NATIONAL COLLEGIATE ATHLETIC ASSOCIATION STANDARD FOR TESTING BASEBALL BAT PERFORMANCE

November, 2005

Revised: 30-October-2006

The following protocol has been adopted by the NCAA and must be followed when baseball bats are submitted for certification. This protocol has been adopted as an addendum to the NCAA baseball rules and does not supersede the rules.

This certification protocol follows ASTM standards where applicable. (http://www.ASTM.org)

Initial Written Notification

To initiate the certification process for all baseball bats that are constructed with materials other than one-piece solid wood, an interested bat manufacturer must send the NCAA Certification Center written notice of its intent to request certification testing on specific models it deems appropriate for testing. This notice, in turn, will be forwarded to the NCAA. This notice of intent must contain a detailed description of all models to be used in NCAA competition, the date of first production, the model number, the bat length and weight combinations of each model to be manufactured, the maximum diameter, the minimum handle diameter, location of the center of gravity (balance point) as measured relative to the tip of the barrel, the weight moment of inertia (MOI), the nominal wall thickness of the barrel and of any other part of the bat with a wall thickness that differs from the barrel, the ultrasonic setting used to determine wall thickness, and the materials (e.g., alloys, composites, any filling or deadening materials) used to make the product (including, without limitation, any materials used inside the bat and the materials composing and/or contained in the bat's end cap). Such information will not be confidential and will be available on request. In addition, either an 8" × 10" color photograph or equivalent digital photograph of each model to be certified, showing all graphics that will appear in the final version, will be provided to the NCAA. At that time, a request number, e.g., NCAA-06-0001, will be assigned to the bat by the Certification Center and only those bat models so registered will be cleared for testing. This written notice can be completed by filling out the online registration form at http://m-5.eng.uml.edu/ncaa.

Indemnification

By registering a bat, the registering party agrees to indemnify the NCAA (and any other governing body that recognizes BESR bats as meeting its bat performance standard), the University of Massachusetts-Lowell Baseball Research Center, and the University of Massachusetts System for any legal actions resulting from the bat so registered.

Certification Process

The NCAA then will require that a manufacturer supply a minimum of two typical bats of every length class (per Table 1), weight class (per Table 2), and model combination for certification to The Baseball Research Center, Department of Mechanical Engineering, University of

Massachusetts at Lowell, One University Avenue, Lowell, Massachusetts 01854 (978/934-2995, james_sherwood@uml.edu). Dr. James A. Sherwood and his research team will conduct the certification tests as stated in the testing protocol on one of the bats for each length, weight and model. All bats which are sold or otherwise provided for NCAA play by the manufacturer must meet the specifications of the new standard in order to be certified for NCAA competition. If approved, the NCAA will provide written confirmation for each approved bat. No bat will be tested for compliance without first being registered. Registered bats will be tested for compliance in the order that they are received by the Certification Center.

Table 1. Length Classes for Bats

Length Class (plus or minus range, in inches)
29.0 -0.25/+0.24
29.5 -0.25/+0.24
30.0 -0.25/+0.24
30.5 -0.25/+0.24
31.0 -0.25/+0.24
31.5 -0.25/+0.24
32.0 -0.25/+0.24
32.5 -0.25/+0.24
33.0 -0.25/+0.24
33.5 -0.25/+0.24
34.0 -0.25/+0.24
34.5 -0.25/+0.24
35.0 -0.25/+0.24
35.5 -0.25/+0.24
36.0 -0.25/+0.24

Table 2. Weight Classes for Bats Without Grip

Weight Class [Unit difference, weight (oz) minus length (in.)]
-3 → -3.000 to -2.100
-2 → -2.095 to -1.100
-1 → -1.095 to -0.100

A mandatory silk-screen or other permanent certification mark will consist of the phrase "BESR Certified" and must be clearly displayed on the barrel end of the bat. The manufacturer may use the certification mark in descriptive materials (such as catalogs) to identify bats that comply with this testing standard, but may not make other use of the mark. Use of the certification mark to advertise or promote the sale or distribution of bats is expressly prohibited. There will be no charge for the use of the certification mark in accordance with this protocol.

In the event that all bats submitted for testing become damaged and/or unusable for testing, the manufacturer will be notified by the Certification Center and requested to submit at least two more bats for certification. The certification of that length, weight and model combination will then go to the next open position in the certification queue, i.e., end of the line, upon receipt of the new bats.

All bats may be returned except for the tested bat(s) and one untested bat for record-keeping purposes. The retained bats will be stored in a secure area and only Certification Center personnel will have access to the area. The manufacturer will be assured by the NCAA that the design of its bat is protected.

