of the ball cannon ~~can~~ must not be ~~any distance~~ more than 3 ft from ~~impact location, as long as it can meet~~ the ~~ball aim requirements and provide six valid impacts in 12 shots or less.~~ impact location.

5.2.3 *Bat Speed Gate*— Light trap, or equivalent, device capable of measuring an edge traveling at speeds ~~in excess~~ of ~~88 ft/s (26.8 m/s)~~ 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 ~~0.5 fps or better (0.2 m/s).~~ 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 ~~15°~~ 25° and no more than ~~20°~~ 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.

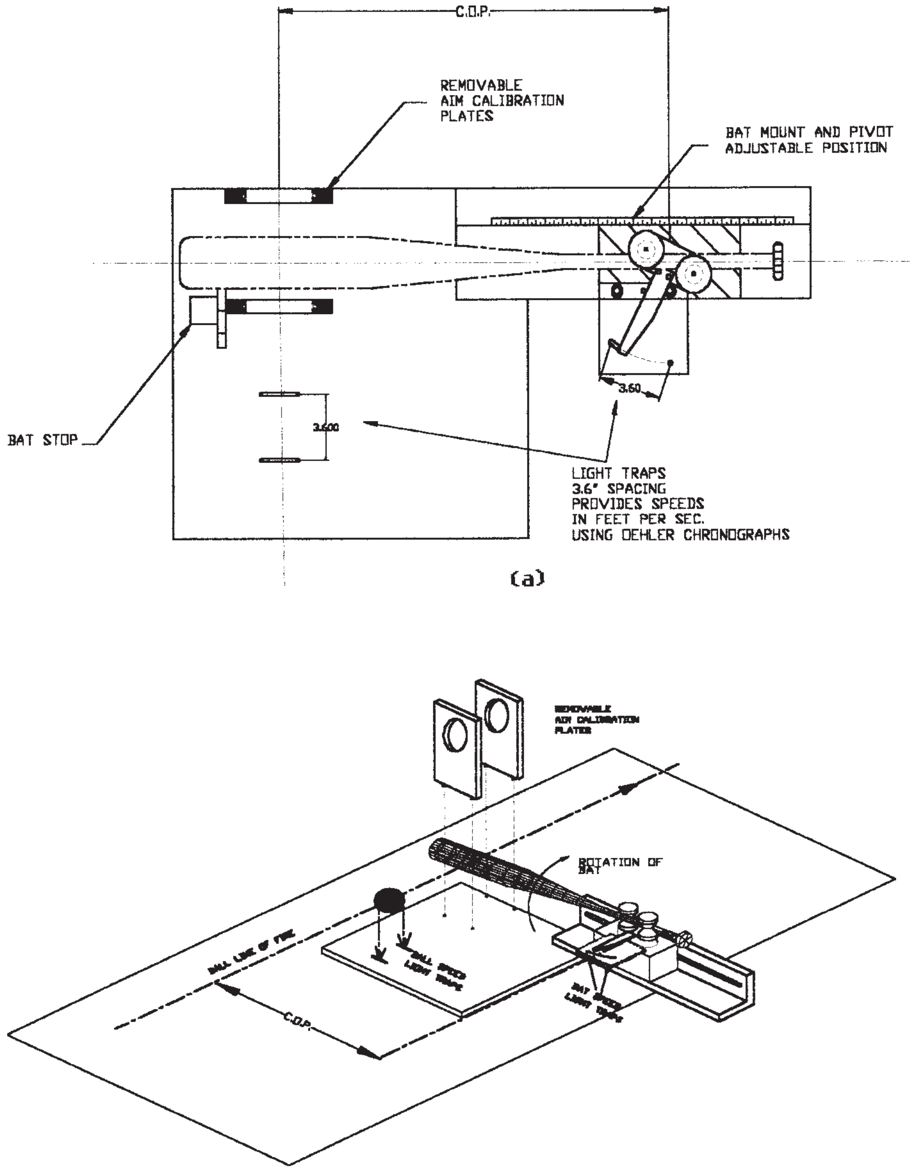
5.2.4 *Ball Speed Gate*— Light trap, or equivalent, device capable of measuring a sphere traveling at speeds ~~in excess of 88~~ between 87 and 89 ft/s (26.~~8~~5 and 27.1 m/s) with an accuracy of ~~0.5 fps (0.2 m/s) or better.~~ at least ±1 % when the distance between the first and second sensor is between 3.6 in. (91.4 mm) and 8 in. (203.2 mm). 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-in. (5-cm) line. The first sensor shall trigger when the ball is no more than 12 in. (30.5 cm) from the bat surface. It is suggested the second trigger be 3.6 in. away from the first and must not be any further than 8 in. (mm) away.

