ROAD COURSE MEASUREMENT

INTERNATIONAL SEMINAR

Phoenix, Arizona - 1994

The second USATF/IAAF International Measurement Seminar was held on May 20-22, 1994. People came from many places to participate. Left to right: Luciano Ramirez (Mexico), Don Shepan (NM), Rodolfo Martinez (Mexico), Marcial Tellez (Mexico, crouching), Doug Loeffler (FL), John Disley (Great Britain), Karen Wickiser (OH), Felix Cichocki (AZ), Mike Wickiser (OH), Bob Baumel (OK), Jean-Francois Delasalle (France), Tom McBrayer (TX), Andy Beach (TX), Dave Yaeger (Canada), Bob Letson (CA), Pete Riegel (OH).

REPORT OF PROCEEDINGS

USA TRACK & FIELD

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July 18, 1994

To All Seminar Attendees and Others,

In this Proceedings you will find all of the work, subsequent to the Seminar, that was submitted by participants. A week after the seminar was done, I sent each participant a letter requesting that comments and analysis be sent to me by July 8. Some responded handsomely, with comprehensive work. Some responded with short letters containing useful comments. Some did not respond at all.

The work of each respondent is identified by initials in the upper right-hand corner of each page, denoting the initials of the submittor.

I wish to particularly thank Bob Baumel for his extensive analysis (first-rate work, as usual), Bob Letson for his superb visual presentation of the results, and Jean-Francois Delasalle who, although English is difficult for him, sent an insightful and useful report and analysis. Special thanks to Doug Loeffler, who spent much of his time at the Seminar acting as translator, guide and mentor to the contingent of Mexican measurers.

We can all thank Felix and Mary Ann Cichocki, for all the work they did in finding the best venue for such a seminar than any of us had yet seen, and for providing the on-site support.

Also, we should be mindful of the commitment USATF has made to road racing. Without their funding of the Seminar, it would not have happened.

In addition to providing the most comprehensive comparative measurement ever done with calibrated bicycles, the Seminar allowed measurers from many areas of the USA and the world to gather together and have fun at our work. I think we found many more things we had in common than ways in which we differed.

I learned from all of you, and enjoyed making new friends and seeing old ones once again.

Have a good read.

Pete Riegel

INTERNATIONAL ROAD COURSE MEASUREMENT SEMINAR

Phoenix, Arizona - May 20-22, 1994

TABLE OF CONTENTS

Section by Pete Riegel

Section by Bob Letson

Section by Bob Baumel

TABLE OF CONTENTS (CONTINUED)

PR

INTERNATIONAL ROAD COURSE MEASUREMENT SEMINAR

Phoenix, Arizona - May 20-22, 1994

INTRODUCTION

The Phoenix measurement seminar was initiated in the summer of 1993, when funding from USATF was applied for in the 1994 budget. A venue was needed, and Phoenix was chosen because of its western location (the last USA seminar was in Columbus, Ohio), its status as a major air terminus, and its proximity to tourist attractions. It was hoped that the latter would encourage people to combine a weekend of measuring with other, less stressful, activities.

Pete Riegel and Felix Cichocki worked together to find a suitable venue for the exercise. Felix was familiar with a newly-developed area near his office which was used by recreational skaters because the streets were absolutely deserted, yet had new pavement with curbing installed. Pete and Felix went through several design iterations in an attempt to get the maximum feasible length out of the area, ending with a test course of about 7400 meters length.

The test course was divided into three segments. The first was basically a rectangle, with no particularly difficult riding. The second consisted mostly of sweeping, gradual right-hand bends. The third was mostly left-hand bends.

A calibration course area was located adjacent to the test course, just over 300 meters in length.

Felix, assisted by his wife, Mary Ann, searched for a local hotel that would give us a reasonable rate and was close to the measurement venue. They found it in Resort Suites of Scottsdale, located about a mile west of the venue.

This seminar was attended by mostly experienced measurers, and it was decided to maximize data-gathering while holding calculation to a minimum, since time was limited, and calculation could be done later.

Activity included the following:

1) 17 individual measurements of the calibration course and calculations of its length.

2) 17 individual measurements of each segment of the test course, ridden in the standard manner with 30 cm offset from all curbs, and calculation of the whole-course length.

3) 12 whole-course measurements made as a contest, to see who could ride the tightest line, and calculation of the result.

4) A comparison of 19 steel and fiberglass tapes.

5) A test of the measurers' ability to accurately estimate a position opposite a point on the other side of a road.

Data, analysis, and conclusions drawn from the seminar will be found in succeeding pages.

MEASURERS WHO ATTENDED THE SEMINAR

Measurer	Report ID
Andy Beach 2502 Diamond Oaks Garland, TX 75044	AB
Bob Baumel 129 Warwick Rd Ponca City, OK 74601	BB
Doug Loeffler 1399 W. Royal Palm Rd. Boca Raton, FL 33486	DL
Don Shepan 3007 Ronna Ave Las Cruces, NM 88001-7531	DS
Dave Yaeger 19 Carondale Cres Scarborough, ONT CANADA M1W 2A9	DY
Tom McBrayer 4021 Montrose Houston, TX 77006-4956	ETM
Felix Cichocki PO Box 35037 Phoenix, AZ 85037	FC
John Disley CBE Hampton House Upper Sunbury Rd Hampton, Middlesex ENGLAND TW12 2DW	JD
Dr. J. F. Delasalle BP 25 80800 Corbie FRANCE	JFD
Karen Wickiser 2939 Vincent Rd Silver Lake, OH 44224	KW
Luciano Ramirez Gallardo Heleotropo 4005 Col. Rafael Ramirez Guadalupe, Nuevo Leon MEXICO	LRC
Marcial Gerardo Tellez Morgan Monte Parnasos 108 Col. Villa Montana San Pedro Garcia, N. L. MEXICO	MGT
Mike Wickiser 2939 Vincent Rd Silver Lake, OH 44224	MW
Pete Riegel 3354 Kirkham Road Columbus, OH 43221-1369	PR
Bob Letson 2870 Amulet St San Diego, CA 92123	RL1 RL2
Rodolfo Martinez Figueroa CP 03410 Delegacion: Benito Juarez Mexico DF MEXICO	RMF

In the section of this report prepared by Pete Riegel, the above ID abbreviations are used throughout to identify the measurers.

PR

MISCELLANEOUS OBSERVATIONS

1) I wish to thank Doug Loeffler for acting as translator, guide, and mentor to the Mexican measurers. This put pressure on him that the rest of us did not have. Whatever effect this may have had on his measurements is unknown, but it probably did not help.

2) The reader will find a lot of numbers in this report. Those who would like a summary that is easier to digest should see Bob Letson's report. It's visual and easy to follow.

3) Bob Letson, using triangulation at each end of the calibration course, estimated that the calibration course lines were non-parallel by 0.06 feet (1.8 cm).

4) Tom McBrayer's data was obtained on an informal ride of the course done with Bob Letson on the night before the seminar. He injured his knee during the ride and was unable to ride the next day. His data is included, but may not indicate his best riding.

5) Bob Letson did two rides. RL1 was done informally the night before the group measurement, RL2 was done with the group. Both rides are included in the analysis.

6) Jean-Francois Delasalle did eight complete course measurements, each with separate precalibration and postcalibration rides. See his report to see how it came out. Only his second measurement was included in the overall analysis, as he was not happy with his first ride, and decided to use the second one as "official." The rest of his rides were done after everybody else went home.

Additional articles based on this report are solicited for Measurement News.

PR

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1) The standard method of measuring road race courses is effective in producing courses that will not be found short upon remeasurement.

2) Use of uncalibrated commercial steel tapes yields results that are accurate enough for establishing useful calibration courses.

3) Non-steel tapes are not accurate enough for our purposes.

4) Quality of measurement results increases with measurement experience.

5) Offset maneuvers should be used with care. Significant error was observed when our ability to judge an opposite point was measured.

6) Calibration change produces uncertainty in measurement.

7) Measuring a proper temperature to use in steel-tape corrections can be harder than it looks.

8) The seminar tested primarily riding ability, with only minimal emphasis on data reduction and calculation skills.

Recommendations

1) For future seminars, use a nail at each end of the calibration course to provide single fixed points at which measurements terminate.

2) Use the larger constant in actual course layouts, for added safety against shortness. It overcomes inaccuracy due to change in calibration. For seminar and comparison purposes, the average is better.

3) Try to resolve the proper line to measure when riding adjacent to a curb with a concrete apron. 30 cm from curb? 30 cm from edge of apron?

4) Know and use the proper tension for your steel tape.

5) Have a session to summarize conclusions, if possible, at the end of the seminar. In this seminar, the only conclusions available were each measurer's own estimate of course length. The rest had to wait until this report came out.

METHODOLOGY

The venue was prepared beforehand by Felix Cichocki. A calibration course of unknown length was established using two strips of duct tape, with the outer edge of the tape marked as the calibration line. A point 30 cm from the curb was marked as the measurement point at each end of the calibration course. Felix also laid down pieces of duct tape marking the start/finish of the loop, and reference points 1 and 2. None of the course lengths was known at this time.

In the morning eight measurers calibrated their bikes and set out to measure the test course. When they were finished calibrating, the other eight measurers taped the calibration course once. The riders first rode the test course in a standard manner, using 30 cm offsets from turns. Then they recalibrated, and set out to measure the course as tightly as they could (zero offset). Then they made a final calibration.

In the afternoon the measurers switched roles, the riders taping, and the tapers riding.

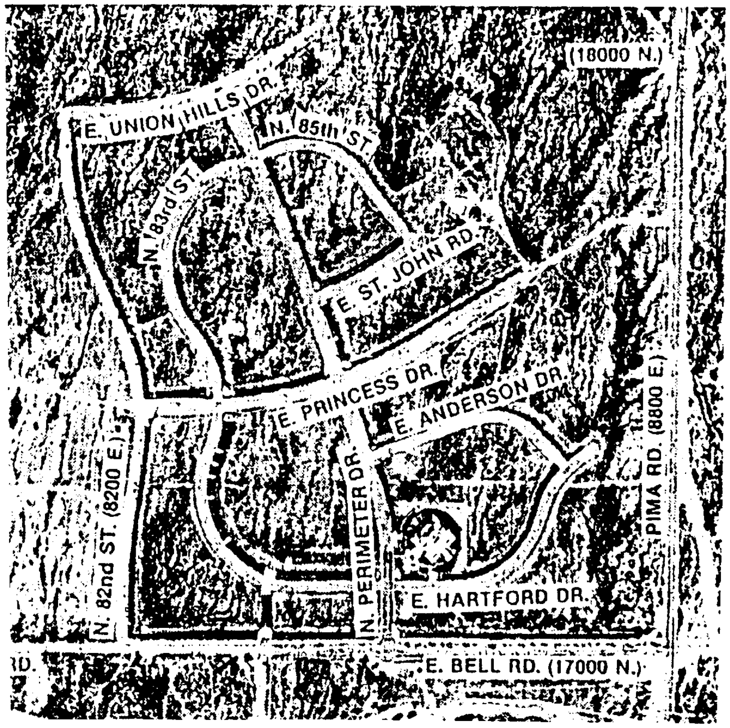
This concluded the bicycle measurement and calibration course taping. Everyone returned to the hotel.

In the parking lot, two more exercises were then performed. First, all available tapes were stretched against two marks about 29 meters apart, to see how they compared. The data was recorded for later analysis.

Then an exercise in judging offset was done. A mark was established on a curb, and a steel tape laid out against the opposite curb, about 12 meters away. The measurers each stood by the tape, and when they thought they were opposite the mark, they read the tape and reported the value quietly to a recorder. Then Bob Baumel and a helper taped a triangle which, when treated geometrically, would yield the correct reading opposite the mark.

At the end of the day the measurers were asked to calculate the length of the calibration course and the lengths of the test course as ridden in the standard way and the zero-offset way. Each measurer handed in his data sheet the next morning. The sheets were duplicated, and each measurer given a copy of all data generated during the seminar.

Measurers were asked to study the data, and send in a copy of any data-reduction they cared to do, as well as comments on the conduct and quality of the seminar. Those responses that were received by the July 8 deadline are included in this report.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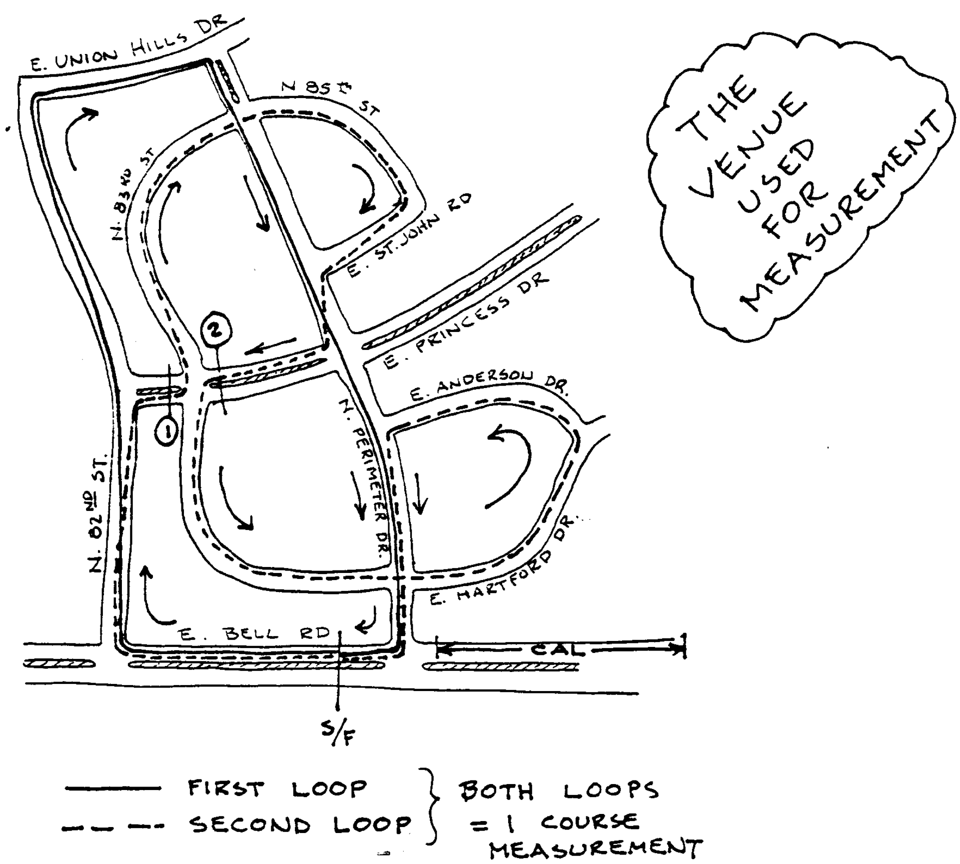
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THE VENUE USED FOR MEASUREMENT
FIRST LOOP
SECOND LOOP
BOTH LOOPS = 1 COURSE MEASUREMENT

CONTEST WINNERS

Before the seminar, it was mentioned that several aspects of the work would be competitively recognized. We had three categories. The first was "who could ride the tightest course?" Here is how that came out:

	Total
JFD	7405.68 meters
DS	7412.79
PR	7413.13
RL1	7413.88
JD	7413.90
DY	7414.16
FC	7415.07
RL2	7415.50
MW	7415.57
BB	7415.99
AB	7418.40
KW	7421.91

Contest winners:

Tightest course - Jean-Francois Delasalle

Best standard measurement - Pete Riegel

Best offset judge - Bob Baumel

Jean-Francois Delasalle's winning performance here is astounding. No, he did not ride up on the curbs at the corners. In his report he describes how he "scootered" around the long bends, keeping his tire almost continually in contact with the curb and keeping his weight on the bike. Bob Baumel calculated that the theoretical difference between tight riding and standard, 30 cm offset riding, ought to amount to 8.4 meters. Jean-Francois calculated it at "between 8 and 9 metres."

In the preliminary material, it was mentioned that the "tightest course" contest was put there so measurers could get competition out of their system. 30 cm offset is desirable, and it was reckoned that experienced people ought to be pretty close to that. So, the median became the desirable number to have, and the closer to the median, the better the measurement. Here is how the overall standard ride came out:

	Measured Value	Difference From Median, m
PR	7420.73	0.00
RL2	7420.48	-0.25
BB	7421.15	0.42
DY	7419.98	-0.74
JFD	7419.65	-1.07
AB	7423.18	2.45
FC	7417.78	-2.95
DS	7417.76	-2.97
DL	7417.64	-3.08
RL1	7417.15	-3.58
MW	7424.38	3.65
ETM	7424.88	4.16
JD	7415.89	-4.84
LRC	7425.80	5.07
KW	7425.97	5.24
RMF	7429.29	8.56
MGT	7431.12	10.39

On the easily calculated, overall basis, Pete Riegel won.
In our final contest, Bob Baumel proved himself the best estimator of when he was exactly opposite a point on the other side of the road.

PR

THE STANDARD METHOD

In the USA, we have developed a standard procedure as follows:

1) Measurer may use average constant, but the larger constant is recommended. (note: the international standard uses the average constant)

2) Two course measurements are required, and they must agree within .0008 (8 meters in 10,000), or they are considered invalid. (there is presently no international standard for agreement)

3) A short course prevention factor of 1.001 (10 meters in 10,000) is added to the course. (this is also the international standard)

If a record time is run on the course, it is checked. The validator measures only once, and uses average constant without the extra 1.001. To provide reasonable certainty of shortness, an allowance for error in the validation measurement is used. The record is denied if the course, using this method, is less than .0005 m/km short - A 10 km course would be considered short if it was validated at less than 9995 meters. Since international courses are rarely validated (because they are measured by "experts") there is no standard for an allowance for error in the validation measurement.

Validation experience in the US shows that about 90 percent of all courses pass the validation test, no matter who measured the course originally. Courses measured by USATF certifiers very rarely fail.

How would our Phoenix results compare with this? To find out, I first compared the ride of every measurer to every other measurer, obtaining 120 pairs. I discarded pairs which disagreed by .0008 or more, leaving 78 pairs of measurements. I used the lower of each pair as the official laid-out distance.

For validation measurements, I used each of the 17 individual course measurements as possible validation measurements, but calculated the lengths <u>without</u> using 1.001 (thus obtaining "true" meters). I did not use an allowance for error in the validation measurement.

I compared the laid-out distances to the validation distances. If the laid out distance was less than any validation distance, it failed the test.

Using this method, 8 out of the 78 courses, or 10 percent, failed validation.

If the 0.0005 m/km allowance for error in the validation is applied, only one course fails.

If larger constant is used in the layouts, no courses fail. Performance of the group exceeds the performance of average US measurers.

PR

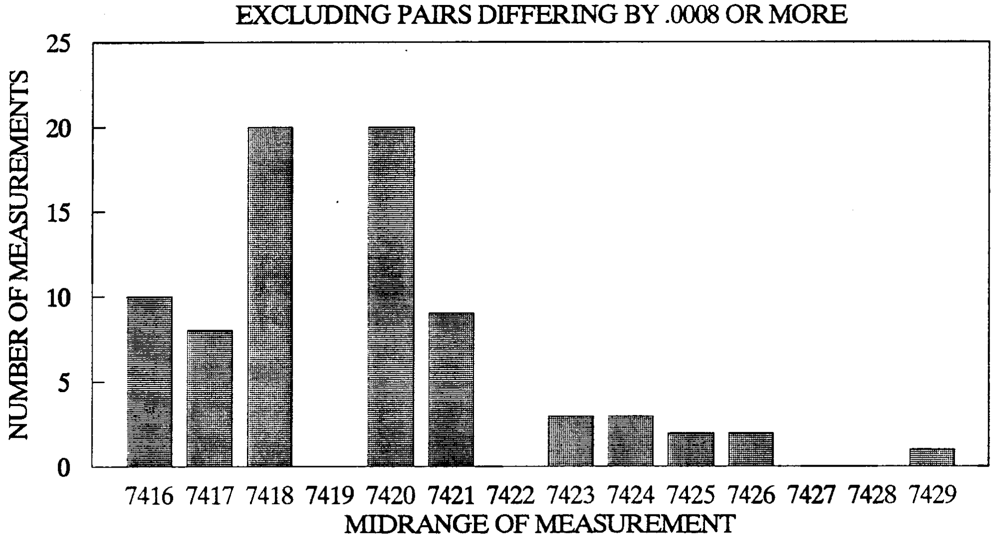
Differences between measured values, meters per 10 km. Note that the US limit is 8.0.

	Value	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	LRC	MGT	MW	PR	RL1	RL2
AB	7423.18															
BB	7421.15	2.7														
DL	7417.64	7.5	4.7													
DS	7417.76	7.3	4.6	0.2												
DY	7419.98	4.3	1.6	3.2	3.0											
ETM	7424.88	2.3	5.0	9.8	9.6	6.6										
FC	7417.78	7.3	4.5	0.2	0.0	3.0	9.6									
JD	7415.89	9.8	7.1	2.4	2.5	5.5	12.1	2.6								
JFD	7419.65	4.8	2.0	2.7	2.6	0.4	7.0	2.5	5.1							
LRC	7425.80	3.5	6.3	11.0	10.8	7.8	1.2	10.8	13.4	8.3						
MGT	7431.12	10.7	13.4	18.2	18.0	15.0	8.4	18.0	20.5	15.5	7.2					
MW	7424.38	1.6	4.4	9.1	8.9	5.9	0.7	8.9	11.5	6.4	1.9	9.1				
PR	7420.73	3.3	0.6	4.2	4.0	1.0	5.6	4.0	6.5	1.4	6.8	14.0	4.9			
RL1	7417.15	8.1	5.4	0.7	0.8	3.8	10.4	0.8	1.7	3.4	11.7	18.8	9.7	4.8		
RL2	7420.47	3.7	0.9	3.8	3.7	0.7	5.9	3.6	6.2	1.1	7.2	14.3	5.3	0.3	4.5	
RMF	7429.29	8.2	11.0	15.7	15.5	12.5	5.9	15.5	18.1	13.0	4.7	2.5	6.6	11.5	16.4	11.9

Boxed values are those that exceed the 8 m in 10 km limit.
These measurements should be checked again.

PAIRED MEASUREMENTS

EXCLUDING PAIRS DIFFERING BY .0008 OR MORE



Paired measurements of all measurers. Combinations with differences exceeding 8 meters in 10 km do not appear. The lower value of the pair is shown.