Test Results

The Certification Center will provide the NCAA in writing with the test results of each length and weight combination for each model submitted by the manufacturer for certification. The NCAA will then forward the test results to the manufacturer. If a bat is submitted for testing by a sponsor other than the manufacturer, the Certification Center will provide the test results in writing to the NCAA, and the NCAA will forward those results to the sponsoring party. If a bat submitted by a sponsor other than the manufacturer fails the certification test, copies of the test results will also be provided in writing to the manufacturer.

Upon request, copies of all data sheets for every hit will be supplied in confidence to the NCAA and to the test sponsor. If a bat that has been submitted for testing by a sponsor other than the manufacturer fails the certification test, copies of all data sheets will also be supplied to the manufacturer upon request. The original data sheets will be filed in hard copy and digital form at the Certification Center and in digital form at a secure off-site location. Information on the data sheet belongs to each test sponsor (and the manufacturer, if the test sponsor is not the manufacturer and the bat fails the certification test) for internal purposes only and will be kept confidential by the Certification Center and the NCAA unless otherwise provided herein. The NCAA will retain the right to announce publicly that a bat has failed the certification test.

Manufacturers may, at their discretion, disclose the results, including test data, of testing on bats that they have manufactured. If a manufacturer discloses such information, however, the NCAA may make any additional disclosure of information from the same test that it deems appropriate.

Testing Expenses

All of the expenses to conduct the testing at the University of Massachusetts at Lowell Baseball Research Center will be funded by the manufacturer or test sponsor for which certification testing will be conducted. All manufacturers should work directly with the Certification Center regarding the testing expenses.

Proof of Certification

Only baseball bats that display an official NCAA certification mark on the barrel-end of the bat signifying compliance with the NCAA's bat performance standard are allowed in regular-season

and post-season competition. Solid bats constructed from a single piece of wood are allowed for NCAA competition without being tested for NCAA bat standard compliance.

Compliance with the Performance Standard

The NCAA will conduct discretionary periodic testing of certified baseball bats at its expense to ensure compliance with the standard. This testing is intended to fairly sample the bats used in NCAA play at the time of the testing. Bats will be obtained from both dealer stock and field service. Teams that provide field-service bats for compliance testing will be reimbursed by the NCAA for the costs of those bats. If any nonconforming bats are identified, the NCAA will notify the manufacturer in writing of its findings. A bat length, weight and model combination will not be declared nonconforming unless three different bats with that length, weight and model combination have failed the compliance testing. The manufacturer will be given the opportunity to review the compliance report and will be allowed an appeal in writing of the findings to the NCAA Baseball Rules Committee within fourteen (14) days upon receipt of the notice of findings. This right to appeal will include a right to retest the bat or bats in question at the manufacturer's expense, and the results of any retest will be provided to the NCAA who will, in turn, forward the results to the manufacturer. Once any retesting is complete, the rules committee will act on the appeal and notify the manufacturer of its decision within seven (7) days. The rules committee will disallow any bat that does not meet the standard for regular-season or post-season competition.

Manufacturer Right to Submit a Competitor's Bat for Compliance

Manufacturer A is permitted to submit Manufacturer B's bat for testing in accordance with the section above titled Compliance with the Performance Standard, and manufacturer A pays for all of the testing associated with the compliance investigation regardless of the outcome. If B's bat does not comply, then the Certification Center will notify the NCAA, and the NCAA will take appropriate steps for noncompliance as described above. The same appeal procedures as described above will apply in this circumstance, and the test sponsor will be entitled to the results of any retest and appeal. The results of the test (including all test data) will be shared with the NCAA and the test sponsor in the manner described above. If the bat fails the certification test, the test results will also be shared with the manufacturer. The compliance bat must be officially registered before any compliance testing can commence at the Certification Center. This registration can be done by completing the online form at http://m-5.eng.uml.edu/ncaa/Competitor_Test.htm. At that time, a request number, e.g., NCAA-C-06-0001, will be assigned to the bat by the Certification Center and only those bat models so registered will be cleared for testing. A copy of this registration will be forwarded to the NCAA.

Penalty for Modification of Bat after It Leaves the OEM

A manufacturer will not be held responsible for noncompliance in the event that an aftermarket party alters the bat in any manner. The NCAA will deal directly with the team that collaborated with the aftermarket party. The manufacturer should make a best effort to produce a tamperproof bat, e.g., no screw-off end cap.

