

BAT PERFORMANCE 2002

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- 1. The BPF System
 - a. Review
 - b. COM and MOI Measurements
 - c. Ball and Bat Dependence
 - d. Data
- 2. Hit Ball Speed
 - a. ASA Test
 - b. Swing Speed
 - c. Velocity Ratio
- 3. Performance Profiles
 - a. Need and Problems
 - b. Solutions
 - c. Data
- 4. High Speed Measurements

1. BPF SYSTEM

- COR:
- $e = (\text{ball.reb.sp} + \text{bat.sp}) / (\text{ball.inc.sp})$
- $e = (v' + V') / v$
- Impact at COP gives field COR

- CONSERVATION:
- $\text{ball.mom.in} = \text{ball.mom.out} + \text{bat.mom}$

- HBS (at COP):
- $(\text{swing.sp} * (1+e) + \text{pitch.sp} * (e-k)) / (1+k)$
- $v' = (V(1+e) + v(e-k)) / (1+k)$
- $k = \text{ball.wt} * \text{COP} / \text{bat.wt} * \text{COM} = w_c / W_a$
- COR, measured with bat at rest,
- gives HBS

QuickTime™ and a
Animation decompressor
are needed to see this picture.

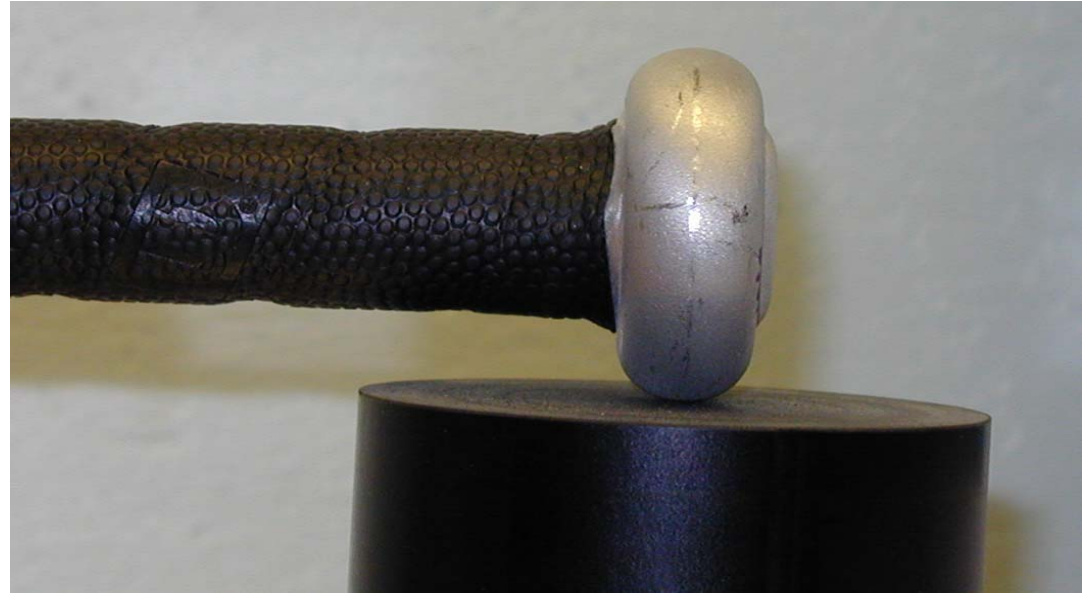
BAT PERFORMANCE FACTOR

- $BPF = \text{BAT-BALL COR} / \text{BALL COR}$
- Independent of ball COR
- Not independent of ball compression or weight
- Current accuracy level: ± 0.004
- 6 shots: 1.23 1.23 1.23 1.23 1.23 1.23

COM MEASUREMENTS

- ASTM METHOD

- W = bat weight
- W_e = scale value
- S = distance from scale to “average” knob loc (± 0.1 ”)
- X = distance from end to “average” knob loc (± 0.1 ”)
- $COM = X - 6” + W_e * S / W$



- NYU METHOD

- $W_{1,2}$ = scale values
- B = distance from scale to scale (± 0.001 ”)
- $COM = W_2 * B / W$



MOI MEASUREMENTS

- PERIOD = T
- $COP = T^2 * g / 4\pi^2$
- $MOI = Wac$
- $= W * COM * COP$
- Bar meas: T=1.2286, 1.2288, 1.2286
- Bar calc: T=1.2288



DEPENDENCE ON BALL AND BAT

BPF AND BBS DEPENDENCE ON BALL AND BAT PARAMETERS						
PARAMETER	PARAMETER CHANGE		BPF CHANGE		BBS CHANGE (fps)	
Ball COR	0.47	0.42	1.20	1.20	123	118
Ball Weight	6.5 oz	6.0 oz		1.21		127
Ball Comp	400 lbs	650 lbs		1.21		123
Bat Wall	0.080 in	0.074 in		1.23		124
Bat End Load	1 oz	3 oz		1.22		126
Bat Knob Load	1 oz	3 oz		1.19		120