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	LRC	MGT	MW	PR	RL1
BB	7421.2													
DL	7417.6	7417.6												
DS	7417.8	7417.8	7417.6											
DY	7420.0	7420.0	7417.6	7417.8										
ETM	7423.2	7421.2			7420.0									
FC	7417.8	7417.8	7417.6	7417.8	7417.8									
JD		7415.9	7415.9	7415.9	7415.9		7415.9							
JFD	7419.7	7419.7	7417.6	7417.8	7419.7	7419.7	7417.8	7415.9						
LRC	7423.2	7421.2			7420.0	7424.9								
MGT										7425.8				
MW	7423.2	7421.2			7420.0	7424.4			7419.7	7424.4				
PR	7420.7	7420.7	7417.6	7417.8	7420.0	7420.7	7417.8	7415.9	7419.7	7420.7		7420.7		
RL1		7417.2	7417.2	7417.2	7417.2		7417.2	7415.9	7417.2				7417.2	
RL2	7420.5	7420.5	7417.6	7417.8	7420.0	7420.5	7417.8	7415.9	7419.7	7420.5		7420.5	7420.5	7417.2
RMF						7424.9				7425.8	7429.3	7424.4		

Boxed values are those that would have failed a validation measurement by one or more of the measurers,

Average	7419.4	Fail Validation	8
Std Deviation	2.77	Fail percent	10.3
High	7429.3	Pass percent	89.7
Low	7415.9		
Number	78		

Values used for validation:
The true meters are used.

	IAAF Meters with 1.001	True Meters w/o 1.001
JD	7415.9	7423.3
RL1	7417.2	7424.6
DL	7417.6	7425.1
DS	7417.8	7425.2
FC	7417.8	7425.2
JFD	7419.7	7427.1
DY	7420.0	7427.4
RL2	7420.5	7427.9
PR	7420.7	7428.1
BB	7421.2	7428.6
AB	7423.2	7430.6
MW	7424.4	7431.8
ETM	7424.9	7432.3
LRC	7425.8	7433.2
RMF	7429.3	7436.7
MGT	7431.1	7438.6

Data for US certifiers only:

	BB	DL	ETM	FC	MW	PR	RL1
DL	7417.6						
ETM	7421.2						
FC	7417.8	7417.6					
MW	7421.2		7424.4				
PR	7420.7	7417.6	7420.7	7417.8	7420.7		
RL1	7417.2	7417.2		7417.2		7417.2	
RL2	7420.5	7417.6	7420.5	7417.8	7420.5	7420.5	7417.2

Average	7419.1	Fail Validation	0
Std Deviation	1.96	Fail percent	0
High	7424.4	Pass percent	100
Low	7417.2		
Number	22		

Data for IAAF measurers only:

	BB	DL	ETM	JD	JFD	MW
DL	7417.6					
ETM	7421.2					
JD	7415.9	7415.9				
JFD	7419.7	7417.6	7419.7	7415.9		
MW	7421.2		7424.4		7419.7	
PR	7420.7	7417.6	7420.7	7415.9	7419.7	7420.7

Average	7419.1	Fail Validation	1
Std Deviation	2.34	Fail percent	5.9
High	7424.4	Pass percent	94.1
Low	7415.9		
Number	17		

DISCUSSION OF THE DATA

Raw Data
Data obtained from submitted data sheets are shown on pages 12-13. There are some gaps in the data:

1) RL2 did not do a calibration between his 30 cm test course measurement and his zero-offset ride. Since he had a solid tire, his calibration did not suffer a serious change.

2) The data of ETM and RL1 were taken from course rides done the night before the official event. During the ride ETM suffered a knee injury and was unable to ride the next day.

3) DL, LRC and RMF ran into time trouble on their 30 cm offset ride of the course and were unable to do a zero-offset ride.

Calculated Values
Pete Riegel's calculations based on the data are shown on pages 13-14.

The corrected calibration course length is seen to differ from the length reported by the participants. The difference is generally small, the exceptions being DL, LRC and AB. DL and LRC evidently reversed the temperature correction.

The section headed CALIBRATION DATA uses the measurement data obtained by each measurer, but uses the corrected length of the calibration course rather than the length stated by each measurer.

Further constants are calculated near the bottom of page 13. Std Ride Constant (SRC) is based on each individual's own corrected measurement of the calibration course. Common SRC assumes that each measurer used a calibration course of 332.1386 meters, which was the median measurement of the calibration course. The average measurement of the calibration course was 332.1346.

Note the difference between the course length as calculated by each participant, and the course length as calculated using the same calibration course length. Some of the difference is due to the differences in calibration course estimates, and the rest may be due to premature rounding of calibration values or other causes.

DATA OBTAINED AT PHOENIX MEASUREMENT SEMINAR

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
First calibration – Counts																	
Start cal 1	79000	70940	59000	91000	43900	466900	95430	38000	465300	885460	29478	89880	2000	15160	31196	672161	3596
End cal 1	82237	74168.5	62669	94290.5	47083	470635	98558.5	41671	469170	889318	32663	93180	5125.5	18362	34856	675896	6808
Start cal 2	82237	74168.5	62669	94290.5	47090	470635	98558.5	41671	469200	889318	32663	93180	5125.5	18362	34856	675896	6993
End cal 2	85474	77397	66339	97579	50273.5	474369.5	1687	45344	473069.5	893177	35847	96468	8251	21564	38516	679630	10206
Start cal 3	85474	77397	66339	97579	50280	474369.5	1687	45344	473100	893177	35847	96468	8251	21564	38516	679630	10509
End cal 3	88711	80624	70009	869	53463.5	478104	4815	49015	476970	897035	39037	99750	11376.5	24766	42177	683364	13723
Start cal 4	88711	80624	70009	869	53470	478104	4815	49015	477000	897035	39037	99750	11376.5	24766	42177	683364	13807
End cal 4	91949	83852.75	73678	4158.5	56653.5	481839	7944	52686	480869.5	900893	42216	3032	14502	27968.5	45837	687098	17019
30 Cm Offset Ride – Counts																	
Begin S/F–S/F	94000	16460	63000	40000	59000	484400	41093.5	55800	574000	903800	16753	79540	17000	58654.5	51987	690427	19500
End S/F–S/F	122873	45234	95715	69323	87380	517716	68977	88500	608496		45165	8891	44882	87208	84619	723729	48178
Begin S/F–R1	122873	45234	95715	69323	87380	517716	68977	16600	608496		45165	8891	44882	88400	84619	723729	4300
End S/F–R1	132927	55255.5	7108	79533	97265	529315	78687.5	27982	620503	950200	55055	19094	54593	98342	95984	735324	14285
Begin R1–R2	132927	55255.5	7108	79533	97265	529315	78687.5	27982	620503	950200	55055	19094	54593	98342	95984	735324	14285
End R1–R2	148041	70326.5	24230	94880	12126	546770	93280.5	45101	638556	968238	69945	34463	69199	13287	13063	752752	29311
Begin R2–S/F	148041	70326.5	24230	94880	12126	546770	93280.5	45101	638556	968238	69945	34463	69199	13287	13063	752752	29311
End R2–S/F	166407	88634	45044	13525	30185	567973	11011	65905	660484	990152	88019	53133	86935	31444	33816	773928	47540
Second Calibration – Counts																	
Start cal 1	69000	91075	48000	15700	32400	570600	13140	68400	667200	993100	90480	55607	89000	34100	36294		50135
End cal 1	72236	94300	51671	18988	35583	574334	16266	72067	671066	996957	93664	58890	92125.5	37300.5	39954		53347
Start cal 2	72236	94300	51671	18988	35590	574334	16266	72067	671100	996957	93664	58890	92125.5	37300.5	39954		53350
End cal 2	75472	97527.5	55341	22276.5	38773	578069	19393	75734	674965	816	96848	62174	95251	40502	43615		56562
Start cal 3	75472	97527.5	55341	22276.5	38780	578069	19393	75734	675000	816	96848	62174	95251	40502	47315		56610
End cal 3	78708	752	59012	25564	41963	581803.5	22519	79400	678865.5	4674	36	65460	98376.5	43702	50976		59821
Start cal 4	78708	752	59012	25564	41970	581803.5	22519	79400	678900	4674	36	65460	98376.5	43702	50976		59822
End cal 4	81943	3978	62682	28852.5	45153.5	585539	25646	83067	682765	8534	3217	68743	1502	46902.5	54638		63032
Zero Offset Ride – Counts																	
Begin S/F–S/F	84000	6500		32000	47000		28000	85900	689500	11500			4000	49340	60798	773928	
S/F–S/F–2	112852	35250		61300	75364		55872	18575	723924				31856	77865	93427	807211	
S/F–R1–1	112852	35250		61300	75364		55872	19960	723924				31856	79050	93427	807211	
S/F–R1–2	122896	45258.5		71500	85239		65578	31338	735906	57900			41558	88981	4788	818799	
R1–R2–1	122896	45258.5		71500	85239		65578	31338	735906	57900			41558	88981	4788	818799	
R1–R2–2	137991	60307		86828	77		80152.5	48441	753889	75918			56137	3903	21860	836211	
R2–S/F–1	137991	60307		86828	77		80152.5	48441	753889	75918			56137	3903	21860	836211	
R2–S/F–2	156324	78591		5452	18111		97871	69222	775743	97802			73852	22031	42603	857373	
Third Calibration – Counts																	
Start cal 1	59000	81168		8000	20600		320	72070	782800	101600			76300	24500	45071	860075	
End cal 1	62233	84393		11286.5	23781		3447.5	75737	786663	105457			79425.5	27700.5	48732	863808	
Start cal 2	62233	84393		11286.5	23780		3447.5	75740	786700	105457			79425.5	27700.5	48732	863808	
End cal 2	65467	87619		14574.5	26962		6574.5	79408	790562	109315			82551	30901.5	52393	867541	
Start cal 3	65467	87619		14574.5	26970		6574.5	79400	790600	109315			82551	30901.5	52393	867541	
End cal 3	68701	90844		17861.5	30152		9700.5	83067.5	794463	113172			85676.5	34101.5	56055	871274	
Start cal 4	68701	90844		17861.5	30160		9700.5	83100	794500	113172			85676.5	34101.5		871274	
End cal 4	71936	94069		21150	33342		12826.5	86767	798363	117032			88802	37302		875008	
Raw Length, m or ft	1089.2	332.109	1089.552	1089.385	332.006	332.109	332.017	332.07	332.05	1089.5	1089.563	332	1089.625	1089.42	1089.765	1089.425	332.06
Temperature, C or F	110	28.5	42	43	40	28.5	47	37	43	88	42	41	77	43	72	115	42
Time of cal measure	1330	840	1035	1330	1500	900	1345	1345	1430	920	1020	1000	830	1320	2140	1400	
Values calculated by participants – below.																	
Corrrected Cal L	332	332.14	332.035	1089.692	332.084	332.141	332.121	332.13	332.138	1089.641	332.039		1089.688	332.15	332.152	332.157	
30 Cm Offset L, m	7419.51	7421.18		7415.9	7418.8	7424.8	7415	7415.7	7419.64	7425.369			7424.345	7420.98	7416.3	7419.5	
Zero Offset L, m	7414.8	7416.02		7411.9	7412.9			7413.7	7405.66	7421.069			7415.533	7413.38	7413.6	7414.5	
Bike Number	6	6	8	9	2	10	3	8	5	5	2	9	3	1	8	10	1

PR

CALIBRATION COURSE MEASUREMENT

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
Raw Length, m or ft	331.9882	332.109	332.0955	332.0445	332.006	332.109	332.017	332.07	332.05	332.0796	332.0987	332	332.1177	332.0552	332.160372	332.0567	332.06
Temp, C	43	28.5	42	42	40	28.5	47	37	43	31	42	41	25	43	22	46	42
Temp Correction, m	0.0899	0.0327	0.0848	0.0847	0.0770	0.0327	0.1040	0.0655	0.0886	0.0428	0.0848	0.0809	0.0193	0.0886	0.0086	0.1006	0.0847
Corrected Length,m	332.078	332.1417	332.1802	332.1293	332.083	332.1417	332.121	332.1355	332.1386	332.1224	332.1834	332.0809	332.137	332.1438	332.168934	332.1573	332.1447
Stated Length, m/ft	332	332.14	332.035	332.1381	332.084	332.141	332.121	332.13	332.138	332.1226	332.039		332.1369	332.15	332.152	332.157	
Difference, cm	7.8	0.2	14.5	−0.9	−0.1	0.1	−0.0	0.5	0.1	−0.0	14.4		0.0	−0.6	1.7	0.0	
CALIBRATION DATA																	
1	3237	3228.5	3669	3290.5	3183	3735	3128.5	3671	3870	3858	3185	3300	3125.5	3202	3660	3735	3212
2	3237	3228.5	3670	3288.5	3183.5	3734.5	3128.5	3673	3869.5	3859	3184	3288	3125.5	3202	3660	3734	3213
3	3237	3227	3670	3290	3183.5	3734.5	3128	3671	3870	3858	3190	3282	3125.5	3202	3661	3734	3214
4	3238	3228.75	3669	3289.5	3183.5	3735	3129	3671	3869.5	3858	3179	3282	3125.5	3202.5	3660	3734	3212
Variation	1	1.75	1	2	0.5	0.5	1	2	0.5	1	11	18	0	0.5	1	1	2
Avg	3237.25	3228.188	3669.5	3289.625	3183.375	3734.75	3128.5	3671.5	3869.75	3858.25	3184.5	3288	3125.5	3202.125	3660.25	3734.25	3212.75
Cts/Km	9758.211	9729.026	11057.76	9914.557	9595.668	11255.69	9429.18	11065.28	11662.66	11628.57	9596.158	9911.104	9419.685	9650.42	11030.2616	11253.66	9682.414
5	3236	3225	3671	3288	3183	3734	3126	3667	3866	3857	3184	3283	3125.5	3200.5	3660		3212
6	3236	3227.5	3670	3288.5	3183	3735	3127	3667	3865	3859	3184	3284	3125.5	3201.5	3661		3212
7	3236	3224.5	3671	3287.5	3183	3734.5	3126	3666	3865.5	3858	3188	3286	3125.5	3200	3661		3211
8	3235	3226	3670	3288.5	3183.5	3735.5	3127	3667	3865	3860	3181	3283	3125.5	3200.5	3662		3210
Variation	1	3	1	1	0.5	1.5	1	1	1	3	7	3	0	1.5	2		2
Avg	3235.75	3225.75	3670.5	3288.125	3183.125	3734.75	3126.5	3666.75	3865.375	3858.5	3184.25	3284	3125.5	3200.625	3661		3211.25
Cts/km	9753.689	9721.68	11060.77	9910.036	9594.914	11255.69	9423.152	11050.96	11649.48	11629.32	9595.405	9899.046	9419.685	9645.899	11032.5218		9677.893
9	3233	3225		3286.5	3181		3127.5	3667	3863	3857			3125.5	3200.5	3661	3733	
10	3234	3226		3288	3182		3127	3668	3862	3858			3125.5	3201	3661	3733	
11	3234	3225		3287	3182		3126	3667.5	3863	3857			3125.5	3200	3662	3733	
12	3235	3225		3288.5	3182		3126	3667	3863	3860			3125.5	3200.5		3734	
Variation	2	1		2	1		1.5	1	1	3			0	1	1	1	
Avg	3234	3225.25		3287.5	3181.75		3126.625	3667.375	3862.75	3858			3125.5	3200.5	3661.33333	3733.25	
Cts/Km	9748.414	9720.173		9908.152	9590.769		9423.529	11052.85	11641.56	11627.82			9419.685	9645.522	11033.5263	11250.64	
Cal 1	9758.211	9729.026	11057.76	9914.557	9595.668	11255.69	9429.18	11065.28	11662.66	11628.57	9596.158	9911.104	9419.685	9650.42	11030.2616	11253.66	9682.414
Cal 2	9753.689	9721.68	11060.77	9910.036	9594.914	11255.69	9423.152	11050.96	11649.48	11629.32	9595.405	9899.046	9419.685	9645.899	11032.5218		9677.893
Cal 3	9748.414	9720.173		9908.152	9590.769		9423.529	11052.85	11641.56	11627.82			9419.685	9645.522	11033.5263	11250.64	

Note: Counts per kilometer shown above are based on each measurer's own measurement of the calibration course.

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
Variation 1	1	1.75	1	2	0.5	0.5	1	2	0.5	1	11	18	0	0.5	1	1	2
Variation 2	1	3	1	1	0.5	1.5	1	1	1	3	7	3	0	1.5	2	0	2
Variation 3	2	1		2	1		1.5	1	1	3			0	1	1	1	
Avg 4−Ride Variation	1.33	1.92	1.00	1.67	0.67	1.00	1.17	1.33	0.83	2.33	9.00	10.50	0.00	1.00	1.33	1.17	2.00
Std Ride Constant	9755.95	9725.353	11059.27	9912.296	9595.291	11255.69	9426.166	11058.12	11656.07	11628.95	9595.782	9905.075	9419.685	9648.159	11031.3917	11252.15	9680.153
Common SRC	9754.171	9725.445	11060.65	9912.019	9593.686	11255.8	9425.666	11058.02	11656.07	11628.38	9597.076	9903.354	9419.639	9648.311	11032.3995	11252.78	9680.333
Zero Offset Constant	9749.273	9721.019		9908.816	9591.237		9422.841	11051.8	11645.52	11628			9419.639	9645.862	11034.032	11252.78	

Median Calibration Course Length = 332.1386 (JFD) 332.1386 meters (JFD)
Average Calibration Course Length = 332.1346 332.1346

Notes:
1) Standard ride constant (SRC) is based on each individual's own measurement of the calibration course.
2) Common SRC constant assumes each measurer uses a calibration course of 332.1386 meters
3) Zero offset constant assumes each measurer uses a calibration course of 332.1386 meters.
4) All constants are based on average of precal and postcal, and include 1.001.

13

PR

CALCULATIONS OF COURSE LENGTH

Counts obtained – STANDARD RIDE

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
S/F to S/F	28873	28774	32715	29323	28380	33316	27883.5	32700	34496		28412	29351	27882	28553.5	32632	33302	28678
S/F to Ref1	10054	10021.5	11393	10210	9885	11599	9710.5	11382	12007	46400	9890	10203	9711	9942	11365	11595	9985
Ref1 to Ref2	15114	15071	17122	15347	14861	17455	14593	17119	18053	18038	14890	15369	14606	14945	17079	17428	15026
Ref2 to S/F	18366	18307.5	20814	18645	18059	21203	17730.5	20804	21928	21914	18074	18670	17736	18157	20753	21176	18229
Total	72407	72174	82044	73525	71185	83573	69917.5	82005	86484	86352	71266	73593	69935	71597.5	81829	83501	71918

Meters obtained – STANDARD RIDE – Based on each measurer's measurement of his own calibration course

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
S/F to S/F	2959.53	2958.66	2958.15	2958.24	2957.70	2959.92	2958.10	2957.10	2959.49	0.00	2960.88	2963.23	2959.97	2959.48	2958.10	2959.61	2962.56
S/F to Ref1	1030.55	1030.45	1030.18	1030.03	1030.19	1030.50	1030.16	1029.29	1030.11	3990.04	1030.66	1030.08	1030.93	1030.46	1030.24	1030.47	1031.49
Ref1 to Ref2	1549.21	1549.66	1548.20	1548.28	1548.78	1550.77	1548.14	1548.09	1548.81	1551.13	1551.72	1551.63	1550.58	1549.00	1548.22	1548.86	1552.25
Ref2 to S/F	1882.54	1882.45	1882.04	1881.00	1882.07	1883.76	1880.99	1881.33	1881.25	1884.44	1883.54	1884.89	1882.87	1881.91	1881.27	1881.95	1883.13
Total	7421.83	7421.22	7418.57	7417.55	7418.74	7424.96	7417.38	7415.82	7419.65	7425.61	7426.81	7429.83	7424.35	7420.85	7417.83	7420.89	7429.43
Stated Total	7419.51	7421.18		7415.9	7418.8	7424.8	7415	7415.7	7419.64	7425.369			7424.345	7420.98	7416.3	7419.5	
Difference	2.3	0.0		1.7	−0.1	0.2	2.4	0.1	0.0	0.2			0.0	−0.1	1.5	1.4	

Meters obtained – STANDARD RIDE – Using calibration course of 332.1386 meters

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
S/F to S/F	2960.07	2958.63	2957.78	2958.33	2958.20	2959.90	2958.25	2957.13	2959.49		2960.48	2963.74	2959.99	2959.43	2957.83	2959.45	2962.50
S/F to Ref1	1030.74	1030.44	1030.05	1030.06	1030.37	1030.49	1030.22	1029.30	1030.11		1030.52	1030.26	1030.93	1030.44	1030.15	1030.41	1031.47
Ref1 to Ref2	1549.49	1549.65	1548.01	1548.32	1549.04	1550.76	1548.22	1548.11	1548.81	1551.21	1551.51	1551.90	1550.59	1548.98	1548.08	1548.77	1552.22
Ref2 to S/F	1882.89	1882.43	1881.81	1881.05	1882.38	1883.74	1881.09	1881.35	1881.25	1884.53	1883.28	1885.22	1882.87	1881.88	1881.10	1881.85	1883.10
Total	7423.18	7421.15	7417.64	7417.76	7419.98	7424.88	7417.78	7415.89	7419.65	7425.97	7425.80	7431.12	7424.38	7420.73	7417.15	7420.47	7429.29

MEASUREMENTS OF SHORTEST POSSIBLE COURSE BASED ON CALIBRATION COURSE OF 332.1386 METERS

Counts obtained – SHORTEST RIDE

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
S/F to S/F	28852	28750		29300	28364		27872	32675	34424				27856	28525	32629	33283	
S/F to Ref1	10044	10008.5		10200	9875		9706	11378	11982				9702	9931	11361	11588	
Ref1 to Ref2	15095	15048.5		15328	14838		14574.5	17103	17983	18018			14579	14922	17072	17412	
Ref2 to S/F	18333	18284		18624	18034		17718.5	20781	21854	21884			17715	18128	20743	21162	
Total	72324	72091		73452	71111		69871	81937	86243	86302			69852	71506	81805	83445	

Meters Obtained – SHORTEST RIDE

	AB	BB	DL	DS	DY	ETM	FC	JD	JFD	KW	LRC	MGT	MW	PR	RL1	RL2	RMF
S/F to S/F	2959.40	2957.51		2956.96	2957.28		2957.92	2956.53	2955.99				2957.23	2957.23	2957.12	2957.76	
S/F to Ref1	1030.23	1029.57		1029.39	1029.59		1030.05	1029.52	1028.89				1029.98	1029.56	1029.63	1029.79	
Ref1 to Ref2	1548.32	1548.04		1546.91	1547.04		1546.72	1547.53	1544.20	1549.54			1547.72	1546.98	1547.21	1547.35	
Ref2 to S/F	1880.45	1880.87		1879.54	1880.26		1880.38	1880.33	1876.60	1882.01			1880.65	1879.36	1879.91	1880.60	
Total	7418.40	7415.99		7412.79	7414.16		7415.07	7413.90	7405.68	7421.91			7415.57	7413.13	7413.88	7415.50	

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HOW LONG WAS THE COURSE ?