5.2.5 *Bat Pivot Support*—A turntable that rotates 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 in. (5 cm). 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 moment of inertia for the clamp turntable assembly shall not exceed 192 oz-in.^{2} (488 g-cm^2).

6. Determination of Bat Features and Test Location

6.1 *Weight*—Measure the weight of the bat to the nearest 0.01 oz (0.28 g).

6.2 *Balance Point*— Measure and record the overall bat length to the nearest 0.063 in. (2 mm) and overall bat weight as specified in 6.1. Place bat on balance point stand as shown in Fig. 3. Adjust height of knob stand to keep bat axis level. Knowledge of the knob and barrel diameters can be helpful here. Measure and record the barrel end weight of the bat. Calculate the balance point, *BP*, of the bat using the following formula:



(b)

FIG. 2 (a) Bat Test Stand Top View and (b) Bat Test Stand Exploded View

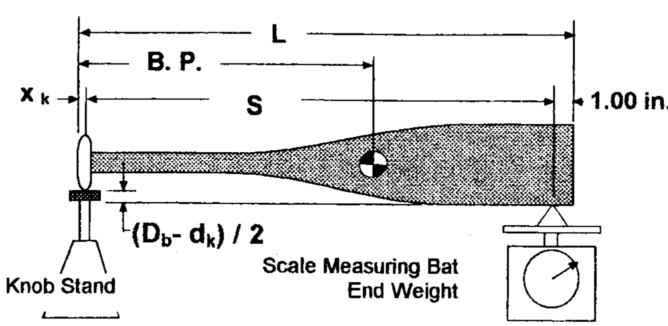


FIG. 3 Balance Point Set-Up

$$(BP - x_k) = \left(\frac{(W_e)(S)}{W_t}\right) \quad (2)$$

where:

L = overall bat length, in.,
x_k = knob overhang, distance from distal end of knob to contact point, in.,
S = span from knob stand to center of scale and bat barrel support, in.,
D_b = barrel diameter, in.,
d_k = knob diameter, in.,
W_t = total bat weight, oz, and
w_e = barrel end weight, oz.

6.3 *Bat Set-Up*—Apply collar or clamp to bat handle so that the pivot location is 6 in. (15.24 cm) from the outermost edge of the knob end of the bat. The bat must be centered to the pivot location. Hang the bat in stand making sure the bat hangs squarely and can swing freely about the pivots. If the bat does not hang squarely, correct by centering the bat to the pivots.

6.4 *COP Test*—Rotate the bat about the pivots to some angle less than 15° from vertical. Release bat and allow to swing freely. Allow bat to swing through approximately five cycles and settled into simple pendulum oscillation. Start the timing device specified in 5.1.3 when the bat reaches either end of the swing cycle. Stop the watch once the bat has completed ten full cycles. Repeat test at least three times to minimize timing errors. Do not use results that vary more than 5 %. If this occurs, retest the bat after verifying the bat is centered securely and properly to the pivots and bat swings freely. Determine and record the average period for the bat as follows:

$$\text{Avg. Period} = \left(\frac{\frac{\text{Time}_1}{\text{No. Cycles}_1} + \frac{\text{Time}_2}{\text{No. Cycles}_2} + \ldots + \frac{\text{Time}_{10}}{\text{No. Cycles}_{10}}}{\text{No. of Tests (3)}} \right) \quad (3)$$

6.5 *COP Location*— Calculate and record bat center of percussion (COP) relative to the 6-in. (15.24-cm) pivot point using the following formula:

$$\text{COP} = \left(\frac{(\text{Avg. Period})^2 \; g}{4\pi^2} \right) \quad (4)$$

$$\text{COP, in.} = (\text{Avg. Period})^2 (9.779) \left(\frac{\text{in.}}{s^2} \right) \quad (5)$$

$$\text{COP, cm} = (\text{Avg. Period})^2 (24.839) \left(\frac{\text{cm}}{s^2} \right) \quad (6)$$

6.6 *Moment of Inertia, MOI*—Calculate and record the moment of inertia (MOI) of the bat using the following formula. The MOI value will be referred to as I throughout the rest of this test method.