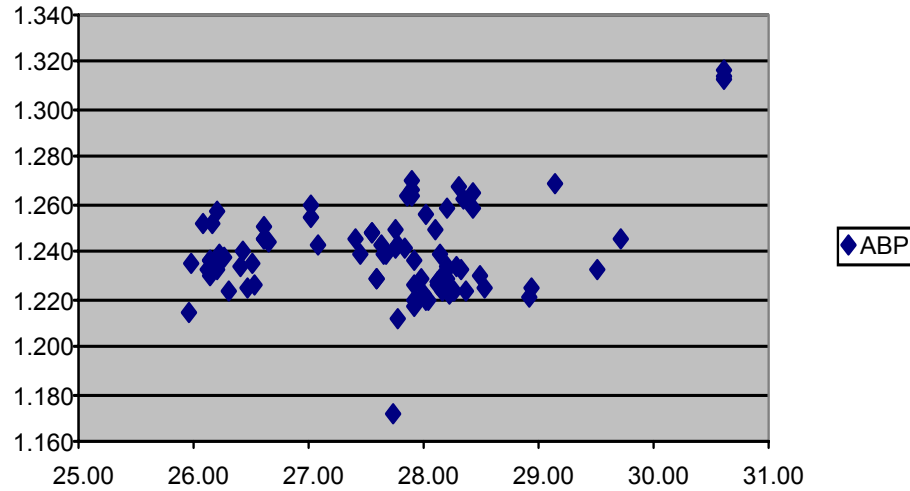
EFFECT OF 3 OZ LOAD INCREASES ON BAT PROPERTIE								
LOCATION	COM CHANGE		COP CHANGE		BPF CHANGE		SS CHANGE	
End Load	14	15.5	22	23	1.20	1.23	22	23
Knob Load	14	12	22	24.4	1.20	1.19	22	22

For a knob-loaded bat, the SS may not be close to the COP.

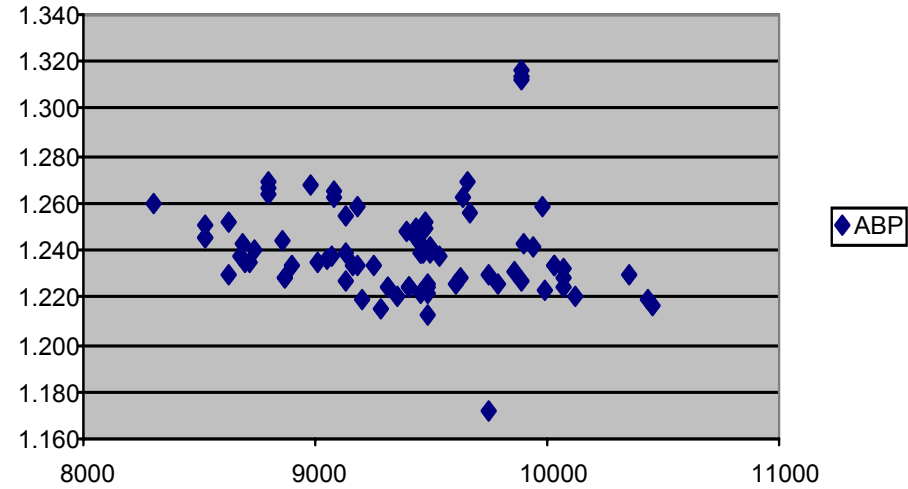
Bat profiles are needed.

ASA DATA (84 BATS)

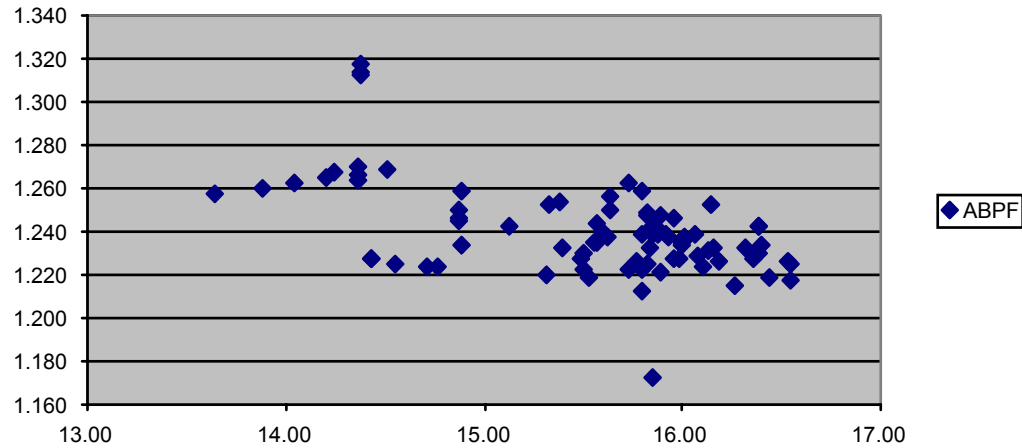
ABPF vs WEIGI



ABPF vs MK



ABPF vs COM



2. HIT BALL SPEED (ASA, at COP)

$$HBS = \frac{V(1 + e) + v(e - k)}{1 + k}, k = \frac{wc}{Wa}$$

$$V = \text{swing.speed} = (70\text{mph})(30\text{oz} / W)^{0.25}$$

$$v = \text{pitch.speed} = 10\text{mph}$$

$$e = \text{bat} - \text{ball.COR} = BPF * 0.47$$

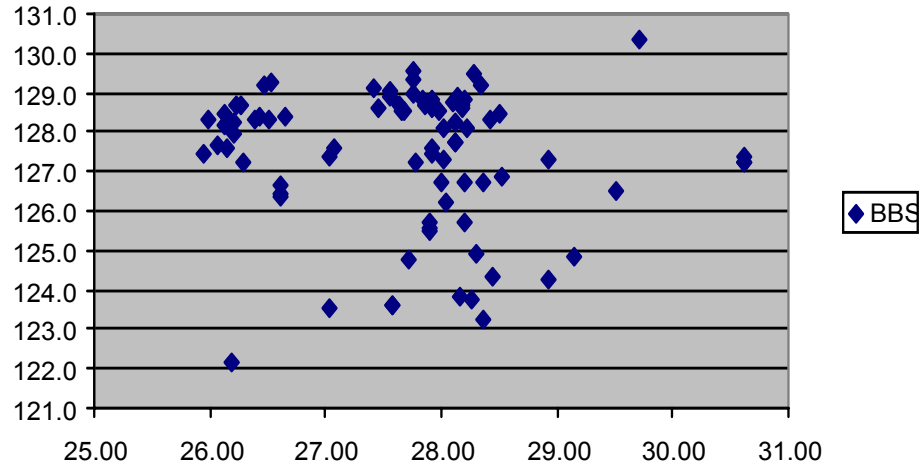
$$w = \text{ball.weight} = 6.5\text{oz}$$