We will never know exactly, but there are several ways to look at the possibilities. The graph below shows the range of measurement for each measurer, assuming that their true constants lie somewhere between the precalibration and postcalibration values.

The most popular possibility for length is the range from 7416.63 to 7417.91, say 7417.27. This length (the "mode") falls within the range of six measurers. No other value falls within so many ranges.

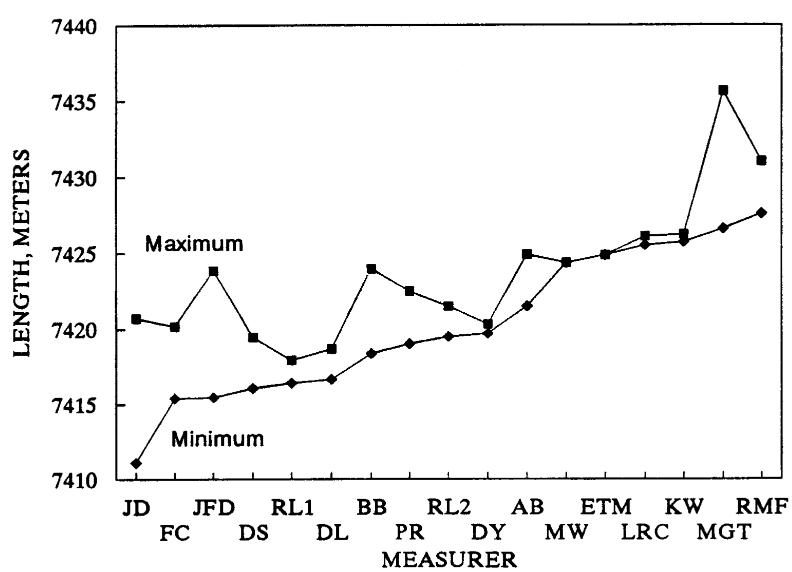
All measurers gave an estimate of course length on site, based on only their own measurements. After the data was passed out, and comments and reports requested, two of us responded with an opinion on "official" course length. Some methods of reckoning the length of the course are:

Based on Overall Measurement of Course	Length Meters
1) Average of overall measurements............................	7421.93
2) Median of overall measurements.............................	7420.73
3) Mode (most popular possibility)............................	7417.27
4) 0.5 percent limit method (favored by Delasalle - see report).	7419.17
Based on Use of Intermediate Split Measurements	
5) Sum of Median Splits (favored by Riegel)....................	7421.25
6) Sum of Shortest Splits......................................	7415.49

Bob Baumel favors use of the larger constant, but did not submit an estimate of an official length. All lengths above are based on the average constant.

Overall Course Measurement based on

	Smaller Constant	Larger Constant
JD	7420.69	7411.09
FC	7420.15	7415.41
JFD	7423.85	7415.46
DS	7419.45	7416.07
RL1	7417.91	7416.39
DL	7418.66	7416.63
BB	7423.96	7418.35
PR	7422.47	7418.99
RL2	7421.47	7419.48
DY	7420.28	7419.69
AB	7424.90	7421.46
MW	7424.38	7424.38
ETM	7424.88	7424.88
LRC	7426.09	7425.51
KW	7426.21	7425.73
MGT	7435.64	7426.60
RMF	7431.03	7427.56



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COMPARISON OF MEASUREMENTS – STANDARD RIDE – Using 332.139 m cal course

	S/F to S/F	S/F to Ref 1	Ref1 to Ref 2	Ref2 to S/F	Total Length	
AB	2960.07	1030.74	1549.49	1882.89	7423.18	
BB	2958.63	1030.44	1549.65	1882.43	7421.15	
DL	2957.78	1030.05	1548.01	1881.81	7417.64	
DS	2958.33	1030.06	1548.32	1881.05	7417.76	
DY	2958.20	1030.37	1549.04	1882.38	7419.98	
ETM	2959.90	1030.49	1550.76	1883.74	7424.88	
FC	2958.25	1030.22	1548.22	1881.09	7417.78	Note:
JD	2957.13	1029.30	1548.11	1881.35	7415.89	Box
JFD	2959.49	1030.11	1548.81	1881.25	7419.65	Indicates
KW			1551.21	1884.53	7425.97	Median
LRC	2960.48	1030.52	1551.51	1883.28	7425.80	
MGT	2963.74	1030.26	1551.90	1885.22	7431.12	
MW	2959.99	1030.93	1550.59	1882.87	7424.38	
PR	2959.43	1030.44	1548.98	1881.88	7420.73	
RL1	2957.83	1030.15	1548.08	1881.10	7417.15	
RL2	2959.45	1030.41	1548.77	1881.85	7420.47	
RMF	2962.50	1031.47	1552.22	1883.10	7429.29	
						Sum of
Average	2959.45	1030.37	1549.63	1882.46	7421.93	Shortest
High	2963.74	1031.47	1552.22	1885.22	7431.12	Splits
Low	2957.13	1029.30	1548.01	1881.05	7415.89	7415.49
Std Dev	1.68	0.45	1.40	1.20	4.28	Sum of
Std Dev, m/km	0.57	0.44	0.90	0.64	0.58	Medians
Median	2959.44	1030.39	1549.04	1882.38	7420.73	7421.25

PR

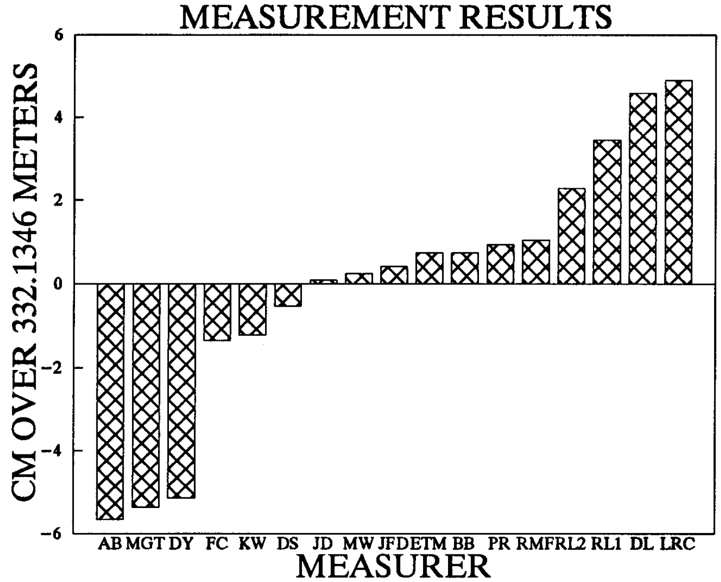
CALIBRATION COURSE MEASUREMENT

USING TAPES

	Length, m	Centimeters over Average	
AB	332.078	−5.7	
MGT	332.081	−5.4	
DY	332.083	−5.2	
FC	332.121	−1.4	
KW	332.122	−1.2	
DS	332.129	−0.5	
JD	332.135	0.1	
MW	332.137	0.2	
JFD	332.139	0.4	Median
ETM	332.142	0.7	
BB	332.142	0.7	
PR	332.144	0.9	
RMF	332.145	1.0	
RL2	332.157	2.3	
RL1	332.169	3.4	
DL	332.180	4.6	
LRC	332.183	4.9	
Average	332.1346		

CALIBRATION COURSE

MEASUREMENT RESULTS



BICYCLE CALIBRATION VARIATION

The ideal result on a series of four calibration rides is to get four identical counts. This is unusual, since we all wobble to some degree, and those who lock the wheel experience some carry-over of the previous reading. If a rider has four perfect rides of exactly 9410.25 counts they will appear in his notes as 9410, 9410.5, 9410.5, 9410, because we generally record only to the nearest half-count. Those who start at a new, round number each time will record 9410, 9410, 9410, 9410 (and will have a small error in the result).

Below is how calibrations varied for our group. The most amazing set of calibrations is that of Mike Wickiser, who had not a single count of variation over the entire 12 calibration rides, even with temperature change.

With few exceptions, the measurers were using bicycles that were new to them. This unfamiliarity with the equipment probably had an effect, but the extent is unknown.

In general, the more experienced measurers had the least variation within a given series, indicating that practice makes perfect.

CALIBRATION VARIATION – Based on each measurer's own calibration course measurement

	First Calib. Cts/km	First Variation Counts	First to Second Change cts/km	Second Calib. Cts/km	Second Variation Counts	Second to Third Change cts/km	Third Calib. Cts/km	Third Variation Counts	Average 4 Ride Variation Counts
AB	9758.2	1	−4.5	9753.7	1	−5.3	9748.4	2	1.3
BB	9729	1.75	−7.3	9721.7	3	−1.5	9720.2	1	1.9
DL	11058	1	3.0	11061	1				1.0
DS	9914.6	2	−4.5	9910	1	−1.9	9908.2	2	1.7
DY	9595.7	0.5	−0.8	9594.9	0.5	−4.1	9590.8	1	0.7
ETM	11256	0.5	0.0	11256	1.5				1.0
FC	9429.2	1	−6.0	9423.2	1	0.4	9423.5	1.5	1.2
JD	11065	2	−14.3	11051	1	1.9	11053	1	1.3
JFD	11663	0.5	−13.2	11649	1	−7.9	11642	1	0.8
KW	11629	1	0.8	11629	3	−1.5	11628	3	2.3
LRC	9596.2	11	−0.8	9595.4	7				9.0
MGT	9911.1	18	−12.1	9899	3				10.5
MW	9419.7	0	0.0	9419.7	0	0.0	9419.7	0	0.0
PR	9650.4	0.5	−4.5	9645.9	1.5	−0.4	9645.5	1	1.0
RL1	11030	1	2.3	11033	2	1.0	11034	1	1.3
RL2	11254	1					11251	0	1.2
RMF	9682.4	2	−4.5	9677.9	2				2.0

Note:
1) Variation is the difference between the greatest and least counts obtained in a calibration series
2) Change is the change in constant between successive calibrations.
3) ETM and RL2 used a solid tire. The rest were pneumatic.

PR

BICYCLE MEASUREMENTS OF THE CALIBRATION COURSE

In addition to having a test course to measure, it was possible to get a bike measurement of a course of known length. This is highly unusual.

Three sets of four calibration rides were made during the exercise by 11 riders. If the middle calibration course is considered to be a straight-line race course, we can use the first set of calibrations as precal, the last set as postcal, and the middle set as four measurements of the race course.

Our measurement of this course was somewhat unusual, as each rider measured the course four times, rather than twice. Rather than try to decide which of the 4 rides was "official" I figured the length three ways: 1) based on lowest count obtained in the 4 rides, 2) based on highest count, and 3) based on average count. The constant used was the average of precal and postcal. Results can be seen on the next page.

Our 11 measurements of the course have variability, most of it due to calibration change. There are no turns in the course, so skill is not a large factor. Only the change of tire size has an effect.

On the average, our bike measurements showed the calibration course to have a length of 332.09 meters, when its taped length was 332.14. This small error of 5 cm (about half a count) in the calibration course would produce an error of 1.4 meters (15 counts) in a 10 km course, since there are about 30 of our calibration courses in 10 km.

We have long assumed, based on informal observation, that the bicycle method has an accuracy of better than 1/1000. This calibration course measurement confirms this, on this measurement occasion.

Conditions were far from optimum for accuracy, since all riders experienced large changes in their calibration values. Individual measurements of the calibration course varied, depending on their individual calibration change, which was beyond the control of the measurers and does not reflect anything about their riding abilities.

Although, on the average, we had excellent accuracy in the bike measurements, it is obvious that it would be unwise for any individual rider to use a bicycle to establish a calibration course.

Because of the straight-line nature of the course, there was less variability (as measured by standard deviation) than on any segment of the test course.

PR

BICYCLE MEASUREMENTS OF THE CALIBRATION COURSE

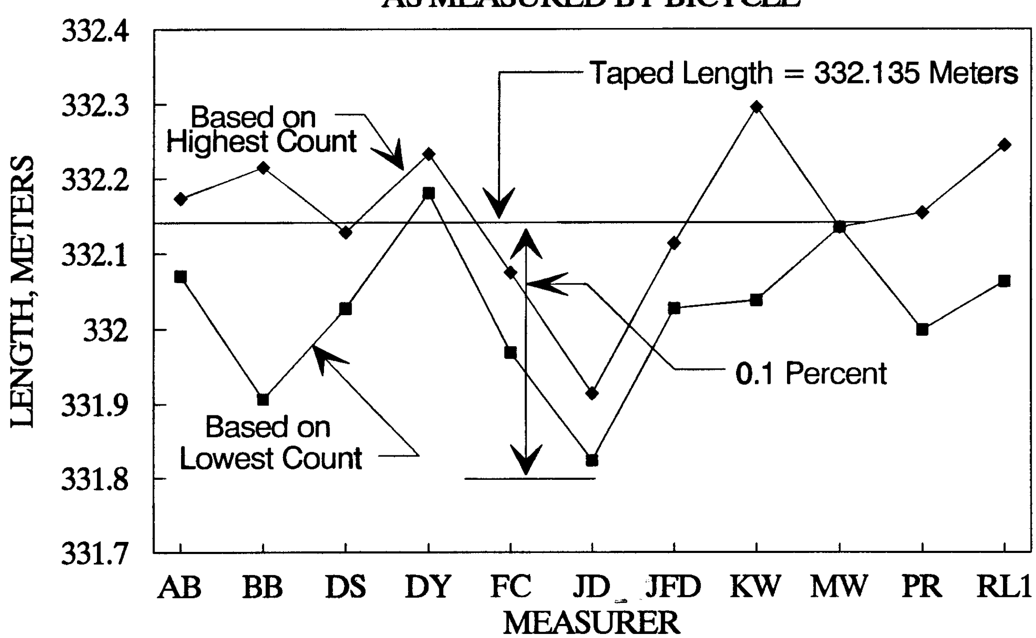
Note: The average constant without 1.001 is used here.
Lowest Count is the lowest of 4 rides on the mid-calibration.
Highest Count is the highest of 4 rides on the mid-calibration
Average Count is the average of the 4 mid-calibration rides.

	MEASURED VALUES BASED ON			Average Meters Error in 10 km
	Lowest Count	Highest Count	Average Count	
AB	332.07	332.17	332.12	-0.40
BB	331.91	332.21	332.06	-2.24
DS	332.03	332.13	332.08	-1.72
DY	332.18	332.23	332.21	2.15
FC	331.97	332.07	332.02	-3.41
JD	331.82	331.91	331.87	-8.02
JFD	332.03	332.11	332.07	-1.95
KW	332.04	332.30	332.17	0.96
MW	332.13	332.13	332.13	-0.01
PR	332.00	332.15	332.08	-1.77
RL1	332.06	332.24	332.15	0.56

Max	332.21	2.15
Min	331.87	-8.02
Avg	332.09	-1.44
Std Dev	0.086	2.593

CALIBRATION COURSE

AS MEASURED BY BICYCLE



COMPARISON OF STEEL TAPES

Fixed end holder: Tom McBrayer
Scale end reader: Dave Yaeger
Scale operator: Doug Loeffler

Either 100 feet or 30 m was held at the fixed end. The reading after tensioning was recorded.

Tape Number	Tape Type	Reading at Fixed End	Reading at Scale End	Tension Pounds	Length meters	mm over Avg	inches over Avg	inches per 100 ft over Avg	Measure-ment obtained for 30 m Target	Measure-ment obtained for 100 ft Target	Error meters in 10 km	
RMF1	fiberglass	30	1.038	10	28.962	−15.08	−0.59	−0.62	30.016	100.052	5.21	Out of spec
JFD9	plastic	30	1.045	10	28.955	−22.08	−0.87	−0.91	30.023	100.076	7.63	Out of spec
ETM1	steel	30	1.025	10	28.975	−2.08	−0.08	−0.09	30.002	100.007	0.72	
DIS1	steel	30	1.024	10	28.976	−1.08	−0.04	−0.04	30.001	100.004	0.37	
LOE1	steel	100	4.9375	10	28.975	−2.03	−0.08	−0.08	30.002	100.007	0.70	
DS	surv chain		95.08	10	28.980	3.30	0.13	0.14	29.997	99.989	−1.14	Out of spec *
DS	steel	100	4.9219	10	28.980	2.73	0.11	0.11	29.997	99.991	−0.94	Out of spec
JFD8	steel	30	1.021	11	28.979	1.92	0.08	0.08	29.998	99.993	−0.66	
BB1	steel	30	1.021	11	28.979	1.92	0.08	0.08	29.998	99.993	−0.66	
BB2	steel	30	1.027	10	28.973	−4.08	−0.16	−0.17	30.004	100.014	1.41	Out of spec
BB3	steel	30	1.022	10	28.978	0.92	0.04	0.04	29.999	99.997	−0.32	
TM1	steel	30	1.023	10	28.977	−0.08	−0.00	−0.00	30.000	100.000	0.03	
FC1	steel	30	1.025	10	28.975	−2.08	−0.08	−0.09	30.002	100.007	0.72	
RL1	steel	100	4.93	10	28.977	0.26	0.01	0.01	30.000	99.999	−0.09	
MW1	steel	100	4.9271	10	28.978	1.14	0.05	0.05	29.999	99.996	−0.39	
MW2	steel	100	4.9271	10	28.978	1.14	0.05	0.05	29.999	99.996	−0.39	
DY5	steel	30	1.025	10	28.975	−2.08	−0.08	−0.09	30.002	100.007	0.72	
PR1	Nylon/steel	100	4.93	4.5	28.977	0.26	0.01	0.01	30.000	99.999	−0.09	
PR2	steel	30	1.023	10	28.977	−0.08	−0.00	−0.00	30.000	100.000	0.03	

Excluding Fiberglass & Plastic

	Length meters	mm over Avg	inches per 100 ft over Avg	Error meters in 10 km
Average	28.9771	−0.00	−0.00	0.00
Std Dev	0.0019	1.94	0.081	0.671
High	28.9804	3.30	0.137	1.408
Low	28.9730	−4.08	−0.169	−1.140

* WE USED THE WRONG TENSION HERE. TAPE IS OK.
SEE BOB BAUMEL'S ANALYSIS.

US Government specification for steel tapes mandates maximum error of 0.1 inch in 100 feet. This is an error of 1 part in 12000, or 0.83 meters in 10 km.
If the average is taken as accurate, three steel tapes are out of spec, but not by an amount which affects bicycle measurements.
The two non−steel tapes are off enough to affect bicycle measurements.

PR

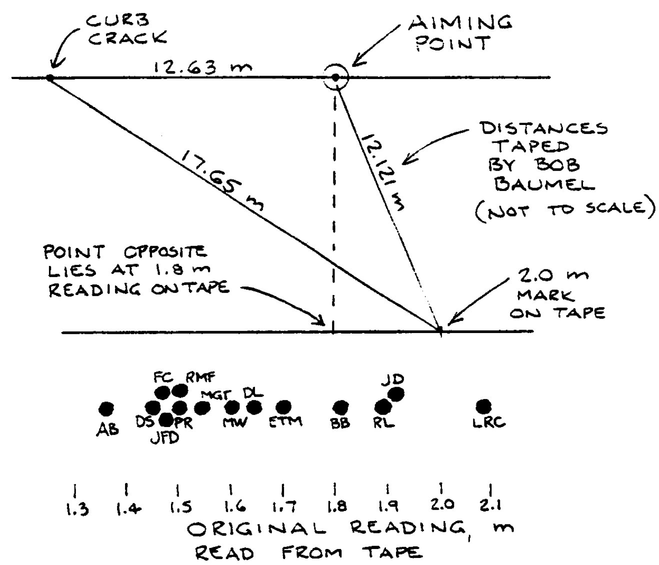
ESTIMATING THE OFFSET

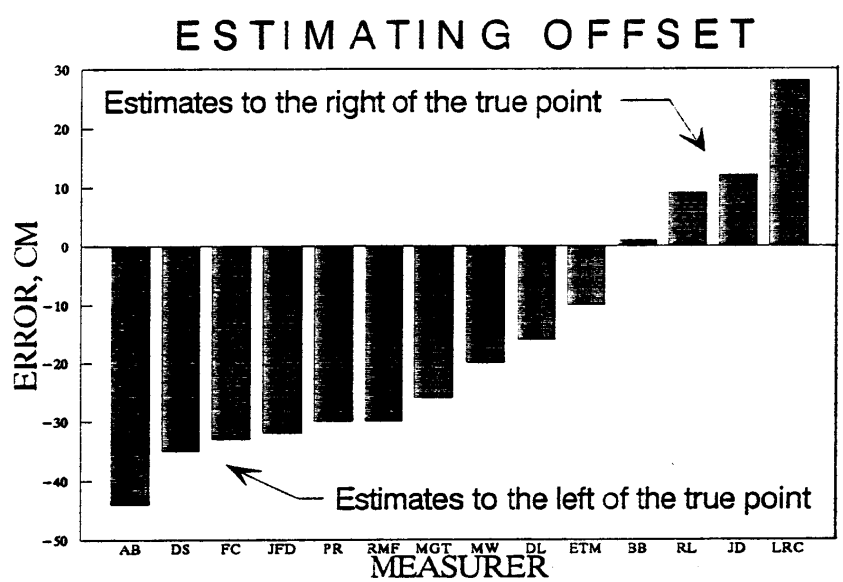
In this exercise, a steel tape was laid down opposite a mark on a curb, about 12 meters from the mark. Measurers estimated when they were opposite the mark, and read the tape.

Correct offset = 1.80 meters, established by Bob Baumel using steel tape triangulation (after making his estimate).

Note: Negative values indicate that the measurer chose a position to the left of the correct mark.

Measurer	Estimate Meters	Error Cm	Order of Accuracy
BB	1.81	1	1
RL	1.89	9	2
ETM	1.7	−10	3
JD	1.92	12	4
DL	1.64	−16	5
MW	1.6	−20	6
MGT	1.54	−26	7
LRC	2.08	28	8
RMF	1.5	−30	9
PR	1.5	−30	9
JFD	1.48	−32	11
FC	1.47	−33	12
DS	1.45	−35	13
AB	1.36	−44	14





PR

ACCURACY AND PRECISION

Each time a group of measurers get together, a spirit of competitiveness prevails. In past seminars, although each measurer was supposed to measure 30 cm from curbs, some rode tighter so as to get a smaller (seen as "better") measured value. This seminar provided a zero-offset ride to allow the competitive measurers to see who could ride the tightest, in the hope that all would try to ride 30 cm out on the standard ride of the course, as instructed.