Testing Protocol

Where possible, this protocol is based on the following standard: ASTM Designation F2219-05, Standard Test Methods for Measuring High-Speed Bat Performance. (http://www.ASTM.org)

Bat Preparation Procedures

1. Measure and record model, length to nearest 1/16 in., weight to nearest 0.005 oz, and location of the center of gravity to the nearest 0.03 in.
2. Draw circumferential lines at 3, 4, 5, 6, 7, 8 and 9 in. from the tip of the barrel and a longitudinal axis line; measure and record the diameter at these locations.
3. Mark a line 4 in. from the base of the knob and attach clamp to ensure rotation about 6 in. from the base of the knob.
4. Measure Weight Moment of Inertia (MOI)
    - Required Apparatus:
      A timer capable of sampling at a rate of at least 1 MHz; a collar to be clamped onto the bat that has a maximum MOI of 4 oz-in.^{2} and is rotationally balanced; a stand that allows for the bat to swing freely and a collar-clamp that pivots on a knife edge. (ASTM F2398-04e1, Test Method for Measuring Moment of Inertia and Center of Percussion of a Baseball or Softball Bat)
    - Procedure:
      Apply MOI collar-clamp to bat handle so that the pivot location (point of the vee on underside of the clamp) is 6 ± 0.03 in. from the proximal end of the bat knob.

      Hang bat in stand making sure that the bat hangs vertically and can swing freely about the pivots. (ASTM F2398-04e1, 6.2.1) Rotate the bat about the pivots to an angle of 5^o from vertical. Release the bat and allow it to swing freely. Allow the bat to swing through five cycles. Then start the electronic timer at the bottom of the swing cycle and stop the timer when the bat has completed an additional ten cycles. The timer will 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 the results if the standard deviation of the five measurements is greater than 0.5% of the mean. Instead, repeat the five measurements after checking the setup. Use the average period for calculating the MOI. (ASTM F2398-04e1, 6.2)
    - Calculation:
      The moment of inertia is calculated from the relation

$$\mathrm{MOI} = 9.779 T^2 W \left(L - D - 6 \right) \qquad (1)$$

      where MOI is the weight moment of inertia (in oz-in.^{2}), T is the average period (in seconds), W is the weight of the bat (in ounces), L is the length of the bat (in

inches), and *D* is the location (in inches) of the center of gravity measured from the barrel end of the bat.

Minimum MOI Rule

The baseball bat must have an MOI about the point 6 inches from the base of the knob greater than or equal to the value identified in Table 3 for the associated length class.

Table 3. Minimum Allowable MOI (oz-in.^{2}) for Associated Length Class

Length (in.)	MOI at 6 in. from base of knob (oz-in.^{2})
29.0	5407
29.5	5725
30.0	6064
30.5	6424
31.0	6805
31.5	7207
32.0	7630
32.5	8073
33.0	8538
33.5	9024
34.0	9530
34.5	10058
35.0	10607
35.5	11176
36.0	11767

Testing System

Ball Cannon:

The device must have a muzzle velocity of at least 150 mph. The ball will not have a spin rate in excess of 10 rpm. Cannon exhaust air must not cause motion of the bat in the absence of an impact. The ball cannon can be any distance from the impact location, as long as it can meet the ball aim requirements. (ASTM F2219-05, 5.2.1)

Ball Speed Gate:

A light trap device, or an equivalent, is required that can measure a sphere traveling in excess of 150 mph with an accuracy within 1.5 mph. The device will measure across a length of no less than half the ball diameter to avoid centering error. The first sensor will trigger when the incoming ball is no more than 18.0 in. from the bat surface. A second sensor will be located 6 in. from the first sensor in the direction of the bat, and a third sensor will be located 6 in. from the second sensor in the direction of the bat. The distance between the sensors must be maintained within 0.005 in. Light sensors 1 and 3 will be those identified in ASTM F2219-05, 5.2.2. The

device must also be able to measure the ball rebound speed using the same sensors. This requires the device to reset and arm quickly enough to capture the ball traveling back through the speed gates. The data acquisition software will calculate the ball speed from each pair of sensors: 1 and 2, 1 and 3, and 2 and 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, is required. The bat will be clamped between 45° vee clamps with a radius of no greater than 2.0 in. The rotating clamp and shaft assembly will not weigh more than 6 lbs and will spin freely via ball bearings. The polar MOI for the clamp turntable assembly will not exceed 192 oz-in.^{2}. (ASTM F2219-05, 5.2.3)

Baseball Lot Preparation
The baseballs used for testing will have a mass of 145.4 ± 1g. The circumference of the ball will be 9.05 ± 0.05 in.