$$W = \text{bat.weight}$$

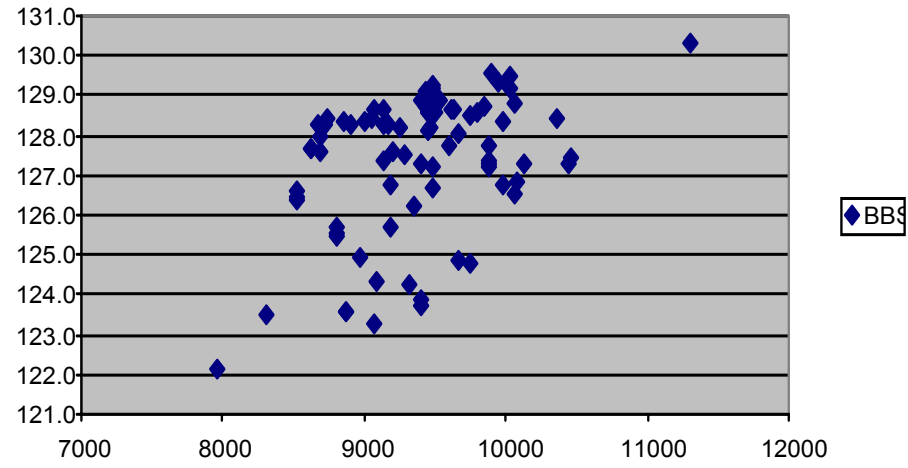
$$c = \text{COP}, a = \text{COM}$$

ASA DATA (84 BATS)

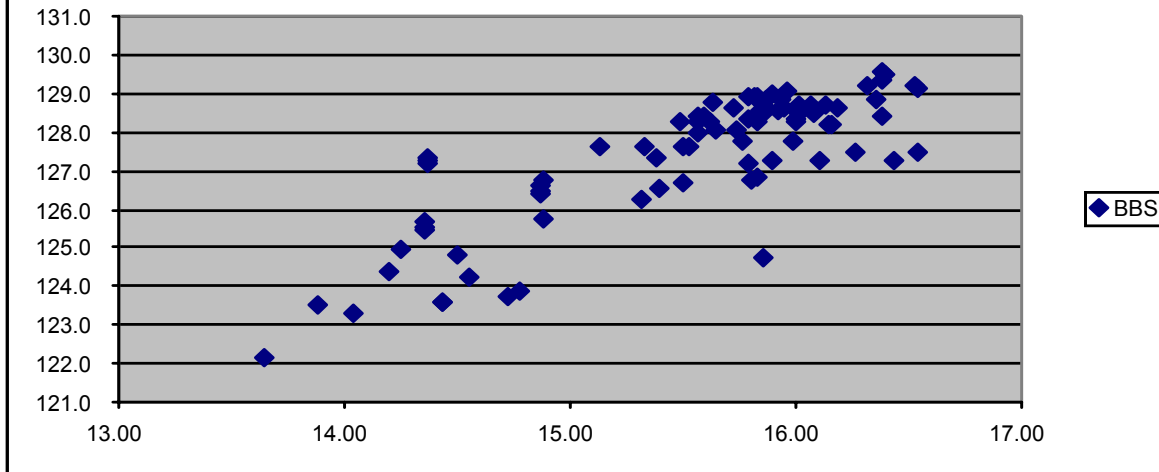
BBS vs WEIGH'



BBS vs MC



BBS vs COM



PROBLEMS WITH SWING SPEED

- 1. It depends on hitter
- 2. Given hitter, it depends on bat
 - Weight W
 - COM a
 - MOI I
- 3. Given hitter and bat, it depends on impact location R

SWING SPEED

- Arises from 2 (or 3) rotations: (hip+arms) & wrists

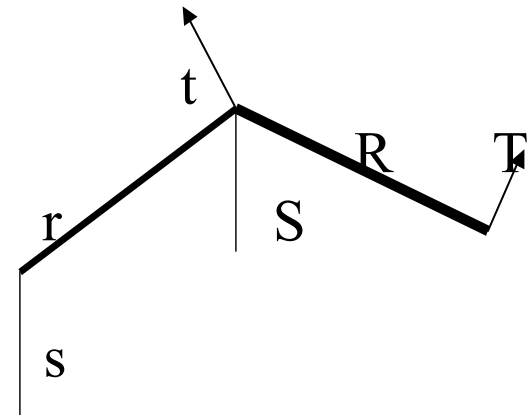
QuickTime™ and a Animation decompressor are needed to see this picture.

SWING SPEED

- Arises from 2 (or 3) rotations: (hip+arms) & wrists
- Depends on bat (Weight, COM, MOI; IMP) and hitter (geometry, torques)
- Guess: 1/2 translation + 1/2 rotation
- Use ASA weight dependence:
- $V_0 * (W_0/W)^p$; $V_0 = 70\text{mph}$, $W_0 = 30\text{oz}$, $p = 0.25$
- Generalization: $(V_0/2)[(W_0/W)^p + (I_0/I)^p]$
- IMP dependence: $V_0 \rightarrow A + B * R = (V_0/2)(1 + R/22)$
- Generalization: $V = (V_0/2)[(W_0/W)^p + (R/R_0) (I_0/I)^p]$

SWING SPEED MODEL

- Two constant torques t , T
- Body arm, angle = r , s
- Bat arm, angle = R , S
- Hitter: $\text{MOI} = i$, r , t , T
- Bat: W , a , I
- Impact distance = R
- Impact angles: $s = S = 180^\circ$
- Impact speed = $rs' + RS'$



SOLUTION OF SWING SPEED MODEL

- Impact speed is function of:
 - W
 - $I + Wr^2 + I$
 - I
 - T, t
 - R

QuickTime™ and a Animation decompressor are needed to see this picture.