How did the measurements turn out? Obviously there are many ways to interpret the data. I sought a method which looked even-handedly at the data. Is there a fair way to determine, from the data alone, how the measurers performed relative to one another?

Good measurement is both accurate and precise. If, on a 10 km course, we have measurements of 9990, 9991, 9990, 9989 we have a very precise measurer - he gets the same thing every time. However, he is 10 meters off the mark.

If our measurements are 9990, 10010, 9995, 10005 we have measurements that average 10,000 - right on the mark. Very accurate, but not precise.

Measurements of 9999, 10001, 9998, 10001 are both accurate and precise.

Here is the Accuracy and Precision (A&P) method of evaluating a group measurement. It is based on measurements of all intervals, rather than just on the overall measurement.

1) Calculate each person's measurement of all intervals using average constant. Although larger constant is safer, it is inferior to the average for statistical purposes.

2) For all intervals, take the median measurement as the best estimate of the length. After the fact a better estimate may become obvious, but we are looking for a way that can be specified beforehand, and the median is probably the best to choose.

3) Calculate the difference between each measurer's measurement of an interval and the median value.

4) Calculate the average of the differences. A perfect average would be zero, indicating that, on the average, the measurer was absolutely accurate.

5) Calculate the standard deviation of the differences. This is a statistically accepted measure of variability. A zero standard deviation would indicate perfect precision - the measurer was always the same difference from the median on each interval.

At this point we have the numbers we need to rank the measurements. Since accuracy and precision are both important, I give them equal weight.

To rank the measurements:

PR

1) Arrange the accuracy values (average differences) in increasing order. When done, the smallest gets a rank of 1, with the rest increasing by 1 until all are assigned a rank.

2) Arrange the precision values (standard deviation of the differences) in increasing order. When done, the smallest gets a rank of 1, with the rest increasing by 1 until all are assigned a rank.

3) For each measurer, sum their ranks. Then score like cross-country, with the least sum of ranks scoring the highest.

Our group was composed of mostly experienced measurers (ten or more courses measured. However, KW, LRC, MGT and RMF have little experience. I did not include them in the group comparison, because they had a disadvantage. I also dropped RL1 from the comparison, since RL2 was done at the same time and under the same conditions as the other measurements. I dropped ETM also, because his knee injury prevented a good ride. This left eleven measurements to be compared.

Obviously it is easier, once the data exists, to look at it and find a better way. It was the purpose of this exercise to find a method which is seen to be reasonably good before the data is taken. This way all participants know the ranking structure before measuring.

Note that the measurement depends on the acceptance of the median as the best estimate of the measured length of an interval. Also note that although an order of accuracy and precision is established, for competitive purposes, no absolute standard of acceptability is proposed. Thus one may have perfectly good measurements, yet come in low on the list because others did slightly better.

Other ranking methods are solicited.

Results of the method for this seminar and some past ones, showing first the top 3 measurers, and then others who were at Phoenix:

Phoenix 1994 (16 measurers, 4 intervals): Pete Riegel, Bob Letson, Dave Yaeger. Note: This course had more curves than normal.

Salouel (France) 1991 (7 measurers, 6 intervals): Pete Riegel, Jean-Francois Delasalle, Michel Tranchant. Note: This course was mostly straight, with few curves.

West Jefferson, Ohio 1990 (14 measurers, 5 intervals): Tom Knight, Mike Wickiser, Scott Hubbard (Tom McBrayer 4th, Pete Riegel 5th, Bob Baumel 6th, John Disley 7th, Doug Loeffler 11th). Note: This course had more curves than normal.

Los Angeles Olympic Marathon intervals 1983 (13 measurers, 13 intervals: Tom Knight, Tom Benjamin, Carl Wisser (Bob Letson 4th, Bob Baumel 5th, Pete Riegel 12th). Note: This course was normal.

PR

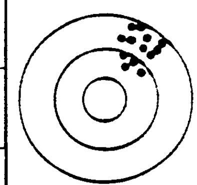
COMPARISON OF PHOENIX MEASUREMENTS – EXPERIENCED MEASURERS

	S/F to S/F	S/F to Ref 1	Ref1 to Ref 2	Ref2 to S/F	Total Length
AB	2960.07	1030.74	1549.49	1882.89	7423.18
BB	2958.63	1030.44	1549.65	1882.43	7421.15
DL	2957.78	1030.05	1548.01	1881.81	7417.64
DS	2958.33	1030.06	1548.32	1881.05	7417.76
DY	2958.20	1030.37	1549.04	1882.38	7419.98
FC	2958.25	1030.22	1548.22	1881.09	7417.78
JD	2957.13	1029.30	1548.11	1881.35	7415.89
JFD	2959.49	1030.11	1548.81	1881.25	7419.65
MW	2959.99	1030.93	1550.59	1882.87	7424.38
PR	2959.43	1030.44	1548.98	1881.88	7420.73
RL2	2959.45	1030.41	1548.77	1881.85	7420.47
Average	2958.79	1030.28	1548.91	1881.90	7419.88
High	2960.07	1030.93	1550.59	1882.89	7424.38
Low	2957.13	1029.30	1548.01	1881.05	7415.89
Std Dev	0.91	0.41	0.74	0.64	2.41
Std Dev, m/km	0.31	0.39	0.48	0.34	0.32
Median	2958.63	1030.37	1548.81	1881.85	1881.85

Note: Box Indicates Median

Sum of Shortest Splits 7415.49

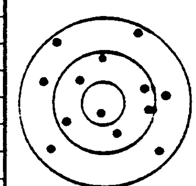
Sum of Medians 7419.65



Precise but not Accurate

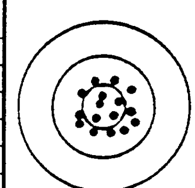
DIFFERENCES FROM THE MEDIAN INTERVAL MEASUREMENTS, M/KM

	S/F to S/F	S/F to Ref 1	Ref1 to Ref 2	Ref2 to S/F	Average of Differences m/km	Std Dev of Differences m/km
AB	0.49	0.36	0.44	0.55	0.461	0.069
BB	0.00	0.07	0.54	0.31	0.232	0.213
DL	−0.29	−0.31	−0.51	−0.02	−0.283	0.175
DS	−0.10	−0.29	−0.31	−0.42	−0.283	0.115
DY	−0.15	0.00	0.15	0.29	0.072	0.162
FC	−0.13	−0.14	−0.38	−0.40	−0.263	0.128
JD	−0.51	−1.04	−0.45	−0.26	−0.564	0.287
JFD	0.29	−0.25	0.00	−0.32	−0.069	0.238
MW	0.46	0.55	1.15	0.55	0.676	0.277
PR	0.27	0.07	0.11	0.02	0.118	0.093
RL2	0.28	0.05	−0.02	0.00	0.075	0.119



Accurate but not Precise

	PRECISION		ACCURACY		CROSS–COUNTRY SCORING	
	Std Dev of Differences m/km	Rank	Average of Differences m/km	Rank	Sum of Ranks	Overall Place
PR	0.093	2	0.118	4	6	1
RL2	0.119	4	0.075	3	7	2
DY	0.162	6	0.072	2	8	3
JFD	0.238	9	−0.069	1	10	4
AB	0.069	1	0.461	9	10	4
DS	0.115	3	−0.283	8	11	6
FC	0.128	5	−0.263	6	11	6
BB	0.213	8	0.232	5	13	8
DL	0.175	7	−0.283	7	14	9
JD	0.287	11	−0.564	10	21	10
MW	0.277	10	0.676	11	21	11



Precise and Accurate

SALOUEL 20 KM ANALYSIS 17 APRIL 1991

	0–3	3–5	5–8	8–10	10–15	15–20	Total
PR	2996.95	1997.90	2999.95	2000.38	5000.85	4995.36	19991.39
JFD	2997.05	1997.80	2999.86	2000.19	5000.57	4994.85	19990.32
MT	2997.05	1997.80	2999.15	2000.43	4999.68	4994.64	19988.75
AV	2996.98	1998.36	2999.09	2000.37	5001.43	4994.30	19990.53
DC	2997.36	1998.26	3001.04	2001.32	5001.42	4996.14	19995.54
GC	2997.45	1998.37	3000.92	2000.99	5001.50	4996.45	19995.68
JPL	2997.21	1998.01	3000.48	2000.33	5002.50	4996.48	19995.01
Avg	2997.15	1998.07	3000.07	2000.57	5001.14	4995.46	19992.46
Med	2997.05	1998.01	2999.95	2000.38	5001.42	4995.36	19991.39

DIFFERENCES FROM THE MEDIAN, M/KM

	0–3	3–5	5–8	8–10	10–15	15–20	Average	Std Dev
PR	−0.033	−0.055	0.000	0.000	−0.114	0.000	−0.034	0.041
JFD	0.000	−0.105	−0.030	−0.095	−0.170	−0.102	−0.084	0.055
MT	0.000	−0.105	−0.267	0.025	−0.348	−0.144	−0.140	0.134
AV	−0.023	0.175	−0.287	−0.005	0.002	−0.212	−0.058	0.152
DC	0.103	0.125	0.363	0.470	0.000	0.156	0.203	0.161
GC	0.133	0.180	0.323	0.305	0.016	0.218	0.196	0.104
JPL	0.053	0.000	0.177	−0.025	0.216	0.224	0.108	0.102

SCORING BY ACCURACY AND PRECISION

	Accuracy Average	Precision Std Dev	Accuracy Rank	Precision Rank	Combined Score	Combined Rank
PR	−0.034	0.041	1	1	2	1
JFD	−0.084	0.055	3	2	5	2
JPL	0.108	0.102	4	3	7	3
AV	−0.058	0.152	2	6	8	4
GC	0.196	0.104	6	4	10	5
MT	−0.140	0.134	5	5	10	5
DC	0.203	0.161	7	7	14	7

PR

WEST JEFFERSON, OHIO SEMINAR – JUNE 16, 1990

		TOTAL	S/1K	1K/2K	2K/3K	3K/4K	4K/F
AM	MORSS	5021.20	1009.82	1003.94	1002.37	988.63	1016.44
BB	BAUMEL	5020.18	1008.56	1003.81	1002.25	989.24	1016.32
BC	CONWAY	5016.95	1007.21	1003.35	1001.84	988.85	1015.70
DL	LOEFFLER	5015.16	1007.07	1002.58	1001.80	988.65	1015.06
ETM	MCBRAYER	5019.11	1008.19	1003.28	1002.08	989.28	1016.29
GT	TILLSON	5020.34	1007.90	1003.60	1003.02	989.52	1016.30
JD	DISLEY	5018.51	1007.62	1004.05	1002.12	988.95	1015.78
JW	WIGHT	5016.42	1007.38	1003.20	1001.91	988.73	1015.20
MW	WICKISER	5019.75	1008.10	1003.87	1002.38	989.19	1016.21
PR	RIEGEL	5018.31	1007.41	1003.31	1002.46	989.39	1015.74
RT	THURSTON	5019.24	1008.54	1003.73	1002.20	988.94	1015.83
SH	HUBBARD	5017.46	1007.80	1003.06	1001.88	989.01	1015.71
TK	KNIGHT	5019.10	1008.24	1003.34	1002.52	989.17	1015.82
WN	NICOLL	5023.29	1009.62	1004.47	1002.75	989.59	1016.85
	AVERAGE	5018.93	1008.10	1003.54	1002.26	989.08	1015.95
	MEDIAN	5019.10	1008.00	1003.47	1002.22	989.09	1015.83

Box = Median. Average of the two medians is used above.

DIFFERENCE FROM MEDIAN VALUE, METERS PER KILOMETER

		S/1K	1K/2K	2K/3K	3K/4K	4K/F	Std Dev	Average
AM	MORSS	1.81	0.47	0.15	−0.47	0.60	0.746	0.512
BB	BAUMEL	0.56	0.34	0.02	0.15	0.49	0.201	0.312
BC	CONWAY	−0.78	−0.13	−0.38	−0.24	−0.12	0.242	−0.330
DL	LOEFFLER	−0.92	−0.89	−0.42	−0.44	−0.76	0.213	−0.687
ETM	MCBRAYEI	0.19	−0.20	−0.15	0.19	0.45	0.242	0.098
GT	TILLSON	−0.10	0.13	0.79	0.44	0.47	0.306	0.345
JD	DISLEY	−0.38	0.58	−0.11	−0.14	−0.05	0.318	−0.019
JW	WIGHT	−0.61	−0.28	−0.31	−0.37	−0.61	0.147	−0.436
MW	WICKISER	0.10	0.40	0.16	0.10	0.38	0.133	0.227
PR	RIEGEL	−0.58	−0.16	0.23	0.31	−0.09	0.315	−0.058
RT	THURSTON	0.54	0.26	−0.02	−0.15	0.00	0.245	0.125
SH	HUBBARD	−0.19	−0.42	−0.34	−0.08	−0.11	0.130	−0.230
TK	KNIGHT	0.24	−0.13	0.30	0.08	−0.00	0.157	0.098
WN	NICOLL	1.61	1.00	0.52	0.51	1.01	0.405	0.931

	PRECISION Std Dev of Differences m/km	Rank	ACCURACY Average of Differences m/km	Rank	CROSS-COUNTRY SCORING Sum of Ranks	Overall Place
TK	0.157	4	0.098	3	7	1
SH	0.130	1	−0.230	7	8	2
MW	0.133	2	0.227	6	8	2
ETM	0.242	7	0.098	4	11	4
PR	0.315	11	−0.058	2	13	5
BB	0.201	5	0.312	8	13	5
JD	0.318	12	−0.019	1	13	5
RT	0.245	9	0.125	5	14	8
JW	0.147	3	−0.436	11	14	8
BC	0.242	8	−0.330	9	17	10
DL	0.213	6	−0.687	13	19	11
GT	0.306	10	0.345	10	20	12
AM	0.746	14	0.512	12	26	13
WN	0.405	13	0.931	14	27	14

PR

1984 Olympic Marathon Measurements over 13 intervals by 13 Measurers – 24 April 1983

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	
BB	1293.98	1593.76	3572.64	4232.47	1918.10	2549.56	4269.26	2034.03	2780.09	5308.06	611.15	575.78	168.93	30907.80	Baumel
BL	1293.90	1593.50	3571.22	4233.11	1917.82	2551.17	4269.43	2034.01	2779.36	5306.83	611.00	575.82	168.76	30905.93	Letson
CW	1293.23	1593.76	3573.47	4234.67	1918.06	2551.32	4270.42	2034.40	2780.20	5307.50	611.42	575.84	168.70	30912.98	Wisser
DK	1294.09	1594.09	3574.10	4233.30	1917.77	2550.91	4271.46	2034.94	2780.48	5307.05	611.13	575.67	168.46	30913.45	Katz
JD	1293.10	1594.05	3574.36	4235.61	1918.09	2550.30	4270.22	2034.82	2779.98	5306.22	611.33	575.33	169.13	30912.54	Delaney
PC	1294.56	1594.00	3571.46	4231.92	1918.15	2551.64	4271.26	2034.87	2779.89	5307.38	610.96	575.61	168.41	30910.11	Christenson
PR	1293.52	1593.73	3574.01	4234.22	1918.75	2551.30	4270.66	2034.43	2781.11	5308.11	611.08	575.83	169.09	30915.84	Riegel
PS	1294.95	1593.35	3572.01	4231.96	1918.21	2549.99	4269.44	2034.01	2780.14	5306.64	611.17	575.88	168.40	30906.15	Shandera
RS	1294.08	1596.67	3573.08	4234.51	1917.68	2550.62	4273.99	2034.39	2780.43	5307.97	611.14	575.85	168.00	30918.41	Scardera
TB	1293.51	1594.30	3573.92	4234.51	1918.53	2550.72	4271.33	2034.53	2779.68	5307.90	610.65	575.70	168.76	30914.05	Benjamin
TD	1293.86	1593.70	3574.15	4233.28	1918.57	2550.77	4270.94	2034.78	2780.06	5306.51	610.90	575.73	168.14	30911.38	Duranti
TK	1293.95	1593.36	3573.37	4233.05	1918.27	2550.15	4269.46	2034.09	2780.00	5307.59	610.99	575.96	168.78	30909.03	Knight
WR	1294.47	1593.65	3572.53	4233.29	1918.07	2549.98	4270.93	2034.74	2779.25	5303.71	610.86	575.47	168.60	30905.55	Rasmussen

Avg	1293.94	1593.99	3573.10	4233.53	1918.16	2550.65	4270.68	2034.46	2780.05	5307.04	611.06	575.73	168.63	30911.02
Med	1293.95	1593.76	3573.37	4233.29	1918.10	2550.72	4270.66	2034.43	2780.06	5307.38	611.08	575.78	168.70	30911.38

Difference from median, meters per kilometer

	1	2	3	4	5	6	7	8	9	10	11	12	13	Average	Std Dev
BB	0.023	0.000	−0.204	−0.194	0.000	−0.455	−0.328	−0.197	0.011	0.128	0.106	0.000	1.387	0.021	0.428
BL	−0.039	−0.163	−0.602	−0.043	−0.146	0.176	−0.288	−0.206	−0.252	−0.104	−0.133	0.071	0.403	−0.102	0.231
CW	−0.556	0.000	0.028	0.326	−0.021	0.235	−0.056	−0.015	0.050	0.023	0.543	0.108	0.000	0.051	0.240
DK	0.108	0.207	0.204	0.002	−0.172	0.074	0.187	0.251	0.151	−0.062	0.082	−0.184	−1.423	−0.044	0.420
JD	−0.657	0.182	0.277	0.548	−0.005	−0.165	−0.103	0.192	−0.029	−0.219	0.396	−0.776	2.602	0.173	0.790
PC	0.471	0.151	−0.535	−0.324	0.026	0.361	0.140	0.216	−0.061	0.000	−0.195	−0.285	−1.707	−0.134	0.529
PR	−0.332	−0.019	0.179	0.220	0.339	0.227	0.000	0.000	0.378	0.138	0.000	0.096	2.312	0.272	0.615
PS	0.773	−0.257	−0.381	−0.314	0.057	−0.286	−0.286	−0.206	0.029	−0.139	0.136	0.186	−1.737	−0.187	0.537
RS	0.100	1.826	−0.081	0.288	−0.219	−0.039	0.780	−0.020	0.133	0.111	0.090	0.135	−4.108	−0.077	1.269
TB	−0.340	0.339	0.154	0.288	0.224	0.000	0.157	0.049	−0.137	0.098	−0.702	−0.127	0.379	0.029	0.289
TD	−0.070	−0.038	0.218	−0.002	0.245	0.020	0.066	0.172	0.000	−0.164	−0.303	−0.085	−3.296	−0.249	0.891
TK	0.000	−0.251	0.000	−0.057	0.089	−0.223	−0.281	−0.167	−0.022	0.040	−0.149	0.328	0.504	−0.015	0.217
WR	0.402	−0.069	−0.235	0.000	−0.016	−0.290	0.063	0.152	−0.291	−0.691	−0.370	−0.526	−0.587	−0.189	0.302

Scoring by accuracy and precision

	Accuracy Average	Precision Std Dev	Accuracy Rank	Precision Rank	Combined Score	Combined Rank
TK	−0.015	0.217	1	1	2	1
TB	0.029	0.289	3	4	7	2
CW	0.051	0.240	5	3	8	3
BL	−0.102	0.231	7	2	9	4
BB	0.021	0.428	2	7	9	4
DK	−0.044	0.420	4	6	10	6
WR	−0.189	0.302	11	5	16	7
PC	−0.134	0.529	8	8	16	7
PS	−0.187	0.537	10	9	19	9
RS	−0.077	1.269	6	13	19	9
JD	0.173	0.790	9	11	20	11
PR	0.272	0.615	13	10	23	12
TD	−0.249	0.891	12	12	24	13

PR

ANALYSIS OF JFD'S 8 PHOENIX RIDES

	S/SF	SF/R1	R1/R2	R2/F	TOTAL
JFD1	2961.39	1030.88	1548.89	1881.69	7422.85
JFD2	2959.50	1030.11	1548.81	1881.26	7419.68 ←
JFD3	2959.47	1030.43	1549.41	1880.97	7420.28
JFD4	2959.10	1030.63	1549.02	1881.86	7420.61
JFD5	2958.98	1030.42	1549.10	1881.78	7420.28
JFD6	2959.71	1030.86	1549.24	1881.58	7421.39
JFD7	2959.94	1030.78	1549.60	1881.79	7422.11
JFD8	2960.78	1030.91	1550.48	1881.87	7424.04
AVG	2959.86	1030.63	1549.32	1881.60	7421.41
MEDIAN	2959.61	1030.71	1549.17	1881.74	7421.00

Difference from the Median, m/km

	S/SF	SF/R1	R1/R2	R2/F	Average	Std Dev
JFD1	0.603	0.170	−0.181	−0.024	0.142	0.294
JFD2	−0.035	−0.577	−0.232	−0.252	−0.274	0.194 ←
JFD3	−0.046	−0.267	0.155	−0.407	−0.141	0.214
JFD4	−0.171	−0.073	−0.097	0.066	−0.068	0.086
JFD5	−0.211	−0.277	−0.045	0.024	−0.127	0.121
JFD6	0.035	0.150	0.045	−0.082	0.037	0.082
JFD7	0.113	0.073	0.278	0.029	0.123	0.094
JFD8	0.397	0.199	0.846	0.072	0.378	0.294

Scoring by Accuracy and Precision

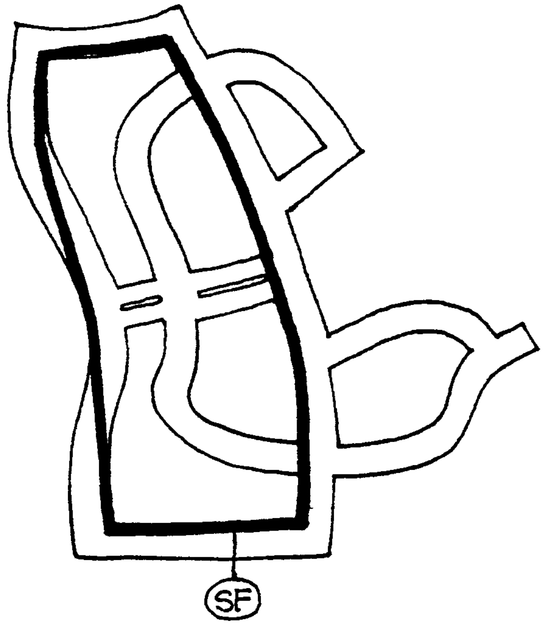
	Accuracy Average	Precision Std Dev	Accuracy Rank	Precision Rank	Combined Score	Combined Rank
JFD6	0.037	0.082	5	1	6	1
JFD4	−0.068	0.086	4	2	6	1
JFD2	−0.274	0.194	1	5	6	1 ←
JFD5	−0.127	0.121	3	4	7	4
JFD3	−0.141	0.214	2	6	8	5
JFD7	0.123	0.094	6	3	9	6
JFD8	0.378	0.294	8	7	15	7
JFD1	0.142	0.294	7	8	15	7