To adjust for the potential of differing baseball properties, each new lot of baseballs will have a sample of 30 valid-hit baseballs tested using the standard bat described in the September 1999 protocol. Each ball in the sample will be tested by impacting the standard bat at the 6 in. location with an impact speed from the air canon of $V = 138 \pm 2$ mph, and the rebound speed v of each ball will be measured. For each ball, determine the correction factor ε as follows:

$$\varepsilon = 0.1884 - \frac{v}{V} \tag{2}$$

Each of the 30 baseballs will be impacted one time. The average for the lot, $\langle \varepsilon \rangle = \Sigma \varepsilon_i / 30$, will be determined by averaging over the 30 valid-hit baseballs.

Bat Testing Procedure

- Mount the bat into the grip such that the proximal end of the knob is 6 in. from the axis of rotation. The grip material may consist of Astroturf placed between the vee clamps and the bat to allow for the rotation of the bat in the grip between hits. The grip material will be uniform from test to test.
- Select a baseball from the lot which has fewer than eight (8) previous impacts. Measure the weight to ensure that it is in the acceptable range, and record the weight and the date on the ball. Then mark the ball with and "x" on the side of the ball that is to be impacted.
- Load the selected test ball in ball cannon. Attempt to load the ball so that its impact with the bat will occur between the stitches of the ball and on the side that the "x" was marked.
- The ball impact must be centered vertically and horizontally on the bat diameter at the desired impact location z, measured in inches from the barrel end of the bat.
- Set the ball cannon to fire the ball at the desired impact speed of $V_{Contact} \pm 2$ mph into the bat that is at rest until impact as calculated using Equation 3 for each impact location z.

For the purposes of certification, a valid hit will require the speed measurements from sensors 1-2 and 2-3 to not differ by more than 2 mph, and similarly, the rebound measurements of sensors 3-2 and 2-1 to also not differ by more than 2 mph.

$$V_{\text{Contact}} = (66 \text{ mph})\left(\frac{L-6-z}{L-12}\right) + 70 \text{ mph} \tag{3}$$

where L is the length of the bat (in inches).

- Verify proper bat alignment by observing the rebound path of the ball after impact with the bat. The ball should rebound directly back towards the cannon, retracing its impact trajectory within $\pm 5^{o}$. (ASTM F2219-05, 8.3.10)
- All bat axial positions are measured with respect to the distance from the tip of the barrel. Raw data inbound and rebound speeds are to be recorded with testing to commence at the 6-in. position. Bat profiling will continue with hits at the 5-in., then the 7-in. positions. The testing will continue with hits at additional points using 0.5-in. and/or 1.0-in. increments at the discretion of the certification personnel until the sweet spot location is isolated.
- Six (6) consecutive valid impacts are to be recorded at each of the bat-axis impact locations. Consecutive valid readings will be determined without regard to any interspersed invalid readings; thus, for example, four valid readings, followed by an invalid reading, followed by two valid readings will be considered six consecutive valid readings. The total number of hits may vary from bat to bat.
- Nonwood bats will be rotated in 1/4- or 3/8-turns or randomly prior to each hit to ensure quasi-even exposure to impacts. The wood bats will be rotated 180^{o} prior to each hit or not rotated at all according to standard wood bat usage, i.e., label up and label down.
- Alignment of the bat will be checked before each hit.

Performance Calculations

Bat performance is specified by using the BESR (Ball Exit Speed Ratio), which is calculated using the inbound and rebound speeds of the ball:

$$\text{BESR} = \frac{V_{\text{R}} - \delta v}{V_{\text{I}} + \delta v} + 0.5 + < \varepsilon > \tag{4}$$

where V_{I} (sensors 1 to 3 measurement) and V_{R} (sensors 3 to 1 measurement) are the ball inbound and rebound speeds, respectively and

$$\delta v = 136 \text{ mph} - V_{\text{Contact}} \tag{5}$$

Equation 3 is used to normalize the data with respect to bat and ball input speed variations. The BESR will be the average of six (6) valid readings at the point of maximum speed, as discussed previously. At the point of maximum exit speed, an average of six (6) valid hits is used to

determine BESR compliance. If at anytime during the certification process, the average of six (6) consecutive valid hits exceeds the limiting BESR, then testing is halted and the bat is concluded to be noncompliant for NCAA competition.

Maximum BESR Rule
The baseball bat must have a BESR less than or equal to the value identified in Table 4 for the associated length class.