Determine dependence
on
 W, a, I
 R

VELOCITY RATIO

- COR: $e = (V' + v')/v$
- BBS: $v'' = [V(1+e) + v(e-k)]/(1+k)$
 - $k = wc/Wa$
- VR (Lab): $q_v = v'/v$
- BBS: $v'' = V(1+q) + vq = V + q(V+v)$
 - $q = q_{V+v}$

Dependence of BBS on q is simpler than dependence on e .

- Relation: $e = q(1+k) + k$
 - $q = (e-k)/(1+k)$

3. PERFORMANCE PROFILES

- Lab measurements are made at COP because
 Lab = Field there
- Previous point of max lab BPF: $MBP = COP \pm 0.5$ ”
- For new bats, especially knob loaded,
 MBP can be further from COP
- Problem: Lab BPF \neq Field BPF away from COP

- Solution 1: Use Lab BPF anyway
- Solution 2: Determine Field BPF from Lab BPF
- Solution 3: Use VR - same in Lab and Field
- Solution 4: Use BBS

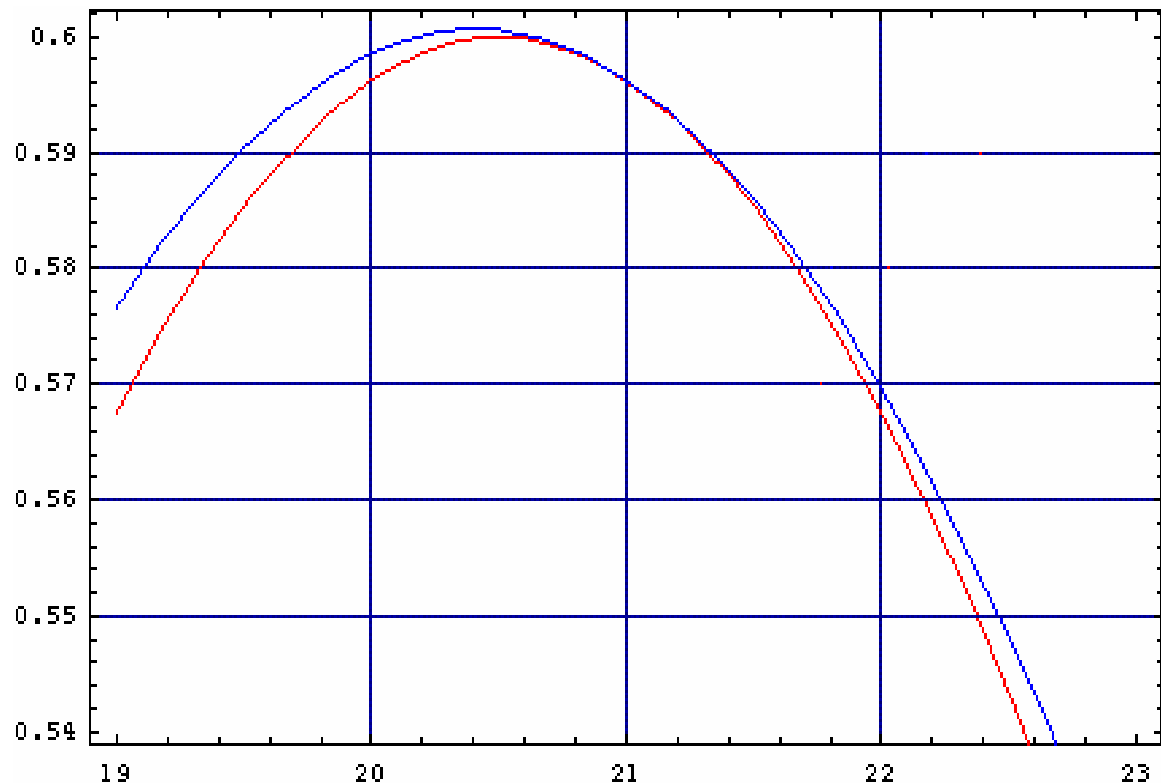
Solution 1: Use Lab BPF anyway

BBS equation correct with Lab COR e and $k = \omega R^2/I$

$$v''_{\text{field}} = [V(1+e_{\text{lab}}) + v(e_{\text{lab}}-k)]/(1+k)$$

Solution 2: Determine Field BPF from Lab BPF

- Field COR \geq Lab COR
- Position and magnitude of maximum is different
- Related by Physics
- Bat dependent