JFD'S OFFICIAL PHOENIX RIDE

METERS — *computed by using the* <u>*average*</u> *of the two adjacent calibration counts, dividing by 1.001, and assuming that the calibration course is 332.14 meters.*

ROUTE	SF-SF		SF-1		1-2		2-SF		TOTAL	
OFFSET	30cm	0cm	30cm	0cm	30cm	0cm	30cm	0cm	30cm	0cm
BL1	2957.8	2957.2	1030.1	1029.6	1548.1	1547.2	1881.1	1879.9	7417.1	7414.0
BL2	2959.5	2957.8	1030.4	1029.8	1548.8	1547.4	1881.9	1880.6	7420.5	7415.5
DS	2958.4	2957.0	1030.1	1029.4	1548.3	1546.9	1881.1	1879.6	7417.8	7412.8
JD	2957.1	2956.5	1029.3	1029.5	1548.1	1547.5	1881.4	1880.3	7415.9	7413.9
MW	2960.0	2957.2	1030.9	1030.0	1550.6	1547.7	1882.9	1880.7	7424.4	7415.6
FC	2958.3	2957.9	1030.2	1030.1	1548.2	1546.7	1881.1	1880.4	7417.8	7415.1
KW					1551.2	1549.5	1884.5	1882.0	7426.0	7421.7
JF	2959.5	2956.0	1030.1	1028.9	1548.8	1544.2	1881.3	1876.6	7419.7	7405.7
DL	2957.8		1030.1		1548.0		1881.8		7417.7	
DY	2958.2	2957.3	1030.4	1029.6	1549.0	1547.0	1882.4	1880.3	7420.0	7414.2
BB	2958.6	2957.5	1030.4	1029.6	1549.6	1548.0	1882.4	1880.9	7421.2	7416.0
PR	2959.5	2957.3	1030.5	1029.6	1549.0	1547.0	1881.9	1879.4	7420.9	7413.2
AB	2960.1	2959.4	1030.7	1030.2	1549.5	1548.3	1882.9	1880.5	7423.2	7418.4
ETM	2959.9		1030.5		1550.8		1883.7		7424.9	
LR	2960.5		1030.5		1551.5		1883.3		7425.8	
MGT	2963.8		1030.3		1551.9		1885.2		7431.2	
RMF	2962.5		1030.4		1552.2		1883.1		7429.3	

RL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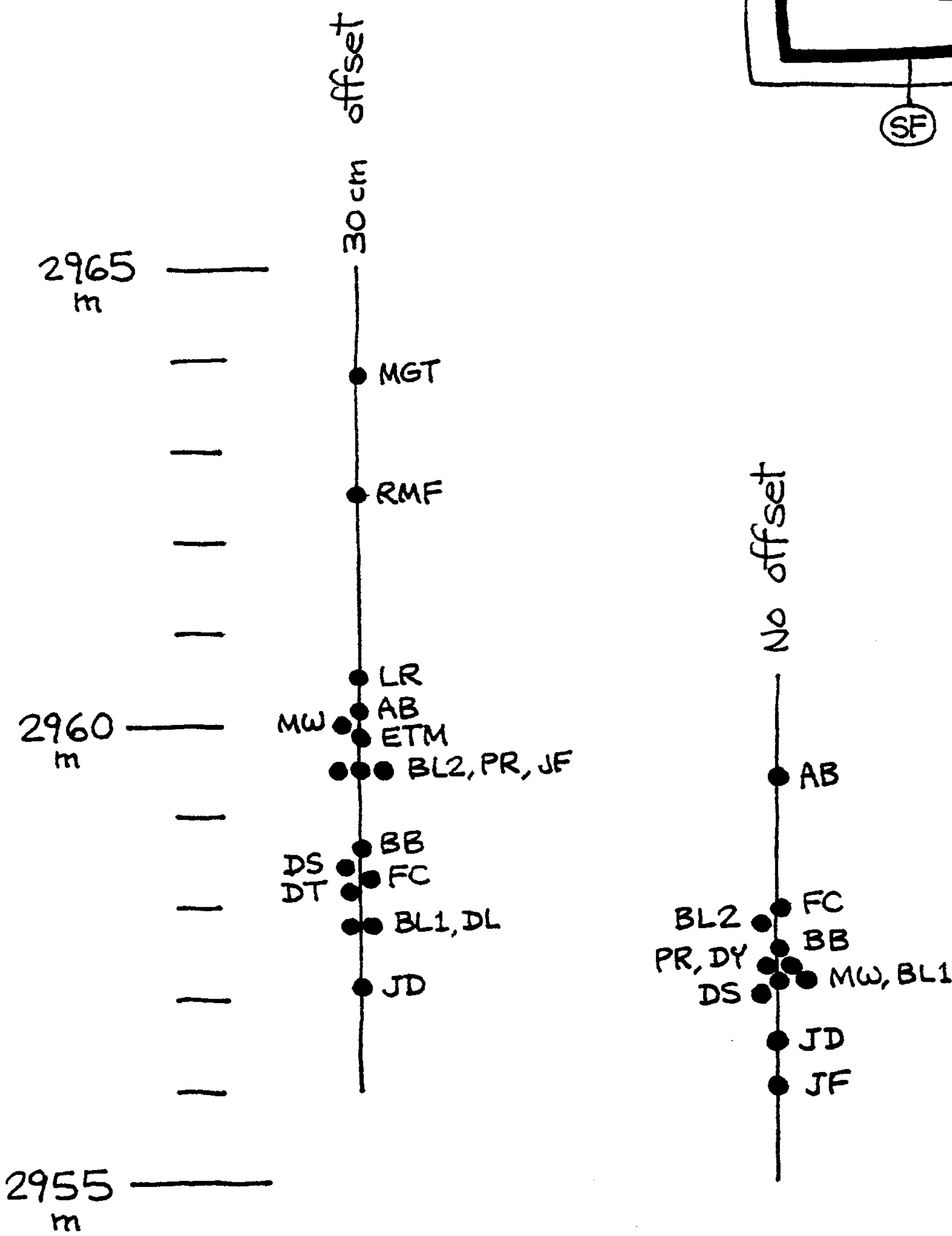
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LR
AB
MW
ETM
2960 m
BL2, PR, JF
BB
DS
FC
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JD
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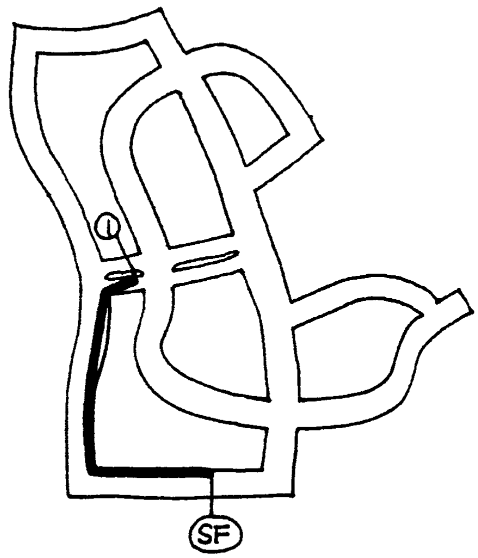
BL2
BB
PR, DY
MW, BL1
DS
JD
JF

RL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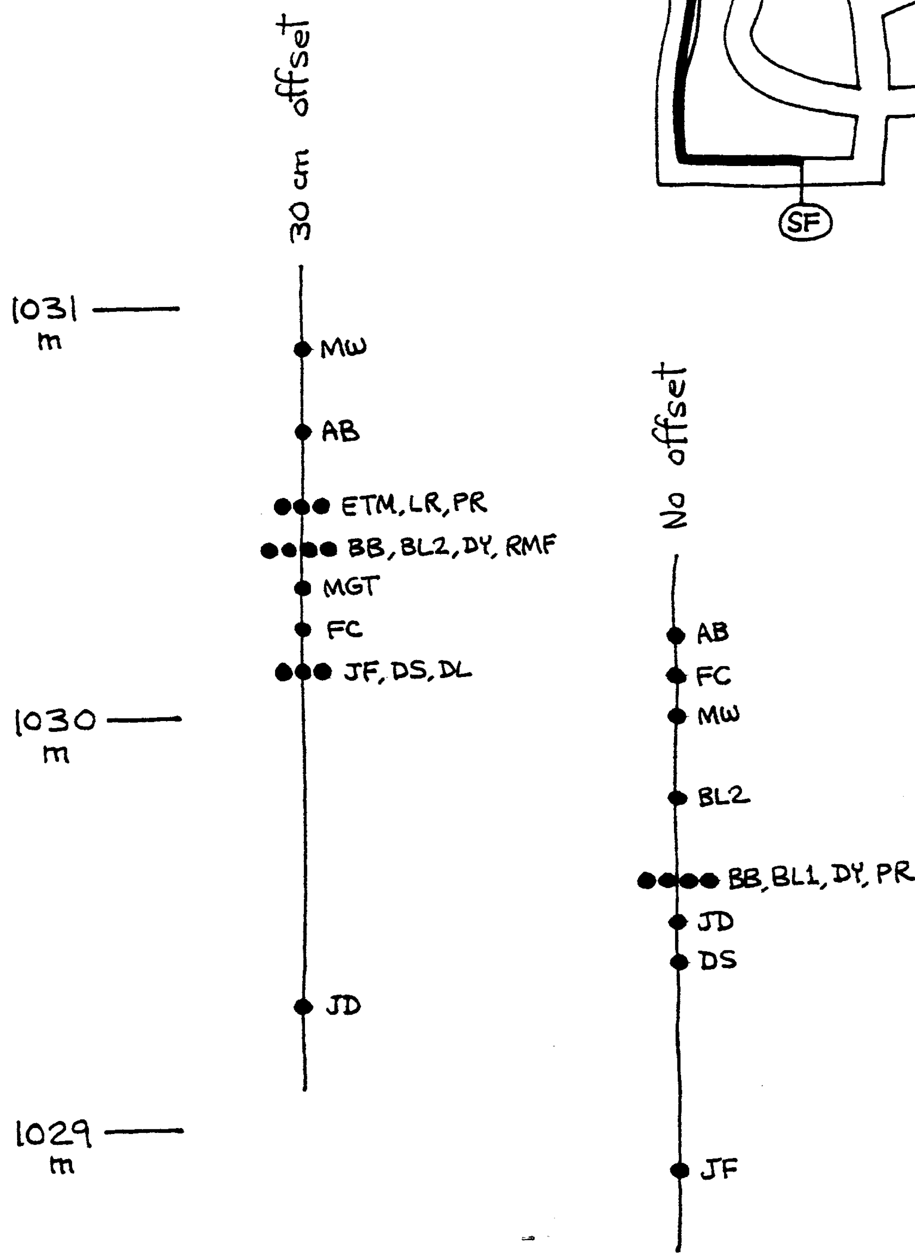
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AB
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MGT
FC
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JD
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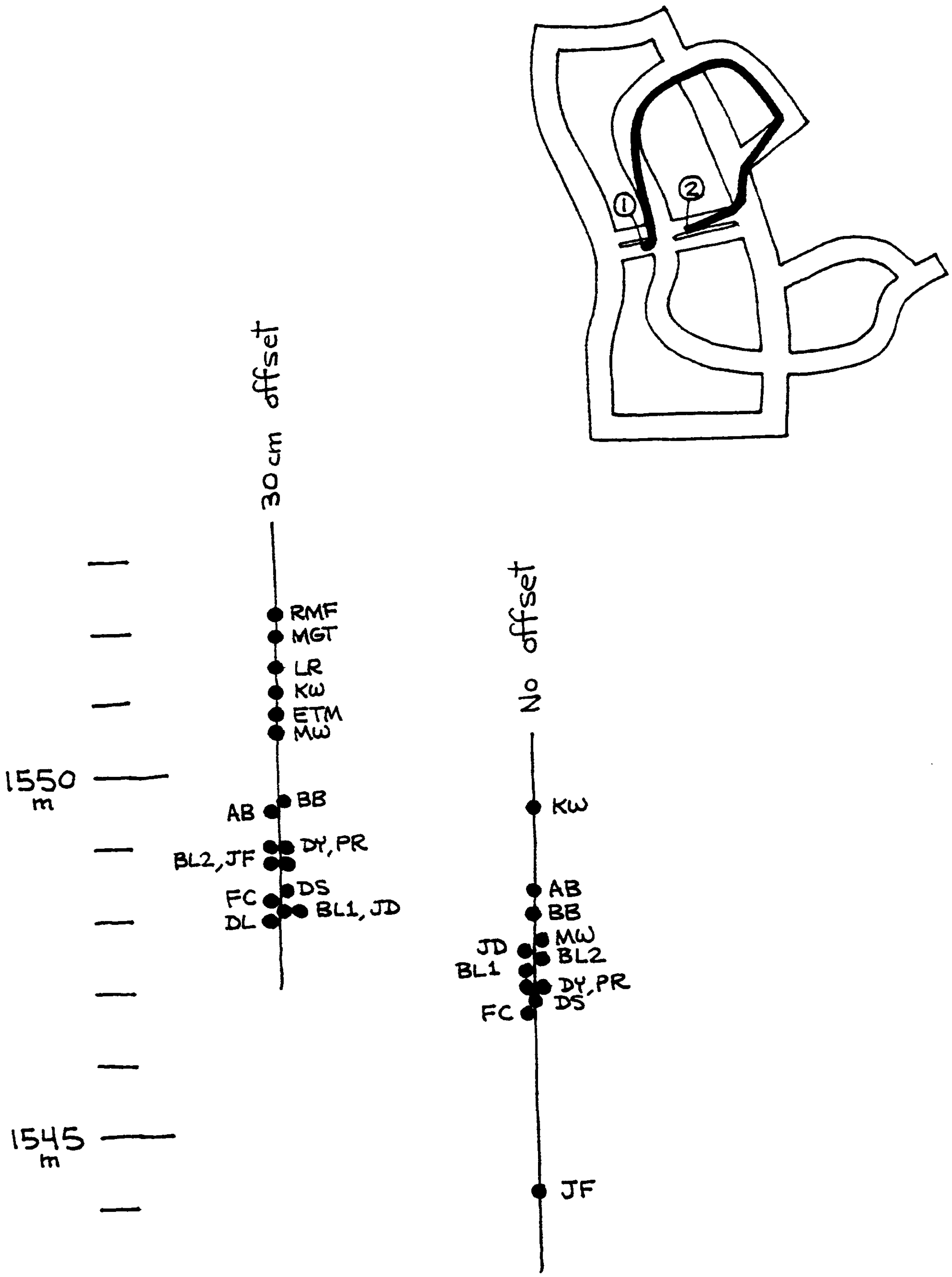
MW
BL2
BB, BL1, DY, PR
JD
DS
JF

RL



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LR
KW
ETM
MW
AB
BB
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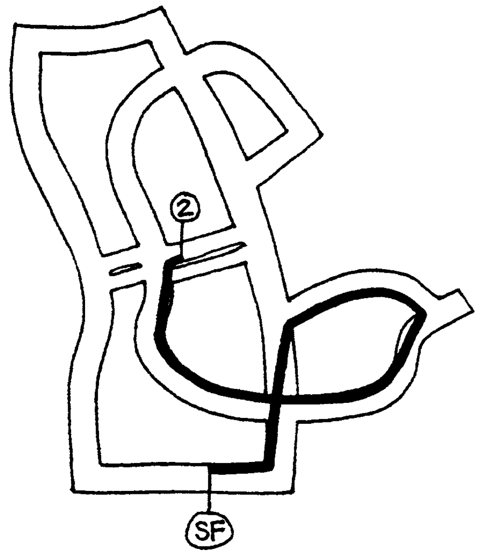
DS
FC
JF

RL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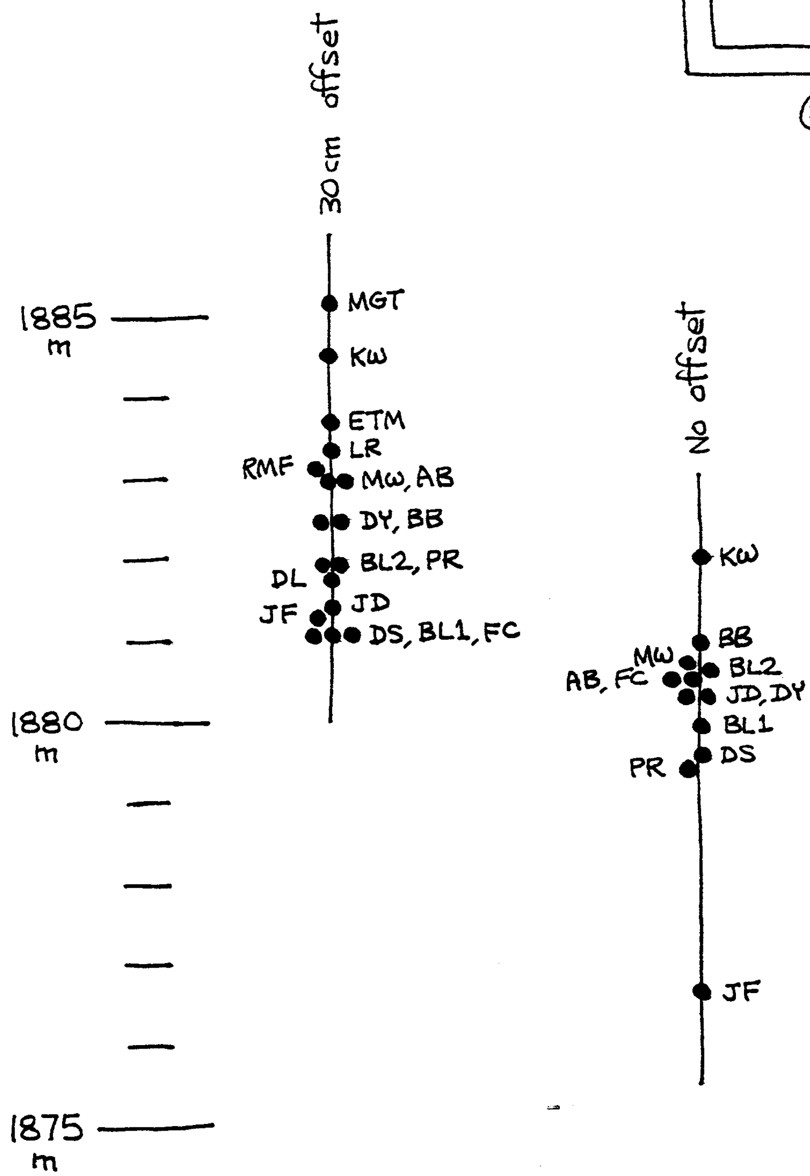
SF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BL2
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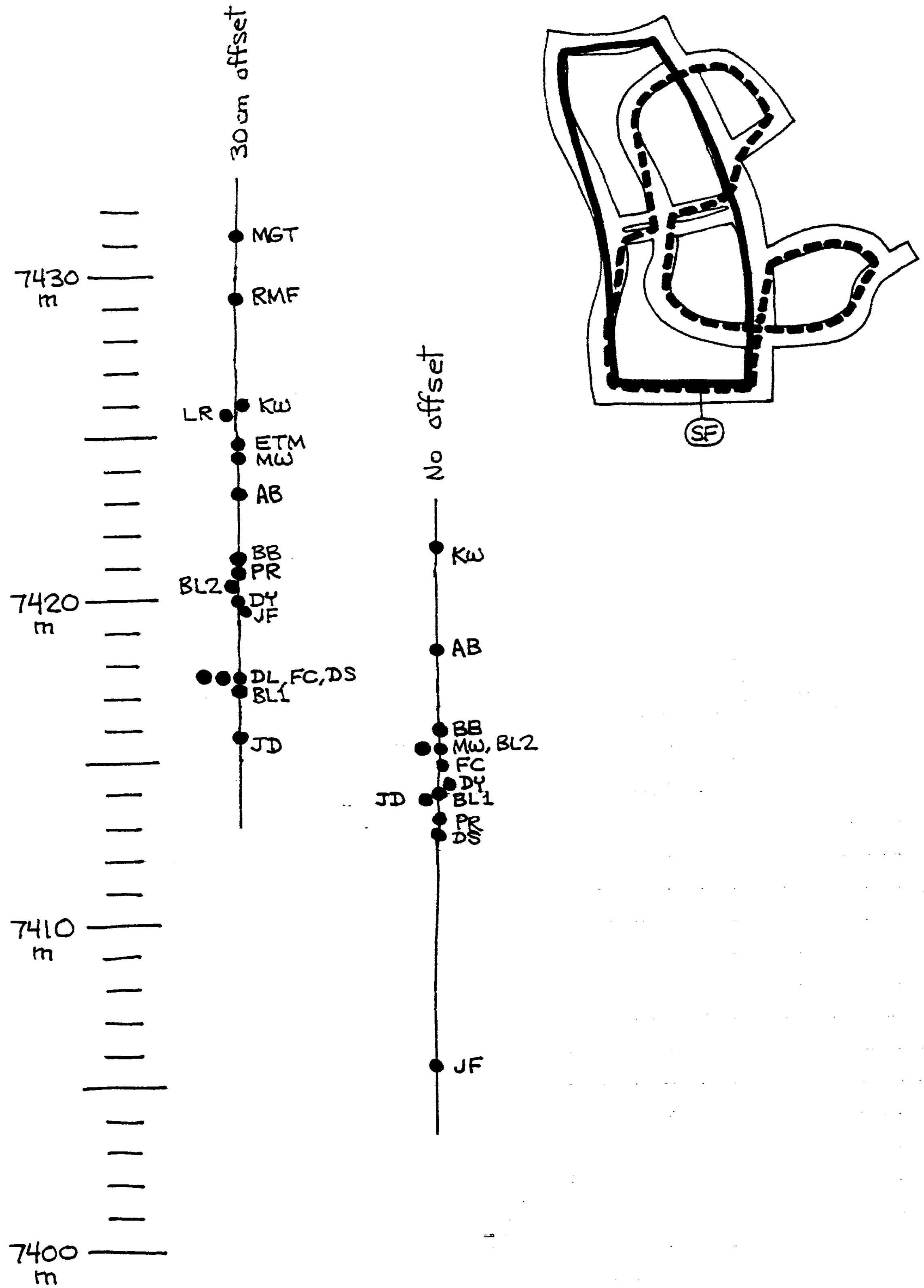
JD, DY
BL1
DS
PR
JF

RL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JD
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KW
AB
BB
MW, BL2
FC
DY
JD
BL1
PR
DS
JF
7430 m
7420 m
7410 m
7400 m
SF

USA Track & Field

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1994-07-05

Data Analysis — Phoenix Seminar, 20-21 May 1994

Here is my analysis of the data from the Phoenix seminar. My discussion is in three parts, covering the Tape Comparison, the Calibration Course Measurements, and the Bike Measuring. For each of these areas, my results are summarized by Tables (numbered 1, 2, and 3), which are printouts of spreadsheets worked up in Lotus 1-2-3.