Table 4. NCAA Maximum BESR Limits
for Associated Length Class

Length (in.)	BESR Limit*
29.0	0.698
29.5	0.701
30.0	0.704
30.5	0.707
31.0	0.710
31.5	0.713
32.0	0.716
32.5	0.719
33.0	0.722
33.5	0.725
34.0	0.728
34.5	0.731
35.0	0.734
35.5	0.737
36.0	0.740

* Relative to Aug.-Sept. 1999 34-in. wood

Length-to-Weight Unit Differential
The length-to-weight unit differential of each nonwood bat will not exceed three units without the grip. Each length-class and weight-class combination of a particular model must be certified for compliance.

Bat Surface
The surface of the bat tested for certification must be the same as that of the production bat model which it represents and may exclude graphics.

Bat Diameter
The barrel diameter will be no greater than 2.625 in. A certified bat ring, 1-in long and greater than ¼-in. thick with a maximum interior diameter of 2.657 +0.001/-0.005 in. must pass

completely over the length of each bat prior to and after each hit or the bat will be certified to be noncompliant.

Conditioning
Baseballs will be stored in the environmental conditions of 72 ± 4 ºF and 50 ± 10% relative humidity until their weight change over a 24 hour period is less than 0.1%. Wood bats will be stored in these same environmental conditions for at least 24 hours prior to testing. Nonwood bats will be stored at these conditions for at least two hours prior to testing. Testing will take place in an environmentally controlled room with a temperature of 72 ± 4 ºF and a relative humidity between 20 and 60%. (ASTM F2219-05, 7)

External Observers
Manufacturer attendance is optional. Outside observers representing the organization that submitted the bat for testing may be present, but must follow the directions of the certification operators.

Work-Hardening
The NCAA is continuing to study the issue of work-hardening in nonwood bats. At this time, the protocol will not contain specifications that attempt to address the issue of work-hardening.

Compliance Testing
All bats submitted for Compliance Testing will be tested per the same protocol as described for Certification Testing and will be judged whether or not to be in compliance by the same Pass-Fail Criteria as are used for Certification Testing with one possible exception.

In the event that a bat submitted for compliance testing, hereafter called the Compliance Bat, fails to satisfy the BESR prong of the pass-fail criteria, an additional performance comparison will be invoked:

- The BESR performance for the bat of the same length/weight/model configuration that was previously found by the Certification Center to meet the BESR requirements, hereafter called the Certification Bat, will be retested per the certification protocol with the same lot of baseballs that was used to test the Compliance Bat.
- The BESR as measured in the original certification test of the Certification Bat will be subtracted from BESR as measured in the retest of the Certification Bat. This difference will be called the "apparent shift".
    - For example, if the certification test BESR value for the Certification Bat was 0.722 and the retest BESR is 0.728, then there is an "apparent shift" in the allowable BESR of +0.006 due to the difference between the two lots of baseballs.
- If the BESR of the Compliance Bat is found to exceed the BESR limit of the baseball lot by more than the "apparent shift", then the Compliance Bat will be concluded to be noncompliant.
    - For example, if the Certification Bat demonstrates an "apparent shift" of 0.006, and the Compliance Bat exceeds the BESR limit for the current lot of baseballs used in the compliance test by 0.007, then the Compliance Bat fails the BESR prong of the Pass-Fail Criteria.
- If the Compliance Bat does not exceed the BESR limit for the baseball lot by more than the "apparent shift", then the Compliance Bat will be concluded to be in compliance with the BESR prong of the Pass-Fail Criteria.
    - For example, if the Certification Bat demonstrates an "apparent shift" of 0.006, and the Compliance Bat exceeds the BESR limit for the current lot of baseballs used in the compliance test by 0.005, then the Compliance Bat satisfies the BESR prong of the Pass-Fail Criteria.

The intent of this comparison of the Certification Bat and the Compliance Bat is to address the potential situation where slight differences in the performance of the ball lot used for compliance testing and the ball lot used for certification testing and/or the standard bat may introduce a small change in the effective BESR measurements of the bat being tested. This method for comparison of the Certification Bat and the Compliance Bat will ensure that a manufacturer is not unfairly penalized.

Summary of Pass-Fail Criteria

1. The bat must meet the size and weight specifications.
2. There are no tolerances for length-weight differences (no greater than three units without the grip) or for maximum barrel diameter.
3. The bat must have an MOI (6 in. from the knob) greater than or equal to the minimum allowable for the bat's length class.
4. The bat ring must pass over the entire length of the bat before and after every hit.
5. The BESR, as determined from an average of six (6) consecutive valid hits at the maximum speed location described above, must not exceed the BESR limit.

Revisions

The NCAA will revise the protocol as needed and reserves the right to change the test equipment, test location and the testing personnel. The NCAA will announce in a timely manner any future changes to the rules or protocol.