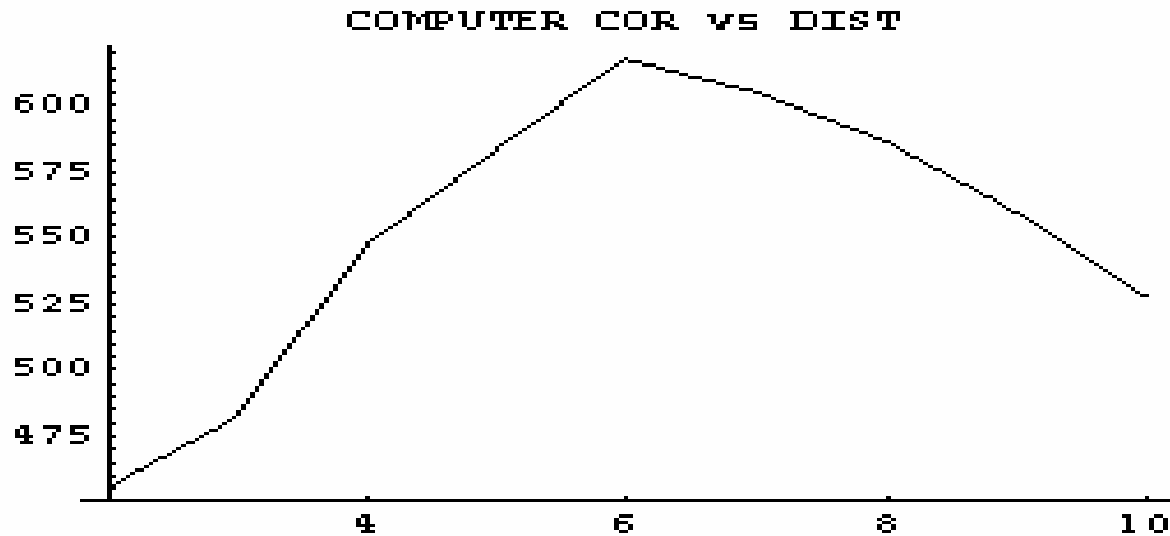
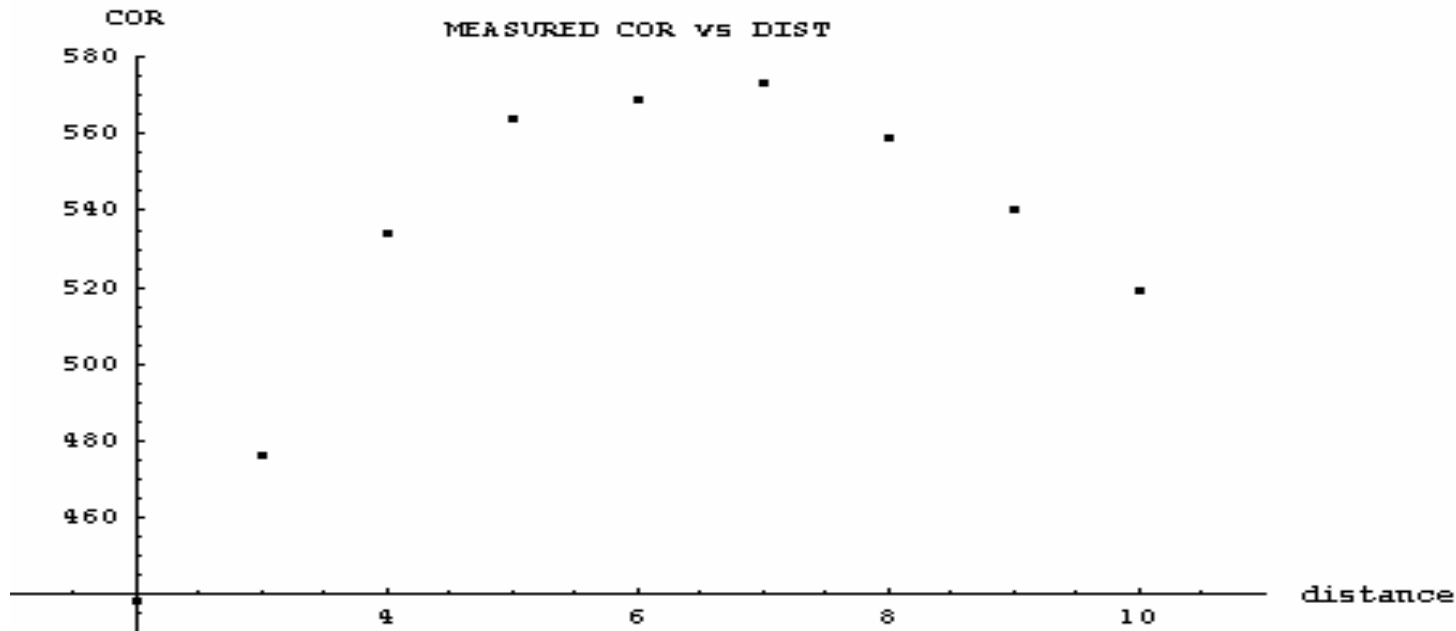