TAPE COMPARISON (See Table 1)

This experiment confirmed that most steel tapes are about as accurate as we expected; therefore, tape manufacturing error is not a serious cause of concern in calibration course taping. Another result I found satisfying was that, based on a "calibration" I had once performed for my own best tape (BB 1), the average measurement of all 17 steel tapes seems to be a pretty accurate estimate of the true distance (to about one part in 60000).

The experiment was, however, marred by a major methodological flaw—many of the tapes were pulled with incorrect force. Another result I find somewhat disturbing: Based on this experiment, I tried deriving correction factors for each tape (final column in Table 1). Unfortunately, use of these correction factors did **not** improve the agreement between our different measurements of the calibration course (See discussion of Calibration Course Measurements later).

Tape manufacturing error (which is probed by this experiment) is, of course, only *one* of the possible errors in taping a calibration course. Other sources of error include failure to apply proper tension or correct for temperature, and outright blunders such as miscounting tape lengths or mis-identifying the tape's zero point.

In addition to the 17 steel tapes tested in this experiment, we included two non-metallic tapes: One (from Rodolfo Martinez) is fiberglass; the other ("JFD 9" from Jean-François Delasalle) is very likely also fiberglass, but was listed on the data sheet only as a "plastic" tape. Our results support the prohibition against using tapes of this type for measuring calibration courses. However, I have not attempted a totally rigorous comparison of these non-metallic tapes with the steel tapes because I lack sufficient information to do so. For example, I don't know the thermal expansion coefficient for fiberglass tapes. Also, in this experiment, the fiberglass tapes were (like many other tapes) pulled with incorrect force.

Tape Tension Confusion

Several mistakes were made in tensioning the tapes. The biggest error was a logical fallacy involving Don Shepan's 200 ft chain-tape (to be described below). Other mistakes were probably simple ignorance (i.e., not knowing the correct tension for various tapes). Most of these errors would have been avoided if I had arrived early enough at the experiment and had been available throughout the experiment to advise the spring scale operators. However, after finishing my bike measurements Saturday afternoon, I was somewhat late arriving at the Tape Comparison experiment.

Before proceeding with this discussion, I feel that I must explain why I'm devoting so much time to this apparently nitpicky subject. Often, when I attempt quantitative discussion of the finer points of taping (such as correct tension), Pete Riegel complains that we make taping too complicated (Sometimes it seems that he wants to do away entirely with spring scales, thermometers, finely-drawn lines on masking tape, etc.). We did partially accommodate that desire for simplification in the 1989 revision of *Course Measurement Procedures*. The book no longer requires use of a spring balance; it is enough simply to estimate the tape tension "by feel."

I agree that in normal calibration course taping, omitting the spring balance is usually a negligible source of error (at least, if the measurers have previously made *some* reasonable attempt to develop a feel for the correct tension). But this "Tape Comparison" experiment was not normal taping. The object of this experiment, as I see it, was to probe an extremely subtle effect, namely, the inherent error in steel tapes due to inaccuracies in manufacturing. We know that the US Government standard for steel-tape accuracy is 1 part in 12000. The question we'd like to answer is: "Do the manufacturers meet that standard?"

In order to probe this minuscule effect, we must be sure that the tiny differences observed between tapes truly represent manufacturing error, as opposed to other factors under our control, such as temperature and tension. These other factors, if not properly controlled, *can* produce errors just as big as the tape manufacturing error that we want to determine.

The design of this experiment (conducted rapidly in the shaded parking lot) successfully eliminated the *temperature* effect (at least, for comparing the *steel* tapes against *each other*). However, *tension* wasn't handled as well. Pete's original plan was apparently to pull every tape with an identical force of 10 lbf (the standard value for US-made 100 ft steel tapes). This is basically what was done, although exceptions were made in three cases. However, the number of exceptions *should* have been considerably greater, because *many more* of our tapes were designed to take tensions other than 10 lbf. (Note: In Table 1, I have calculated corrections for three of the tapes that were tensioned incorrectly.)

Clearly, if the object was to probe tape manufacturing error, then each tape should have been pulled with the correct force intended by its manufacturer. Otherwise, the observed measurement differences could reflect mainly our errors in tape tension instead of the effect we wanted to study.

The most serious error in tape tension occurred with Don Shepan's chain-tape [identified "DS(chain)" in Table 1]. This is a 200-ft heavy-gauge steel tape, intended to be used with tension of 20 pounds-force (lbf), which is about 90 newtons (N). The force actually applied was only 10 lbf (≈ 45 N). This was a major logical fallacy, as I will explain later. But first, I will mention some other tensioning errors in the experiment:

Most metric steel tapes should be pulled with the Internationally standard tension of 50 N (≈ 11 lbf) rather than 10 lbf. During the experiment, I tried to inform Pete of this fact, but my comment was apparently misunderstood. The correct 50 N tension was used for *only two* of the metric tapes ("JFD 8" and "BB 1"), while all of the *other* metric tapes were pulled with 10 lbf (as if they were 100 ft tapes). Fortunately, this was a very small error.

The fiberglass tapes were pulled much too hard. According to my Lufkin catalog, fiberglass tapes take a light pull of 20 N (≈ 4.5 lbf). However, in this experiment, the fiberglass tapes were pulled with the (much stronger) force of 10 lbf which is standard for 100 ft *steel* tapes. Most of the apparent disagreement between the fiberglass and steel tapes was probably due to this tensioning mistake.

Now, let's return to the error made when testing Don Shepan's 200 ft tape. I said this was a logical fallacy. I describe it this way because I'm sure that Pete Riegel, who was running the experiment, *knew* that this tape is intended to take 20 lbf. However, perhaps Pete decided (incorrectly) that the full 20 lbf tension is needed only when using whole 200-ft tape lengths. Here we used only about *half* the tape length, so maybe it seemed reasonable to apply only 10 lbf, which is the standard tension for 100 ft tapes.

Such reasoning is fallacious because tape tension is a *local* property. Consider a 200 ft tape designed to take a 20 lbf pull. We know to apply a 20 lbf force when using the whole 200-ft tape length. When this is done, the local tension is 20 lbf in the tape's first half, and 20 lbf in its second half. And if the tape has no manufacturing error, then local spacings between adjacent graduations in all parts of the tape will be correct. If the local tension in the tape's first half is reduced to 10 lbf, then spacings between graduations in this portion of the tape will *no longer* be correct (In fact, they will be too close together).

Thus, even if we use only half the tape, we must tension this used portion to the full value intended for the tape—20 lbf in this particular case. (Of course, there is no need to tension the half of the tape that we aren't using.) The moral is that each tape *should* have been tensioned to the full value intended by its manufacturer, regardless of the fraction of the tape actually used.

Two other common fallacies regarding tape tension are relevant to events at this seminar: First, there's the **"skinny tape" fallacy** (See my comments on this subject in July '91 *Measurement News* pp 15–17, and Sept '92 *MN* pp 15–20). In this experiment, Pete Riegel's nylon-clad steel tape (PR 1) was pulled with a very light force of only 20 N (≈ 4.5 lbf). This seems to follow a statement on page 14 of *Course Measurement Procedures* (1989 edition), which specifies this tiny force for all nylon-clad steel tapes. Unfortunately, **the book is wrong** in this case!

In general, 20 N is the correct tension only for *fiberglass* tapes. *Steel* tapes (of all weights, with or without nylon coatings) normally take at least 45 or 50 N.

Nevertheless, the tiny 20 N tension used with tape PR 1 was *correct in this particular case.* But this is a very special case. Tape PR 1, purchased by Pete in 1984, was one of the *very earliest* Japanese-made nylon-clad steel tapes. After much discussion about this topic, it seems most likely that the manufacturer *made a mistake* in this case—by graduating the tape to be accurate at the tension standard for fiberglass tapes instead of steel tapes. This error was corrected in later production by the Japanese tape makers. The 20 N tension figure does *not* apply to other nylon-clad steel tapes such as tape BB 1, which takes 50 N. Clearly, the mistaken assertion about 20 N tension must be removed from our book!

The other common fallacy is the **"long tape" fallacy**. This is the assumption that all steel tapes longer than 100 ft require an extra-strong pull of 20 lbf (≈ 90 N). Actually, according to my Lufkin catalog, this applies only to "surveyor's tapes of heavy gauge steel." Don Shepan's 200 ft chain-tape falls in this class, but most of our other tapes are lighter, and take less tension, even in lengths considerably exceeding 30 m. An example is tape BB 1, a lightweight 60 m steel tape that takes only 50 N. At the 1990 seminar in Ohio, Bob Thurston brought a tape identical to BB 1. He had been using it with 90 N, until I located the correct 50 N specification marked on its blade. An even more extreme example surfaced during the present Phoenix seminar, namely, Dave Yaeger's 100 m steel tape (labelled by the number "5" in the data sheets). Here also, the tape's owner (Yaeger) had been using 90 N tension, until I discovered the marking on its blade showing that 50 N is correct.

Contents of Table 1

The first four columns contain the tape identifier, the tape's units (metres or feet), and the tension applied to the tape in both newtons and pounds-force. Note: These tension figures (in both units) are expressed as rounded values, and were all keyed into the table by hand (I *did not* program an exact conversion factor into the spreadsheet). In case you would like

BB

Tape Comparison – Analysis by Bob Baumel

Table 1

Fixed End Holder/Reader: McBrayer
Scale End Holder/Reader: Yaeger
Scale Operator/Reader: Loeffler

Tape Identifier	Units (m or ft)	Tension (N)	Tension (lbf)	Fixed End (m or ft)	Scale End (m or ft)	Scale End (+ inches)	Meas'ment (m)	Corrected (m)	Notes	Corr Factor
ETM 1	m	45	10	30	1.025		28.9750	28.9750	Lufkin 30 m/100 ft	1.0000663
DIS 1	m	45	10	30	1.024		28.9760	28.9760	Rabone Chesterman 50 m	1.0000318
LOE 1	ft	45	10	100	4	11.25	28.9751	28.9751	Lufkin 100 ft	1.0000646
DS(chain)	ft	45	10	95	-0.08		28.9804	28.9787	Lufkin 200 ft (Corr to 20 lbf)*	0.9999392
DS	ft	45	10	100	4	11.0625	28.9798	28.9798	Sears Craftsman 100 ft	0.9999002
Rodolfo	m	45	10	30	1.038		28.9620		FIBERGLASS – Truper 75 m	
JFD 8	m	50	11	30	1.021		28.9790	28.9790	Stanley 50 m	0.9999283
JFD 9	m	45	10	30	1.045		28.9550		"PLASTIC" – 50 m	
BB 1	m	50	11	30	1.021		28.9790	28.9790	Lietz 60 m Nylon-coated	0.9999283
BB 2	m	45	10	30	1.027		28.9730	28.9725	Evans 30 m (Corr to 50 N)*	1.0001526
BB 3	m	45	10	30	1.022		28.9780	28.9775	Lufkin 30 m/100 ft (Corr to 50 N)*	0.9999800
TM 1	m	45	10	30	1.023		28.9770	28.9770	Who owns THIS tape?	0.9999973
FC	m	45	10	30	1.025		28.9750	28.9750	Irwin 30 m/100 ft	1.0000663
RL	ft	45	10	100	4.93		28.9773	28.9773	Lufkin 100 ft	0.9999857
MW 1	ft	45	10	100	4	11.125	28.9782	28.9782	Lufkin 100 ft	0.9999550
MW 2	ft	45	10	100	4	11.125	28.9782	28.9782		0.9999550
5	m	45	10	30	1.025		28.9750	28.9750	Lufkin 100 m	1.0000663
PR 1	ft	20	4.5	100	4.93		28.9773	28.9773	Lietz 100 ft Nylon-coated	0.9999857
PR 2	m	45	10	30	1.023		28.9770	28.9770	Lufkin 30 m/100 ft	0.9999973
							Average:	28.9769		
							Std Dev:	0.0019		

greater precision, the conversion (to eight significant figures) is: 1 lbf = 4.4482216 N.

The next few columns contain the readings at the "fixed end" and "scale end" obtained with each tape. These are messy-looking because we had tapes with three different types of graduations: Metric, Decimal Feet, and Feet/Inch. Generally, the fixed-end reading was chosen as 30 m for metric tapes and 100 ft for English tapes, with just one exception: Don Shepan's chain-tape is, through most of its length, graduated only in whole-foot increments. The only finely-graduated part of this tape is a reverse-graduated foot preceding the zero mark. For this tape, we used the 95 ft mark as the fixed-end reading; the scale-end reading was then within the reverse-graduated foot, at a point 0.08 ft *before* the zero mark.

The column labelled "Meas'ment" contains each tape's measurement (in metres) for the distance between the two points we had marked on the road. In this column, my Lotus 1-2-3 spreadsheet actually contains a somewhat complicated formula which subtracts the scale-end reading from the fixed-end reading, checks the "Units" column, and converts from feet to metres when necessary.

The "Corrected" column is an attempt to correct for errors in tape tension. Actually, I calculated tension corrections for *only three* of the tapes (where I had enough data to make this calculation), namely: DS(chain), BB 2, and BB 3. Specifically, I tried to calculate the readings we *would* have observed if we had pulled tape DS(chain) with 20 lbf (90 N) instead of 10 lbf (45 N), and if we had pulled tapes BB 2 and BB 3 with 50 N instead of 10 lbf (45 N).

The change in length of a steel tape due to a given change in applied tension can be calculated with one of the following formulas. If we know the tape's cross-sectional area:

$$\text{Change in Length (cm/km)} = \frac{0.5 \times [\text{Change in Tension (N)}]}{\text{Cross-Sectional Area (mm}^2\text{)}} \qquad (1)$$

or, if we know the tape's linear density (which can be found by *weighing* the tape):

$$\text{Change in Length (cm/km)} = \frac{4.0 \times [\text{Change in Tension (N)}]}{\text{Linear Density (g/m)}} \qquad (2)$$

Note: In deriving these formulas, I approximated slightly to obtain round-number coefficients; nevertheless, the equations are generally accurate to within around 5%. For steel tapes with thick nylon or plastic coatings, these formulas require cross-sectional area or linear density of the tape's *steel core* rather than the complete tape.

For Don Shepan's 200 ft chain-tape, Don told me it's a Lufkin "Super Hi-Way Chrome Clad" model. I looked this model up in my Lufkin catalog, and found that its cross-sectional area is 3.8 mm^2. Equation (1) then predicts that a 45 N change in tension produces a length change of 5.9 cm/km, which is 1.7 mm in a distance of 29 m. Therefore, the reading would have been 1.7 mm less if the tape had been pulled with 90 N instead of 45 N.

For tapes BB 2 and BB 3, I know by direct weighing that their linear density is about 10 g/m (which corresponds to a cross-sectional area of about 1.3 mm^2, or about 1/3 the area of Shepan's chain-tape). From Equation (2), a 5 N change in tension produces a length change of 2 cm/km, which is 0.58 mm in a length of 29 m. Thus, the readings would be reduced by about half a millimetre if these tapes were pulled with 50 N instead of 45 N.

I do not have enough data to compute tension corrections for the 14 *other* steel tapes, even though it's clear that some of them were also pulled with incorrect force. For these 14 tapes, the "Corrected" column is an exact copy of the raw "Meas'ment" column.

I listed the two non-metallic tapes in the raw "Meas'ment" column, but have omitted them from the "Corrected" column. I am unable to compute corrections for the non-metallic tapes to allow direct comparisons between them and the steel tapes. Thus, my final analysis is mainly a comparison of the steel tapes *against each other*.

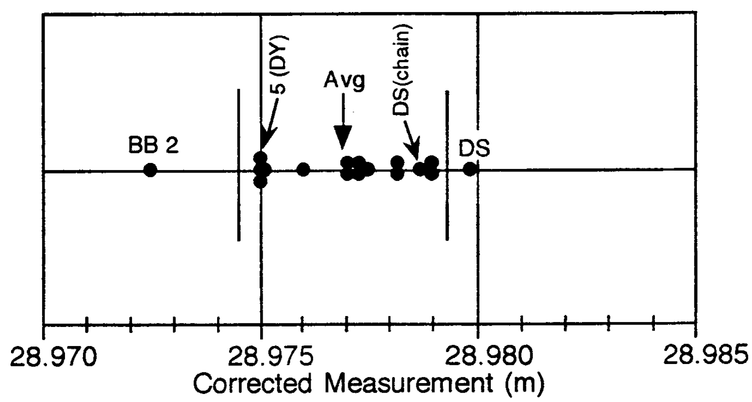
At the bottom of the "Corrected" column, I have computed the Average and Standard Deviation of the 17 "corrected" steel tape measurements displayed in that column.

Finally, the last column of Table 1, headed "Corr Factor," lists the ratio of the Average corrected measurement to the corrected measurement obtained with each individual tape. This is the factor that measurements from this tape should be multiplied by in order to agree with the average of all 17 steel tapes.

Results of Tape Comparison

Figure 1 is a plot of the numbers from the "Corrected" column of Table 1. On this plot, I have identified the average measurement; also, I've drawn vertical lines marking the range of values whose difference from the average does not exceed one part in 12000 (which is the tolerance specified by the US Government steel-tape accuracy standard).

Figure 1: Tape Comparison Results



A natural assumption when viewing Figure 1 is that the *average* measurement provides a measure of absolute accuracy. This can be partly justified on statistical grounds: Assuming that the manufacturing process is not biased toward either long or short tapes, the possible error in our average measurement is indicated by the "standard deviation of the mean," calculated as the standard deviation from Table 1 divided by the square root of the number of measurements; i.e., 1.9 mm / $\sqrt{17} \approx$ 0.46 mm. Thus, we might expect our average measurement to be accurate within about half a millimetre.

Further justification for accuracy of the average measurement comes from a "calibration" I once did for my 60 m tape (BB 1) by checking it on a stretch of road measured with EDM. From that "calibration," I determined that the correction factor for tape BB 1 (used at 50 N tension) is 0.999946. If that factor is multiplied by the measurement from tape BB 1 in the present Tape Comparison (28.979 m), the result is 28.9774 m, which differs from our average measurement (28.9769 m) by only 0.5 mm.

Assuming that deviation from the average is a good indication of accuracy, Figure 1 shows that 15 of our 17 steel tapes meet the US Government standard. Of the two tapes that seem to violate the standard, tape "DS" (Don Shepan's 2nd tape—a Sears Craftsman model) is only *very slightly* outside the tolerance. However, tape "BB 2" (my Evans 30 m tape) seems to be very clearly out-of-spec, as its difference from the average measurement was nearly *twice* the official tolerance.

Note: tape BB 2 was not used for any calibration course measurements during this seminar; however, it *had* been used during the earlier 1990 Ohio seminar by one of the taping teams under Wayne Nicoll's direction. Possibly, this out-of-spec tape was responsible for some of the confusion observed during the taping on that occasion.

The two other labelled points in Figure 1, tape "DS(chain)" (Don Shepan's heavy chain-tape) and tape "5" (Dave Yaeger's 100 m tape), both meet the government standard. However, these cases are interesting in connection with previously-discussed tape tension errors:

For tape DS(chain), the value plotted in Figure 1 (28.9787 m) falls within the tolerance. However, this is my *corrected* value (the calculated reading that *would* have been obtained if the tape were pulled with correct force of 20 lbf). The reading actually obtained with this tape (tensioned incorrectly to 10 lbf) was 28.9804 m—which lies *outside* the tolerance.

For tape "5" (Yaeger's 100 m tape), the value plotted in Figure 1 (28.975 m) was the reading officially recorded in the experiment, using a *nearly* correct tension of 45 N (which differs only negligibly from the correct value of 50 N). However, as mentioned earlier, Yaeger had been fooled by the "long tape" fallacy. Prior to this experiment, he was pulling his tape with the far-too-strong force of 90 N. During the Tape Comparison, Yaeger did (out of curiosity) test his tape with the incorrect 90 N pull. This result was not recorded on the official data sheet, but Dave told me that he obtained 28.972 m. If included in Figure 1, this would plot slightly to the left of BB 2, clearly *way* out-of-spec.

Some differences between manufacturers are evident in the Tape Comparison results. Those manufacturers that specifically sell to the surveying profession, such as Lufkin and Lietz, seem to always meet the standard. Others may be more borderline. The *least* accurate tape in this test was my Evans 30 m tape (BB 2). I now consider Evans a brand to avoid.

Curiously, this out-of-spec Evans tape was sold in a package bearing the legend: "The blade in this tape conforms to all United States Government Specifications for accuracy." I should note that many tapes made by Evans are not actually labelled with the Evans name, but are sold under a variety of store-brand names. For example, Evans tapes are sold in the US as an Ace Hardware store-brand, and in Canada as a Canadian Tire store-brand.

Finally, what about the fiberglass tapes, which do not appear in Figure 1? If plotted, they would be *way off the left-hand edge* of the graph. (By the way, the comparison becomes even worse after accounting for temperature, which could be ignored when comparing only the steel tapes *against each other*. The temperature correction shifts all the steel-tape measurements about 5 mm to the right, but does not shift the fiberglass-tape results.)

The main reason why the fiberglass-tape measurements came out so low is that *we pulled the fiberglass tapes too hard*. Fiberglass tapes are intended to take a light tension of 20 N, but we used 45 N, which was too strong by 25 N. This produced very large errors—and this is precisely the reason why fiberglass tapes are not acceptable for calibration course taping: They are simply *too sensitive to tension errors*.