$$I = \left(\frac{(\text{Avg. Period})^2 \; g \, Wd}{4\pi^2} \right) \quad (7)$$

where:
W = bat weight, and
a = distance from pivot point to balance point, BP, thus:

$$a = \text{balance point} - 6 \text{ in. } (15.24 \text{ cm}) \quad (8)$$

$$I, \text{oz} \times \text{in}^2 = (\text{Avg. Period})^2 (9.779)(W(BP - 6 \text{ in.})) \quad (9)$$

$$I, \text{g} \times \text{cm}^2 = (\text{Avg. Period})^2 (24.839)(W(BP - 15.24 \text{ cm}) \quad (10)$$

7. Procedure

7.1 *Ball and Bat Conditioning*:

7.1.1 Balls and bats shall be stored at the test environmental conditions for at least 24 h prior to testing.

7.1.2 Temperature is to be maintained at 72 ± 2°F (22 ± 1°C).

7.1.3 Relative humidity is to be maintained at 50 ± 5 %.

7.1.4 Bats and balls are to be tested within 1 h after removal from controlled area.

7.2 *Test Room Conditions*:

7.2.1 The test room will be environmentally-controlled.

7.2.2 Temperature is to be maintained at 72 ± 2°F (22 ± 1°C).

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

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

7.5 Select a test ball, record ball weight and the verified COR of the individual ball.

7.6 Set ball cannon, or equivalent device, to fire the ball at a speed of 88 ft/s (26.8 m/s). Speed needs to be maintained within ±3 ft/s (0.9 m/s).

7.7 Align cannon, or equivalent, to squarely hit a flat plate placed in the desired bat impact area. Use carbon paper or equivalent pressure sensitive film to verify the center of the impact. The impact must be perpendicular to plate. The use of reference pins or stops to locate the vertical and horizontal center of the impact is strongly suggested. These references will be used to position the bat relative to the cannon's aim.

7.8 Mount bat in the clamps on the pivoting stage. The outermost edge of the knob end of the bat must be 6 in. (15.24 cm) from the center of the stage. Any reference stop must be removed prior to testing as the added inertia may have adverse effect on test results (see Fig. 2).

7.9 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 on the bat diameter and horizontally at the previously measured COP. Adjust the pivot location along the slide assembly to position the COP at the impact center line.

7.10 Position the bat against the start position reference which must place the bat axis perpendicular to the ball line of travel.

7.11 Verify speed traps are reset and ready to take data.

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

7.13 Record ball inbound speed and bat rebound speed. Do not use data where the ball inbound speed is less than 85 ft/s (25.9 m/s) or more than 91 ft/s (27.7 m/s).

7.14 Continue testing until for six valid impact readings or for 12 total impacts. If six valid impacts are not achieved prior to 12 total impacts, fix the set-up to alleviate cause of invalid impacts. Verify that the support system for the bat, timer, or cannon are rigid. Retest using a new ball.

7.15 Calculate the bat-ball collision COR using the following formula:

$$\text{Bat}-\text{Ball COR} = \left(1 + \frac{I}{wR^2}\right)\left(\frac{DRt}{drT}\right) - 1 \tag{11}$$

where:

D = distance between bat speed sensors, in. (cm),
d = distance between ball speed sensors, in. (cm),
I = moment of inertia (MOI), oz.-in^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).

7.15.1 *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:

$$\frac{D}{dr} = \frac{1 + \text{Ball COR}}{\left(1 + \frac{I}{wR^2}\right)\left(\frac{Rt}{T}\right)} \tag{12}$$

7.15.2 Calculate the Bat Performance Factor using the following formula:

$$\text{Bat Performance Factor} = \left[\frac{\text{Bat}-\text{Ball COR}}{\text{Ball COR}}\right] \tag{13}$$

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

7.16 Calculate the bat performance factor, BPF, for the test bat by calculating the average bat performance results for the six bat-ball COR events. When different balls are used to test the same bat, be sure to always calculate the results using the actual weight of the ball used in each of the six events:

$$\text{BPF} = \frac{(\text{BPF})_1 + (\text{BPF})_2 + \ldots + (\text{BPF})_6}{6} \tag{14}$$

8. Report

8.1 Report the following information:

8.1.1 Name of the test operator,

8.1.2 Test date,

8.1.3 Test conditions,

8.1.4 Test equipment used for this test method,

8.1.5 Ball models used in test including the individual COR test data report, 8.1.6 Bat model, length, weight tested and any other pertinent data, such as condition of the bat or modification to the bat,

8.1.7 Bat MOI and COP,

8.1.8 Bat-ball COR results for each event along with the ball COR used in each test event. Incoming ball speed also should be included to verify validity of impacts,

8.1.9 *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, and

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