Solution 3: Use VR - same in Lab and Field

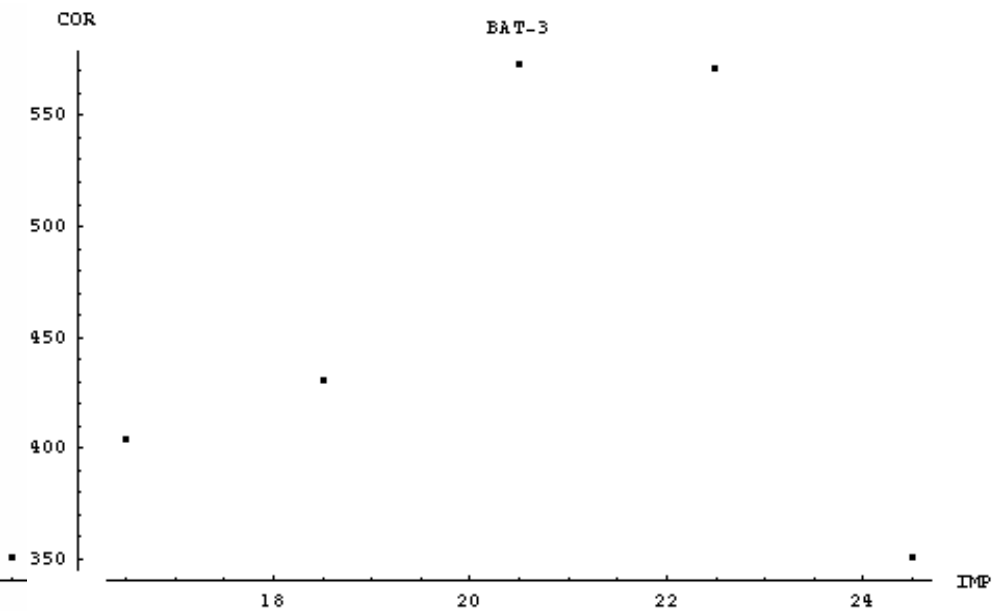
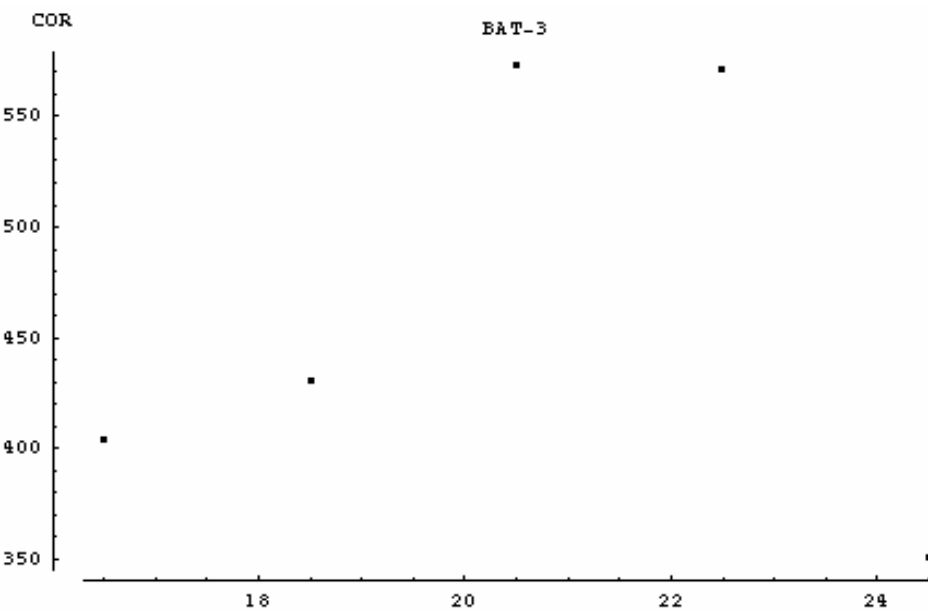
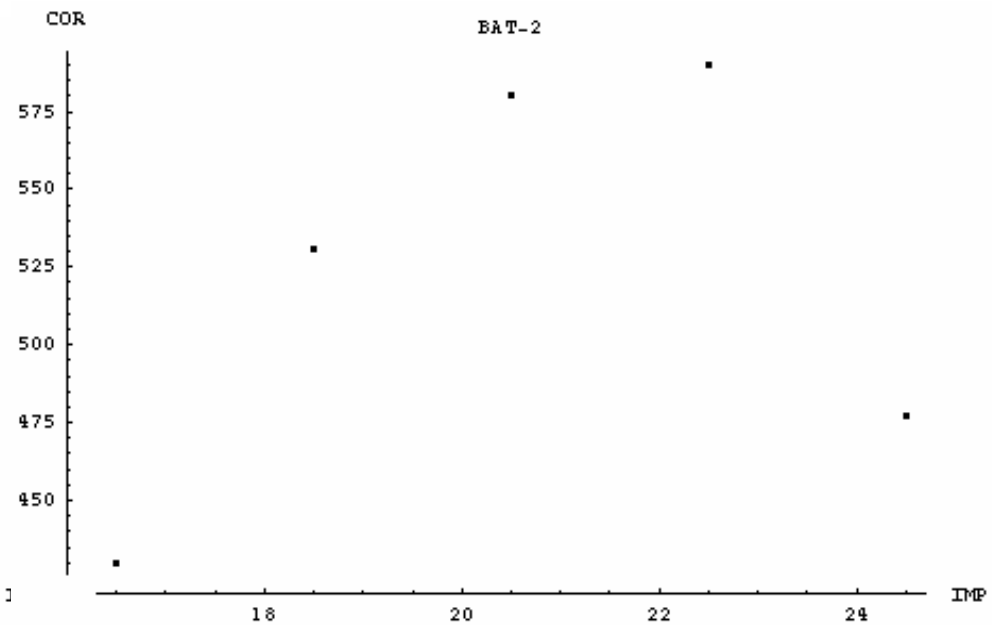
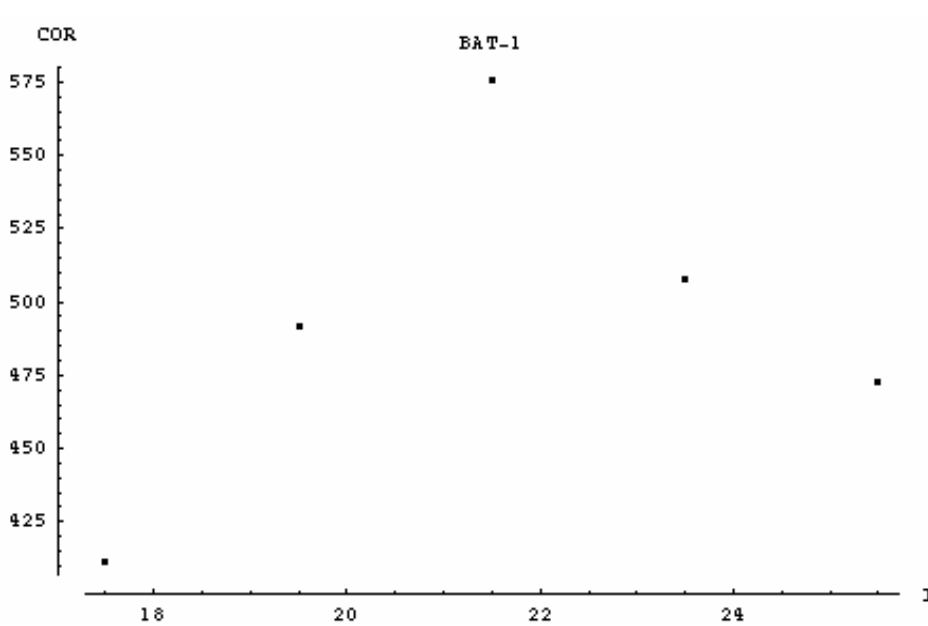
$$q_{V+v} = v'/(V+v)$$