Figures in my Lufkin catalog suggest that fiberglass tapes are five times as stretchy as the lightest steel tapes. For our lightweight steel tapes (such as BB 2, BB 3, and probably also PR 1 and BB 1), a 25 N tension error produces a 10 cm/km distance error, which is only 1/10 of our "Short Course Prevention Factor," and is probably tolerable. For fiberglass tapes, however, the same 25 N tension error produces a 50 cm/km distance error, which is fully *half* of the SCPF, and is clearly unacceptable.

In the Track & Field world, fiberglass tapes have been accepted for measuring distances in field events. This may have been due more to popular demand than legitimate accuracy considerations. (Note that a 25 N tension error in fiberglass taping can produce errors of about 1 cm in a 20 m shotput, or 4 cm in an 80 m javelin throw.) However, we in RRTC do not make the rules for Track & Field. We do set the standards for road course measurement, and we choose not to allow fiberglass tapes for calibration course taping.

Resolution of This Experiment

After all of the preceding analysis, I have realized that there was a second major flaw in the methodology of this Tape Comparison experiment. The *first* big flaw was the incorrect tension applied to some tapes, especially Don Shepan's chain-tape. The *second* flaw was the low resolution with which many of the tape measurements were recorded. Specifically, each reading was recorded in whole tape graduations, based on whatever units the tape was graduated in (i.e., the experimenters never estimated fractions of graduations).

Using this approach, the best resolution was achieved for the metric tapes, all of which were graduated throughout in millimetres. Resolution was much worse for the Imperial tapes: Decimal-Foot tapes are graduated in units of 0.01 ft (≈ 3.05 mm). Most Feet/Inch tapes are graduated in units of 1/8 inch (≈ 3.2 mm), although some Feet/Inch tapes are graduated to 1/16 inch (≈ 1.6 mm). These low resolutions were responsible for the "clustering" of measurements observed in Figure 1.

Recall that our object was to detect small differences between tapes, typically within 1 part in 12 000 (which is the Government tolerance). On our 29 m test course, a 1 part in 12 000 difference is about 2.4 mm, which may be difficult to detect when the tape graduations are 3 mm apart and we make no attempt to estimate fractional graduations.

Let's see what happened with the Imperial tapes. First, there were three Decimal-Foot tapes: Tapes RL and PR 1 obtained identical readings of 95.07 ft, which converts to 28.9773 m, and happens to agree remarkably well with our *average* measurement. Notice, however, that readings of either 95.06 ft or 95.08 ft would plot as out-of-spec in Figure 1. Tape DS(chain) did obtain a reading of 95.08 ft; however, it had been pulled with too little force (10 lbf instead of 20 lbf). I calculated that using the correct 20 lbf tension would have reduced the reading by 1.7 mm. *Actually*, if the tape were tensioned correctly to 20 lbf, and the reading taken in whole 0.01 ft units, the measurement would probably be 95.07 ft, exactly matching the results from tapes RL and PR 1.

There were four Feet/Inch tapes. Tapes MW 1 and MW 2 obtained identical results of 28.9782 m. That's *as close as you can get* to the average measurement, given a tape read in whole 1/8 inch units. The next closest possibility (at 1/8 inch resolution) is 28.9751 m, obtained by tape LOE 1. That's about 2 mm *below* the average, as opposed to tapes MW 1 and MW 2 which tested about 1 mm *above* the average. Tape DS, which is graduated to 1/16 inch resolution, came out somewhat farther from the average, and truly appears to be of borderline accuracy by the Government standard.

What's the practical effect of the limited resolution in this experiment? I believe that most of my previous statements about relative accuracy of various tapes remain valid. The problem arises when the tape correction factors computed in Table 1 are applied to actual measurements made with the tapes (as I do in Table 2), because the results have huge error bars. First, if we were to plot error bars in Figure 1 (which would make the plot unreadable due to all the overlap), the uncertainties are ±0.5 mm for the metric tapes, ±1.5 mm for Decimal-Foot tapes, ±1.6 mm for tapes with 1/8 inch graduations, and ±0.8 mm for tapes with 1/16 inch graduations. Then, when these correction factors are applied to measurements of the 332 m calibration course, the possible length errors due to these uncertainties become ±0.6 cm, ±1.7 cm, ±1.8 cm, and ±0.9 mm respectively.

In view of these large error bars, it is questionable whether the correction factors derived from the Tape Comparison can really improve measurements made with these tapes.

CALIBRATION COURSE MEASUREMENTS (See Table 2)

Here I calculate everybody's measurement of the calibration course, corrected for temperature using the measurers' own reported temperatures, and also with a tape correction derived from the Tape Comparison experiment. As we will see, use of corrections derived from the Tape Comparison experiment did *not* improve the agreement among measurements of the calibration course. I will discuss these results, and examine various sources of error in the calibration course measurements.

Contents of Table 2

The first two columns list the measurer's name and the time of day of taping. (Bob Letson taped the course *twice*—first in evening of May 20, then in afternoon of May 21.) Note that I arranged this table in chronological order.

The third column of Table 2 contains a tape identifier, matching the identifiers from Table 1 (column 1), for matching up the tapes used in calibration course measurements with tapes tested in the Tape Comparison experiment. No identifier is listed for Andy Beach's tape (a 100 ft Sears Craftsman), which was mistakenly omitted from the Tape Comparison because it got confused with another tape of the same make owned by Don Shepan.

The 4th column of Table 2 lists each tape's units (metres or feet). Then I list the Raw Measurements. As in Table 1, these look messy because we had tapes with three kinds of graduations: Metric, Decimal Feet, and Feet/Inch.

Note: Table 2 includes *corrected* data for Tom McBrayer, who listed incorrect raw measurement and temperature figures on his data sheet. I happen to know Tom's *correct* data on the calibration course taping because he and I taped together. Tom and I taped the course twice: first from west to east with myself leading, then from east to west with Tom leading. Unfortunately, when Tom filled out his data sheet, he mistakenly entered the data from our *first* measurement (led by Baumel). I have corrected this in Table 2, where the data entered for McBrayer is from our *second* taping—the one actually led by McBrayer!

The "Raw Length" column displays all of the raw measurements in metres. In my Lotus 1-2-3 spreadsheet, this column contains a slightly-complicated formula which checks the "Units" column, and converts from feet (or feet & inches) to metres when necessary.

The "Temp" and "Temp Unit" columns list each measurer's recorded temperature along with the units (°C or °F) of that temperature. Some measurers listed two temperatures on their data sheets (e.g., temperatures in sun and shade, or before & after measuring). In all these cases, the temperature entered in Table 2 is the *average* of all temperatures listed by the measurer. For Baumel and McBrayer, the listed temperatures are averages of sun and shade temperatures, and have *also* been *interpolated in time* to roughly the midpoints of the time intervals of the measurements led by Baumel and McBrayer respectively.

The "Temp Factor" column contains the steel-tape temperature correction factor computed from each measurer's stated temperature. To be precise, I should explain that the formula programmed into my spreadsheet internally converts any Fahrenheit temperatures to Celsius, and then always uses the *Celsius* version of the temperature correction equation:

$$\text{Temp Factor} = 1.0000000 + (0.0000116 \times [T_C - 20]) \quad (3)$$

where T_C is temperature in °C. This is *not quite* identical to the Fahrenheit version:

$$\text{Temp Factor} = 1.0000000 + (0.00000645 \times [T_F - 68]) \quad (4)$$

where T_F is temperature in °F. However, the difference is minuscule. In our case (maximum temperature 47 °C), the difference between temperature-corrected measurements computed

Calibration Course Measurements — Analysis by Bob Baumel

Table 2

Measurer	Time (hh:mm)	Tape Identifier	Units (m or ft)	Raw Meas (m or ft)	Additional (+ inches)	Raw Length (m)	Temp (C or F)	Temp Unit (C or F)	Temp Factor	Temp Corr (m)	Tape Factor	Final Corr (m)
Letson-night	21:40	RL	ft	1089.765		332.1604	72	F	1.0000258	332.1689	0.9999857	332.1642
M Wickiser	08:30	MW 1	ft	1089	7.5	332.1177	77	F	1.0000580	332.1370	0.9999550	332.1220
Baumel	08:40	BB 1	m	332.109		332.1090	28.5	C	1.0000986	332.1417	0.9999283	332.1179
McBrayer	09:00	BB 1	m	332.098		332.0980	31	C	1.0001276	332.1404	0.9999283	332.1166
K Wickiser	09:20	MW 1	ft	1089	6	332.0796	88	F	1.0001289	332.1224	0.9999550	332.1075
Tellez	10:00	Rodolfo	m	332		332.0000	36	C	(fiberglass)			
Rodolfo	10:03	Rodolfo	m	332.06		332.0600	36	C	(fiberglass)			
Ramirez	10:22	LOE 1	ft	1089	6.75	332.0986	36.5	C	1.0001914	332.1622	1.0000646	332.1837
Loeffler	10:35	LOE 1	ft	1089	6.625	332.0955	42	C	1.0002552	332.1802	1.0000646	332.2017
Shepan	13:14	DS(chain)	ft	1089.385		332.0445	42.75	C	1.0002639	332.1322	0.9999392	332.1120
Riegel	13:20	PR 1	ft	1089.42		332.0552	43	C	1.0002668	332.1438	0.9999857	332.1391
Beach	13:30	??	ft	1089	2.875	332.0002	110	F	1.0002707	332.0901		
Disley	13:45	DIS 1	m	332.07		332.0700	37	C	1.0001972	332.1355	1.0000318	332.1460
Cichocki	13:45	FC	m	332.017		332.0170	47	C	1.0003132	332.1210	1.0000663	332.1430
Letson-day	14:00	RL	ft	1089.425		332.0567	115	F	1.0003029	332.1573	0.9999857	332.1526
Delasalle	14:30	JFD 8	m	332.05		332.0500	43	C	1.0002668	332.1386	0.9999283	332.1148
Yaeger	15:00	5	m	332.0065		332.0065	40	C	1.0002320	332.0835	1.0000663	332.1055
									Average:	332.1370	Average:	332.1376
									Std Dev:	0.0262	Std Dev:	0.0297

BB

from Equation (3) or (4) never exceeds 0.1 mm over the 332 m calibration course.

I have not computed temperature corrections for the two calibration course measurements made with a *fiberglass* tape — because fiberglass tapes do not exhibit the same temperature behavior as steel tapes. Consequently, the fiberglass-tape measurements are also omitted from all subsequent columns in Table 2.

The "Temp Corr" column contains the temperature-corrected measurements in metres. This is simply the product of the "Raw Length" and the "Temp Factor."

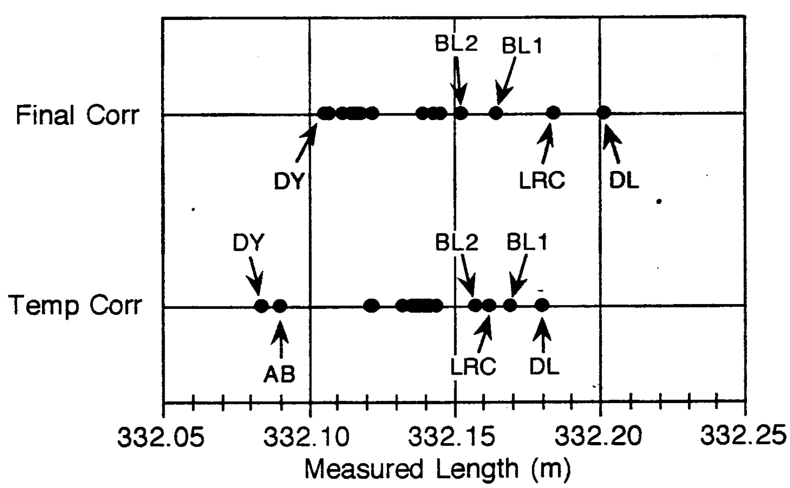
The "Tape Factor" column contains the tape correction factor, as determined in the Tape Comparison experiment, carried from the "Corr Factor" column in Table 1 (based on the "Tape Identifier"). I have not listed a "Tape Factor" for Andy Beach because his tape was not tested in the Tape Comparison experiment.

The "Final Corr" column in Table 2 is the final corrected measurement, which is just the product of the numbers in the "Temp Corr" and "Tape Factor" columns. Thus, it is the temperature-corrected measurement, with an additional correction for tape manufacturing error derived from the Tape Comparison experiment.

Results

Figure 2 is a plot of the "Temp Corr" and "Final Corr" numbers from Table 2. Recall that the "Temp Corr" numbers have been corrected for temperature but do not include the tape correction factors from the Tape Comparison experiment. The "Final Corr" numbers include these tape factors as well as the temperature correction.

Figure 2: Cal Course Measurements
With & Without Tape Factors



On this plot, I have labelled the measurements from six particular measurers who ended up at either the low or high end of the range. Dave Yaeger and Andy Beach had the lowest measurements—which is especially obvious in the "Temp Corr" results, where DY and AB are separated from everybody else by a big gap. As I will explain, DY and AB made definite (fully-verified) *mistakes*, resulting in their anomalous low measurements. The *highest* calibration course measurements were obtained by Bob Letson (in both his Friday night taping "BL1" and Saturday afternoon taping "BL2"), and Luciano Ramirez and Doug Loeffler. (Ramirez' and Loeffler's measurements were not independent because they taped together.)

The error made by Yaeger has already been described. He was fooled by the "long tape" fallacy. He was pulling his 100 m tape with the extra-strong force of 90 N (20 lbf), although the correct tension for this particular tape is 50 N. We discovered this error during the Tape Comparison experiment (*after* all of the calibration course and race course measuring). Thus, Dave had still been using the incorrect 90 N force when taping the calibration course. Because of this error, his measurement of the calibration course was probably about 3 cm lower than if he had tensioned his tape correctly.

Andy Beach's error was even simpler: He taped the wrong course! This happened because the calibration course endpoints were not marked unambiguously (e.g., with nails); instead, they were marked by relatively large pieces of duct tape. (Presumably, this was done because Felix felt obligated not to deface these newly-paved roads with nails and paint.) The intended calibration course ran between the *outer* edges of the two duct-tape markers; i.e. from the west edge of the west marker to the east edge of the east marker. However, Andy measured the wrong edge of one of these markers, thereby reducing his measurement by the 5 cm width of the duct tape.

The erroneous low measurements by DY and AB are very obvious in the "Temp Corr" plot in Figure 2, although they aren't as obvious in the "Final Corr" results. DY's measurement is still the lowest of the "Final Corr" measurements, but is not well-separated from the others. AB doesn't appear at all in the "Final Corr" results, because his tape was omitted from the Tape Comparison; therefore, I could not compute a tape factor for him.

Now let's consider the *highest* measurements of the calibration course—by Letson, Ramirez and Loeffler. Here, the situation is less clear-cut. I am not entirely sure that these high measurements were erroneous, although I will discuss possible problems in these measurements. Thus, my discussion here will be somewhat more speculative.

In Letson's case, we do know that he made a slight error in choosing his measuring line, followed by a (possibly questionable) mathematical adjustment to compensate for that discrepancy. As in Andy Beach's case, Letson's measured-path problem resulted from the ambiguous duct-tape markers at the calibration course endpoints. Each piece of duct tape extended some distance from the curb; therefore, it was not clear how far from the curb to choose the measuring line for taping.

On the Saturday morning when most of us began measuring, Pete Riegel attempted to resolve this ambiguity by declaring that the "official" measuring line for calibration course taping was on the asphalt, 30 cm from the concrete curb apron. But not everybody got this message. (Letson made his first calibration course measurement on Friday evening, *before* Pete Riegel chose this "official" measuring line.) Letson, and possibly some other measurers as well, made a *different* natural choice of measuring line—along the white line marking the southern edge of the bike lane.

After realizing that he hadn't measured Pete's official path, Letson attempted to determine the difference in length between the two paths. After much effort, he concluded that Pete's intended path was 0.06 ft (≈ 1.8 cm) *longer* than the distance along the white line where Letson taped. Therefore, Bob added this extra 1.8 cm to his taped distances.

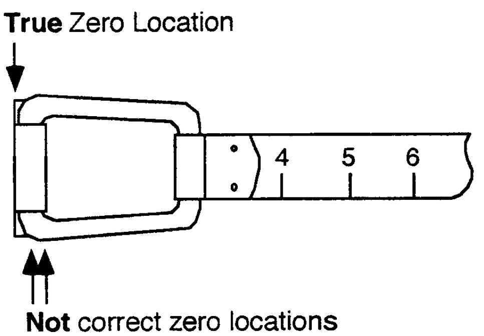
Letson's measurements, as listed in Table 2 and plotted in Figure 2, do include this 1.8 cm addition. Possibly, this adjustment is very accurate. However, I am skeptical for two reasons: First, it was not corroborated by anyone else. (If I had been aware of this situation, I might have checked the path-length difference myself, using a "swing offset" method, as described some years ago in *Measurement News* – March '85 *MN* p 5 and May '85 *MN* p 10.) Secondly, Figure 2 shows that Letson's results (*including* this 1.8 cm adjustment) came out a few centimetres higher than nearly everybody else's measurements; however, if we take away Letson's 1.8 cm adjustment, the agreement looks much better. This suggests that perhaps the duct-tape markers were more nearly parallel than Letson thought, so maybe his 1.8 cm adjustment was not warranted.

Ramirez and Loeffler (who taped together) obtained the highest calibration course measurements—which look even more isolated in Figure 2 if we ignore the questionable 1.8 cm adjustment in Bob Letson's measurement. Did Loeffler and Ramirez make some mistake which effectively shortened their tape, resulting in erroneously high measurements?

One way to effectively shorten your tape is by pulling it with less than the correct force. If Loeffler and Ramirez did this, it would mean that both our lowest and highest calibration course measurements resulted from tension errors. (Recall that Yaeger obtained the *lowest* calibration course measurement by pulling his tape *too hard*.) But life is not so simple. I have phoned Loeffler, who assured me that he and Ramirez did *not* make any significant error in tape tension.

Another way to effectively shorten your tape is by misjudging its zero point. As this is a standard subject discussed in our *Course Measurement* manual, and Doug Loeffler is a very experienced measurer, any possible error due to this source must have been very small. Even so, Doug's tape probably has a construction-style "hook-ring" at the end. These are confusing because zero is not on the graduated part of the tape.

Figure 3: Construction-Style Hook-Ring



As shown in Figure 3, true zero on this type of tape is at the *very outermost edge* of the hook-ring assembly (with the hook folded closed). Figure 3 also shows some locations that a measurer might *incorrectly* assume to be the zero point, but are actually 3 to 5 mm from the true zero. Note that if Loeffler and Ramirez effectively shortened their 100 ft tape by 3 to 5 mm, this would have increased their measurement of the calibration course by 3.3 to 5.5 cm.

I have no verification that Loeffler and Ramirez (or anybody else at this seminar) misjudged their tape's zero point. Nevertheless, these considerations suggest that such errors may be more common than we think. The book warns that a 3 cm error (possible by using the junction of hook-ring and tape blade), on a 30 m tape, produces a 1/1000 error, cancelling the Short Course Prevention Factor. But even a 3 mm error, as illustrated in Figure 3, is as serious as a 9 °C temperature error or a 25 N tension error with a lightweight steel tape.

Perhaps most importantly, errors due to misjudged zero point (on a construction-style tape) are in *only one direction*. Because true zero is at the *very outer edge* of the hook-ring, any error in locating this position invariably produces *short* calibration courses and, therefore, short race courses. Our book *could* do more to avoid this type of error. Currently, the instructions are rather vague about the construction-style hook-ring. However, we know very well that on these tapes, zero is at the *very outer edge* of the hook-ring, so the book should say this clearly. Also, the book needs to include a diagram like Figure 3.

Did The Tape Factors Help?

If we ignore the two lowest and four highest measurements in Figure 2, we are left with nine steel-tape measurements in the middle. For the "Temp Corr" results (which include temperature correction but **not** the tape factors from the Tape Comparison experiment), these nine fall within a narrow span of only 2.3 cm, from 332.121 m to 332.144 m. However, in the "Final Corr" results (which do include the tape factors) these nine measurements span a *wider* range of 3.8 cm, from 332.108 m to 332.146 m. Thus, it appears that including tape factors from the Tape Comparison experiment *worsens* the agreement between calibration course measurements!

Many other analyses lead to this same conclusion. For example, considering *all* of the steel tape measurements of the calibration course, Table 2 shows that the Standard Deviation of the "Final Corr" results is greater than that of the "Temp Corr" results. The *simplest* way to study this question is to cross-plot the (nearly raw) results of the Tape Comparison experiment against the calibration course measurements (without any Tape Factors):

Figure 4: Cal Course Meas vs. Tape Comparison

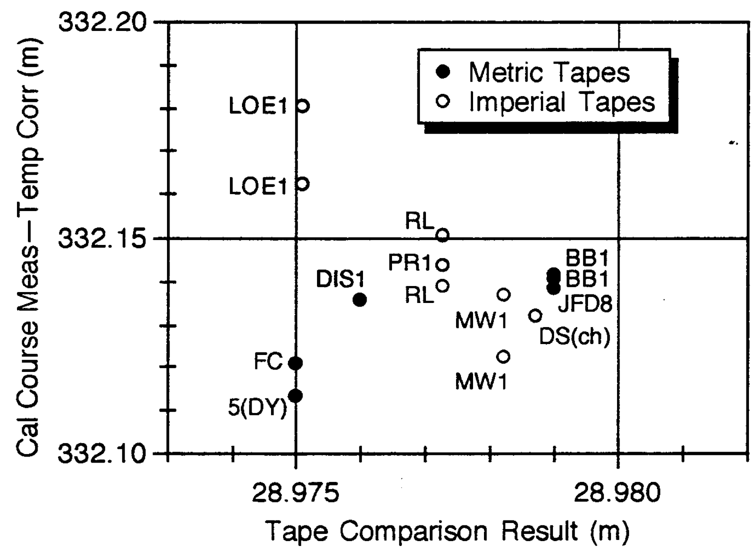


Figure 4 covers 14 calibration course measurements, made with 10 different steel tapes. Of these 10 tapes, 5 were metric and 5 Imperial. I plotted the metric and Imperial tapes with different symbols in view of the resolution problem described earlier: The Tape Comparison experiment had *semi*-reasonable resolution for the metric tapes (readings taken in whole millimetre increments), but had *extremely poor* resolution for the Imperial tapes (readings in whole 0.01 ft or 1/8 inch increments, which are both about 3 mm).