- Solution 4: Use BBS
- $v'_{\text{field}} = V(1+q_{\text{lab}}) + vq_{\text{lab}}$
- Still have swing speed (V) problems
 - Dependence on hitter
 - Dependence on bat (W, a, c)
 - Dependence on impact point R
- Point of maximum BBS
 - is not necessarily MBP and
 - is player (hitter and pitcher) dependent
 - is not a bat property

COR PROFILES

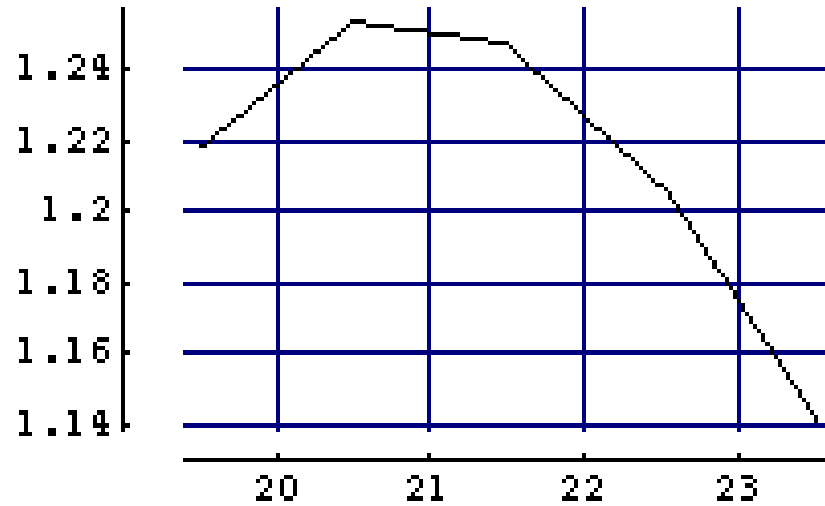


COR PROFILE DATA

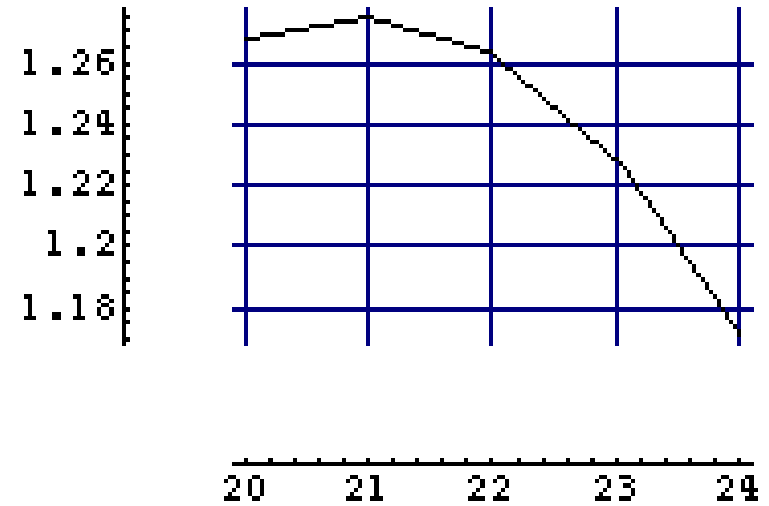


BPF PROFILE EXAMPLES (ASA)

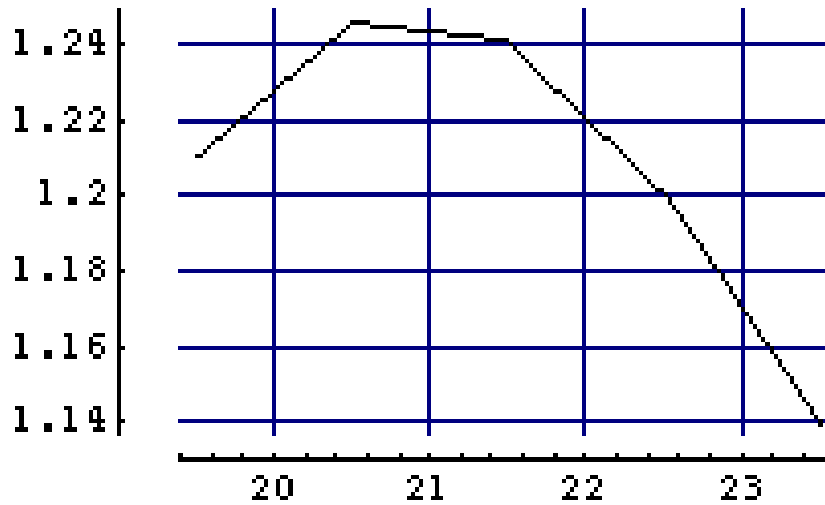
alum 1 (27.8,15.8,21.5)



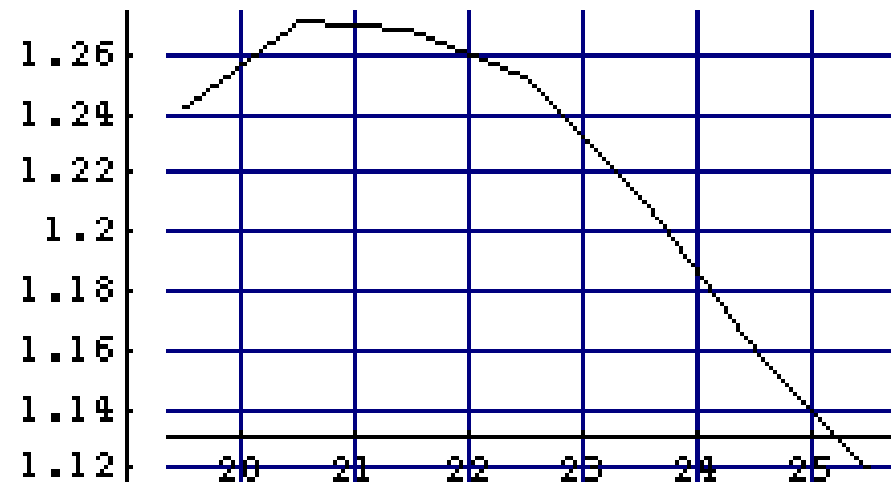
comp 1 (27.2,13.9,22.1)



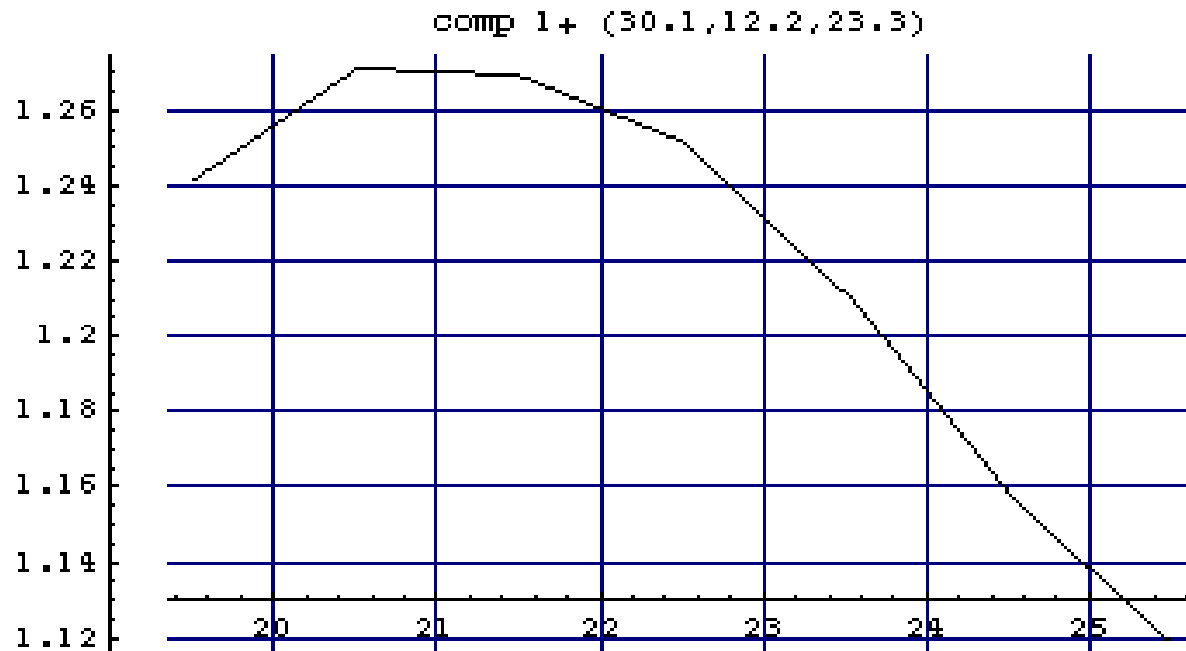
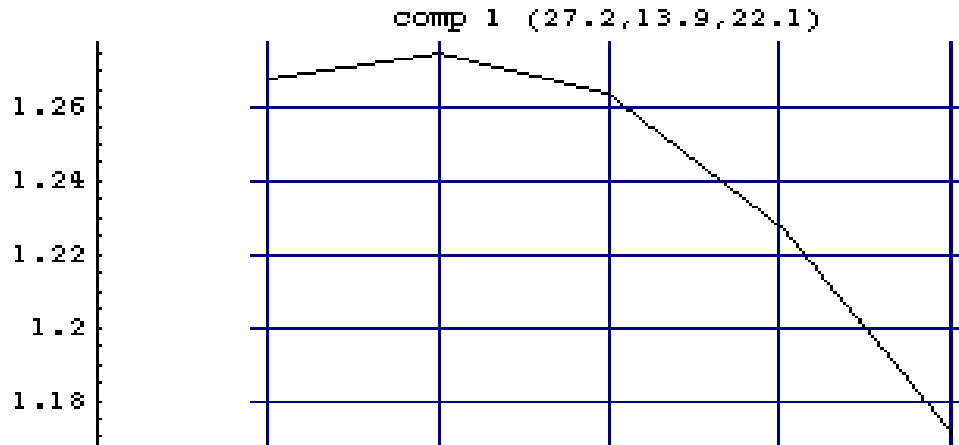
alum 2 (26.4,16.0,21.6)



comp 1+ (30.1,12.2,23.3)



EFFECT ON BPF OF ADDING 3 OZ TO KNOB



4. HIGH SPEED (150 MPH) MEASUREMENTS

- Need 150 mph impact speed for college baseball
- Hit ball speeds of 100 mph
- Need light material for speed
- Need strong material for stability
- Use computer to design and test
- Safety concerns

HIGH SPEED BAT VIBRATIONS

- At high speed, bat vibrations effect bat speed measurement
- Measuring rebound ball velocity is:
 - 1) difficult (3-dimensions)
 - 2) subtle (which component?)
 - 3) erroneous (ball vibrations)
 - 4) not necessary
- Measuring bat speed is:
 - 1) easy
 - 2) correct (component)
 - 3) very accurate

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Animation decompressor
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BAT ROTATION SPEED AND POSITION