Plotted "Tape Comparison" results (horizontal axis) are from the "Corrected" column of Table 1; these are raw measurements from each tape, except that for DS(chain), 1.7 mm was subtracted to correct a tensioning error. Calibration Course measurements (vertical axis) are from the "Temp Corr" column of Table 2 (which includes temperature correction but *not* the Tape Factors), although I've made adjustments in two cases: I added 3 cm to Dave Yaeger's calibration course measurement to account for his tensioning error. Also, I plotted Bob Letson's measurements *without* his 1.8 cm path-length adjustment.

Note: I have arranged the axes in Figure 4 so that, percentage-wise, the displayed ranges in the horizontal and vertical directions are nearly equal—about 0.03% in both cases.

Our expectation for Figure 4 is to see a correlation, indicated by a trend line running from lower-left to upper-right. For example, if a tape returns a lower-than-average result in the

Tape Comparison experiment, this suggests that the tape is slightly oversized, so we also expect a lower-than-average measurement of the calibration course.

Actually, the data in Figure 4 are slightly *anticorrelated*—with the trend from upper-left to lower-right. This varies, however, between metric and Imperial tapes. For the Imperial tapes, where the Tape Comparison experiment had virtually *no* sensitivity, the data are rather strongly anticorrelated. For the metric tapes, the data show *some positive* correlation, although it is weaker than expected.

The anticorrelation in Figure 4 illustrates graphically why use of tape factors from the Tape Comparison did not improve (and actually worsened) agreement between calibration course measurements. Clearly, the tape factors were of no value for the Imperial tapes. Possibly, they provided some improvement for a few of the measurements made with metric tapes.

I still feel that the Tape Comparison results did contain real information about the tapes. If the calibration course measurements had followed a protocol similar to the Tape Comparison experiment; i.e., a *single* measuring team using all of the different tapes with consistent technique, the calibration course measurements would have correlated much better with the Tape Comparison results. In reality, however, the differences between our calibration course measurements were probably dominated by variations in technique rather than the error inherent in the tapes.

Variations in technique include differences in applied tension, differences in marking and reading tape lengths (which are usually assumed to be random but *could* have a systematic component), errors in judging the zero point of construction-style tapes as illustrated above in Figure 3, and differences in temperature recording. Temperature is probably the most significant of these effects, and will be discussed in the next two sections.

By the way, even if the Tape Comparison results did not seem helpful for our calibration course measurements, recall that tape BB 2, which we found to be out-of-spec in the Tape Comparison, was not used for any calibration course measurements in this seminar. It *had* been used during the 1990 Ohio seminar, where it apparently caused confusion.

How Hot Was It?

When measuring the calibration course, people set out many different thermometers, both liquid-in-glass and bimetallic, usually on the pavement, some shaded from the sun, some exposed to the sun. Individual measurers recorded either a shaded temperature, or sun temperature, or sometimes an average of shade and sun temperatures.

One interesting contrast involved John Disley and Felix Cichocki. As listed in Table 2, they both reported measuring at the same time of day (13:45). Nevertheless, Disley stated a temperature of 37 °C, while Cichocki reported 47 °C. Presumably, Disley was reading a shaded thermometer, while Cichocki's thermometer was exposed to the sun. [For those US measurers who are not yet adept at thinking in Celsius, I should explain that 37 °C happens to be normal human body temperature.]

Instead of trying to choose between all of the recorded temperatures, I will attempt a more indirect method of "backing out" the correct temperature from our data. Figure 5 shows all of the "raw" calibration course measurements, made with steel tapes on Saturday May 21, plotted as a function of time. These calibration course measurements are from the "Raw Length" column of Table 2, except that I made adjustments in three cases: I added 5 cm to Andy Beach's measurement to correct his error in using the wrong edge of the duct tape; I added 3 cm to Dave Yaeger's measurement to correct his tensioning error; and I plotted Bob Letson's measurement *without* his 1.8 cm path-length adjustment. (Note: Figure 5 includes Letson's Saturday afternoon measurement but not his Friday evening measurement.)

Figure 5: Cal Course Meas – No Temp Corr

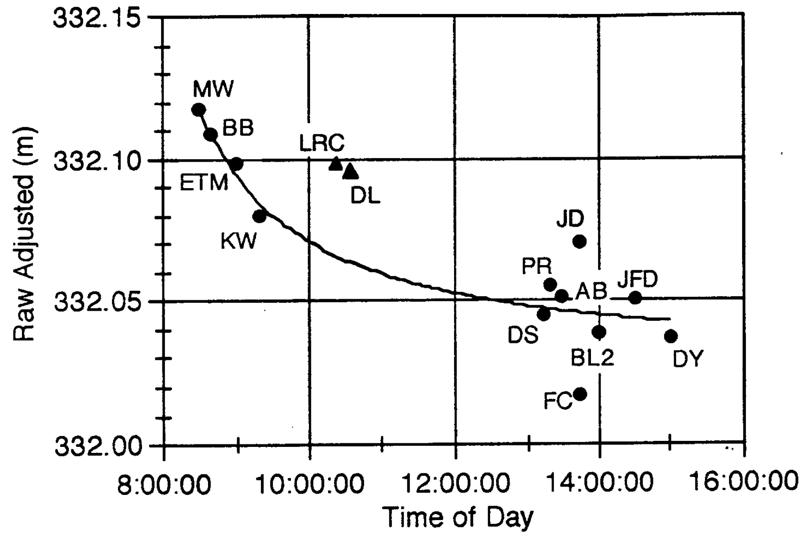
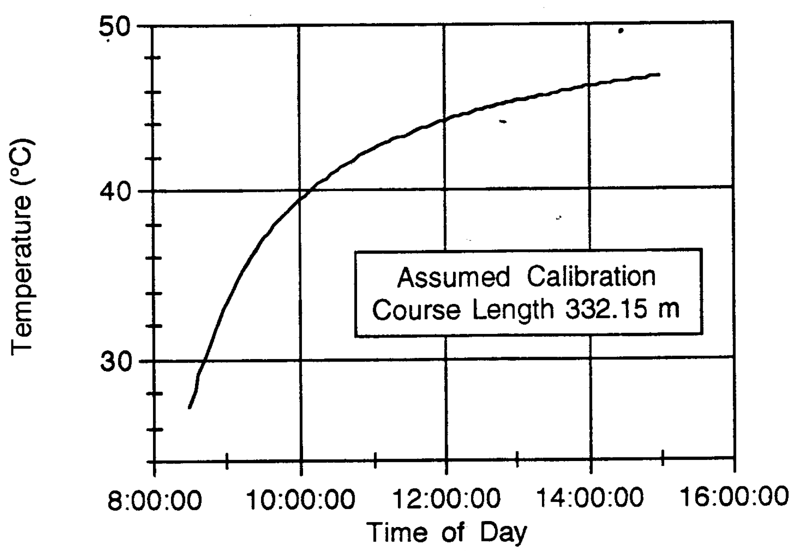


Figure 5 includes a smooth trend of decreasing raw measurements, corresponding to steadily increasing temperature during the day. The smooth curve in Figure 5 is a portion of a hyperbola, obtained by fitting all of the data points except the measurements by LRC and DL which seem to be anomalous. (The measurements by JD and FC also appear to be anomalous; however, FC's result *would not* appear anomalous if we used tape factors from the Tape Comparison experiment. FC's is the only clear case where accuracy is obviously *improved* by using the result of the Tape Comparison.)

Figure 6: Backed Out Temperature



Given the smooth curve of raw measurements in Figure 5, we can use the temperature correction formula (Equation 3) to "back out" the correct temperatures (plotted in Figure 6), assuming that we know the calibration course's *true* length. To estimate this true length I use Bob Letson's Friday night measurement, which is arguably our most accurate measurement because it was the one measurement performed *without* the complication of sunlight. Specifically, Bob's Friday night measurement, including temperature correction but *without* his 1.8 cm path-length adjustment, was 332.15 m.

I realize that this estimate is rather tenuous. It is based on only one measurement (I wish that several more people had taped at night!). I am assuming that Letson's nighttime taping and his nighttime temperature measurement (72°F) were accurate, although I am *not* accepting his 1.8 cm path-length adjustment. (If I did include that path-length adjustment, all of my calculated temperatures in Figure 6 would be about 5 °C higher, which is too high to believe.) In any case, please note that any error in my assumed calibration course length would simply shift the calculated temperature curve of Figure 6 up or down a few degrees, but would not change the basic shape of the curve.

Assuming the calculated temperatures of Figure 6 to be accurate, these generally match the *highest* temperatures that people recorded, corresponding to readings from thermometers exposed to the sun. For example, at the time of Ramirez' and Loeffler's measurements, Figure 6 suggests temperatures of 41 to 42 °C, while Ramirez' data sheet listed a shade temperature of 31 °C and sun temperature of 42 °C. By mid-afternoon, Figure 6 indicates around 46 to 47 °C, in good agreement with Cichocki's reading of 47 °C and Letson's (daytime) reading of 115°F (≈ 46.1 °C).

Also, returning to early morning, the temperatures recorded by BB and ETM were time-interpolated averages of sun and shade readings. However, my field notes indicate sun temperatures of 30 °C before BB's measurement and 37 °C after ETM's measurement, in good agreement with the curve of Figure 6.

These calculations suggest that the *best* readings are obtained from thermometers exposed to the sun. This makes sense because the real object is to determine the *steel tape temperature*, so if the tape is lying on the pavement exposed to the sun, shouldn't the thermometer be exposed in the same way? Nevertheless, our book says to use a shaded thermometer. This is actually a *safety factor* (for course layout). In sunny conditions, the reading of a shaded thermometer is a guaranteed *under*-estimate of the tape temperature. If you underestimate the temperature, then you underestimate your laid-out distance, and you are guaranteed that your calibration course is *at least* as long as you think it is.

With a liquid-in-glass thermometer exposed to the sun, it is *possible* (if the thermometer's liquid is darker than your steel tape) that the thermometer absorbs more energy than the tape, and therefore *over*-estimates the tape temperature. However, my calculations (which are admittedly tenuous) suggest that you probably won't overestimate the tape temperature by more than a degree or two.

If you use liquid-in-glass thermometers, you will avoid overestimating the tape temperature if you set out *two* such thermometers—one shaded and one exposed to sun—and average their readings. This may actually underestimate your tape temperature by 5 °C, in which case you will underestimate your laid-out distance by about 1 part in 17 000.

If you use a bimetallic thermometer, it is probably quite safe to expose it to the sun. The probes of these thermometers tend to be light in color, and don't make good contact with the pavement; therefore, the reading of a bimetallic thermometer exposed to the sun is typically similar to a sun–shade average obtained with liquid-in-glass thermometers.

You may, of course, choose to follow the book's recommendation and use a shaded thermometer. In this case, you may underestimate your tape temperature by around 10 °C, thereby underestimating your laid-out distance by about 1 part in 9000.

Finally, if you want the *most* accurate results, then tape on a cloudy day, or at night, when sunlight is not a factor.

Mistakes in Temperature Correction

Unfortunately, the reported results on many of the measurers' data sheets include errors in "corrected" calibration course length. Actually, only one genuine error was made in calculating a temperature correction; the others involved complete omission of the temperature correction. I will describe errors by Beach, Letson, Loeffler and Ramirez, and I also mention a *very small* error in Dave Yaeger's temperature calculation.

Andy Beach was one of the people who omitted the temperature correction. His data sheet is curious in that he included notations showing that he *does know how* to calculate the temperature correction. However, his final "corrected" length was simply a conversion to metres of his raw measurement (originally in feet and inches) with no temperature correction at all. Apparently, he simply *forgot* to include the temperature correction in his final result!

Veteran measurer Bob Letson reversed the direction of the temperature correction for his Friday night measurement. (By this, I mean reversing the sign of the $[T_C - 20]$ term in Equation 3 or the $[T_F - 68]$ term in Equation 4.) Specifically, his recorded temperature was 4°F *warmer* than 68°F, but he calculated as if it were 4°F *cooler* than 68°F. Fortunately, he made no such error in his Saturday afternoon measurement.

By the way, Letson was not actually using Equation (3) or (4), i.e. the versions of the temperature correction formula in our book. Instead, he used an older calculation method, where the temperature correction is handled as an additive term. The particular mistake made by Letson rarely occurs when people use the formulas in our book.

The mistake made by Loeffler and Ramirez was harder to figure out. In both cases, their "corrected" length was about 6 cm *less* than their raw measurement. First, I wondered whether they reversed the direction of the temperature correction (like Letson). But the numbers didn't work out. Then, I noticed that their figures *would* be correct at about 4.4 °C, which is just about 40°F. So I wondered whether they confused Celsius and Fahrenheit (i.e., the temperature was about 40 °C, but did they work out the correction for 40°F?).

Then I phoned Loeffler. Neither of the above explanations was correct. Loeffler computed no temperature correction at all because he hadn't memorized the correction formula, and he didn't have the manual with him. The figures reported by Loeffler and Ramirez (as in Beach's case) were conversions to metres of raw feet/inch measurements. But Loeffler & Ramirez also mis-copied numbers from their calculator! For example, the conversion of Loeffler's raw measurement, worked out using an 8-digit calculator (doing calculations in a certain order), is exactly 332.09544 m. Loeffler reported 332.03544 m. Evidently, he mis-copied a "9" as a "3" (and Ramirez made a similar mistake). Maybe Loeffler's calculator had some burned-out LCDs or LEDs (or it was overheating, or its battery running down).

Dave Yaeger's temperature calculation was basically correct, but he used a *slightly incorrect* value of 0.0000118 /°C for the steel-tape expansion coefficient (instead of the correct value 0.0000116 /°C from Equation 3). Yaeger's incorrect value was taken directly from Canadian course measurement instructions, which apparently have included this number for a long time. (It probably started as a typo, but has been reprinted many times.) The error due to this incorrect coefficient is very small (less than 2 mm for our 332 m calibration course at our highest recorded temperature of 47 °C). Even so, I think Dave should try getting this figure corrected in the Canadian instructions.

BIKE MEASUREMENTS (See Table 3)

Table 3 summarizes results of everybody's bike measurements, computed eight ways. These are actually the end-product of a large spreadsheet, but there is no need to include a print-out of my entire spreadsheet, as Pete Riegel has already provided listings of all the raw bike data. I computed everybody's results using a single assumed calibration course length of 332.137 m, which is basically the average measurement in Table 2. This is not necessarily my current best estimate of the calibration course length, but this is unimportant. What matters is that by calculating everything using the *same* assumed calibration course length, I evaluate the bike measurements independently from the calibration course measuring.

I have calculated eight types of results in Table 3. These are the measurements by "Normal" and "Circus" riding, measurements of the Entire course or of the Initial Rectangle, and results computed by Average or Larger Constant.

"Normal" riding refers to standard measuring, supposedly with a clearance of 30 cm from curbs. (All streets on this course had curbs.) "Circus" riding is the term (which I consider very apt) coined by Jean-François Delasalle for the attempt to reduce clearance from curbs as closely as possible to zero. (Jean-François was also the clear "winner" of this competition.) Clearly, measurers have very different conceptions of a 30 cm clearance from curbs; for example, John Disley's "normal" measurement came out about the same as my "circus" ride. Unfortunately, five of the measurers lacked sufficient time to attempt "circus" rides.

An initial, roughly rectangular, portion of the test course was isolated in the hope that it may be somewhat more representative of "normal" real-world race courses than our entire test course, which is very curvy. However, this difference in curviness apparently made little difference. Referring to Table 3, our measurements of the *entire* course spanned a range of 0.21%, while measurements of the initial rectangle covered a 0.22% range (These figures are for "normal" rides computed by Average constant). Thus, we did no better on the initial rectangle than on the full course. (Note: there were 17 measurements of the full course but only 16 measurements of the initial rectangle because Karen Wickiser neglected to record a counter reading at the end of that initial segment.)

I computed all measurements by both *Average* Constant (used for most IAAF layout measurements and all USATF validation measurements) and *Larger* Constant (standard for USATF layout measurements). Initially, I computed these results only by Average constant, as requested by Pete. However, when I attempted detailed comparisons, I noticed that some measurers experienced large calibration variations which affected accuracy. Therefore, I decided to compute Larger Constant results also. The Larger constant results are not really any more "accurate" than Average constant results, but have interesting implications for validation measurements, as I will explain below in connection with Figure 7.

Given the eight types of results listed in Table 3, it can be difficult to specify exactly which type I am talking about. Therefore, my convention in the following is that, unless specified otherwise, I refer to *Normal* rides, of the *Entire* race course, computed by *Average* Constant.

Before proceeding further, I would like to comment on the data and calculations for a few individual measurers. For Andy Beach, I referred earlier to his mistake in taping the calibration course (measuring the wrong edge of the duct tape). Actually, Andy told me that he probably made the same mistake in *riding* the calibration course. If Andy truly rode a calibration course that was 5 cm shorter than ridden by everybody else, we should probably subtract about 1.1 m from his measurements of the (full) race course as listed in Table 3.

Luciano Ramirez' counter readings at pre-calibration include strange fluctuations which suggest a mis-copied reading. Quite possibly, his counter reading at the end of his third calibration ride (and start of fourth ride) was really 39031 rather than 39037. (Meanwhile,

Summary of Bike Measurements – by Bob Baumel

Assumed Length of Calibration Course: **332.137 m**

Table 3

Measurements computed by AVERAGE constant

Measurements of ENTIRE Course:

Normal	Circus	Measurer
7415.85	7413.87	Disley
7417.12	7413.94	Letson (5/20)
7417.61		Loeffler
7417.73	7412.76	Shepan
7417.74	7415.03	Cichocki
7419.62	7405.65	Delasalle
7419.95	7414.13	Yaeger
7420.44	7415.46	Letson (5/21)
7420.69	7413.09	Riegel
7421.12	7415.96	Baumel
7423.15	7418.36	Beach
7424.35	7415.54	M Wickiser
7424.85		McBrayer
7425.77		Ramirez
7425.94	7421.88	K Wickiser
7429.25		Rodolfo
7431.08		Tellez

Measurements of Initial RECTANGLE

Normal	Circus	Measurer
2957.12	2956.52	Disley
2957.77		Loeffler
2957.82	2957.20	Letson (5/20)
2958.18	2957.27	Yaeger
2958.24	2957.90	Cichocki
2958.31	2956.95	Shepan
2958.62	2957.49	Baumel
2959.42	2957.21	Riegel
2959.43	2957.74	Letson (5/21)
2959.47	2955.97	Delasalle
2959.88		McBrayer
2959.97	2957.21	M Wickiser
2960.05	2959.39	Beach
2960.47		Ramirez
2962.49		Rodolfo
2963.73		Tellez

Measurements computed by LARGER constant

Measurements of ENTIRE Course:

Normal	Circus	Measurer
7411.05	7413.24	Disley
7415.37	7414.88	Cichocki
7415.42	7403.13	Delasalle
7416.04	7412.05	Shepan
7416.36	7414.27	Letson (5/20)
7416.60		Loeffler
7418.31	7415.38	Baumel
7418.96	7412.95	Riegel
7419.45	7414.47	Letson (5/21)
7419.66	7412.53	Yaeger
7421.43	7416.36	Beach
7424.35	7415.54	M Wickiser
7424.85		McBrayer
7425.48		Ramirez
7425.69	7421.39	K Wickiser
7426.56		Tellez
7427.52		Rodolfo

Measurements of Initial RECTANGLE

Normal	Circus	Measurer
2955.20	2956.27	Disley
2957.29	2957.85	Cichocki
2957.36		Loeffler
2957.50	2957.27	Baumel
2957.52	2957.34	Letson (5/20)
2957.64	2956.67	Shepan
2957.80	2954.97	Delasalle
2958.07	2956.63	Yaeger
2958.72	2957.15	Riegel
2959.04	2957.35	Letson (5/21)
2959.37	2958.59	Beach
2959.88		McBrayer
2959.97	2957.21	M Wickiser
2960.35		Ramirez
2961.80		Rodolfo
2961.93		Tellez

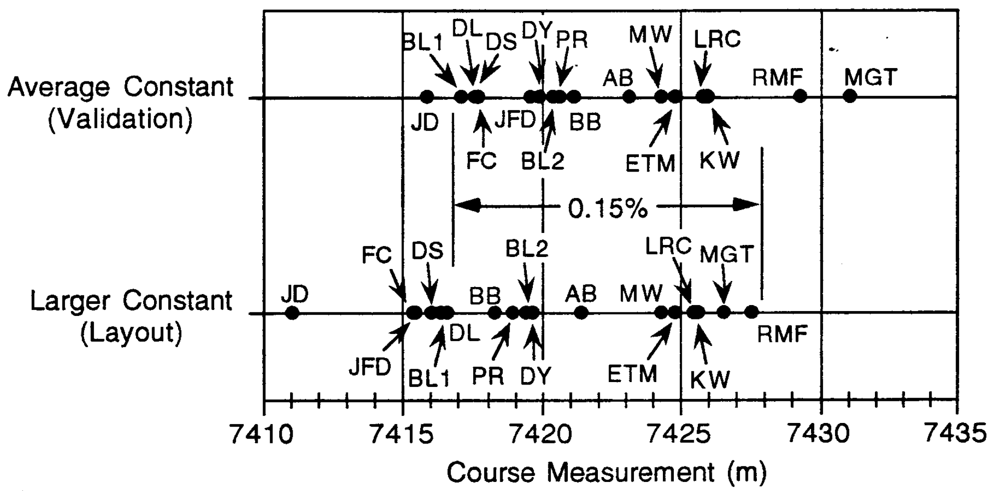
Note: Median of "Normal" and Lowest of "Circus" measurements are boxed the large fluctuations in Marcial Tellez' pre-calibration data were probably just the natural "settling down" of a new measurer riding a calibration course for the first time.)

Comments on Range of Measurements

As indicated earlier, our measurements spanned a range of about 0.21%. This is rather disappointing because it is more than twice the "Short Course Prevention Factor" of 0.1%. Therefore, I will discuss possible explanations for our large range.

The range of measurements is plotted in Figure 7 (which shows only "normal" rides of the *entire* course). The figure looks "busy" because I have labelled every data point. We had 17 measurements (by only 16 measurers) because Bob Letson measured twice: "BL1" denotes his preliminary measurement on Friday May 20, and "BL2" his second measurement on Saturday May 21. Figure 7 shows results computed by both Average and Larger Constant. In the present section, I discuss mainly the *Average* Constant results.

Figure 7: Course Measurements by Average and Larger Constant



In discussing the range of measurements, let me start with the *highest* values. Generally, the highest results were obtained by inexperienced measurers (the Mexicans in this case), which is totally understandable. These measurers will probably improve rapidly as they gain experience, *and* as they realize how serious we are about measuring a tight line!

Some of the *experienced* measurers also obtained fairly high measured distances. These occurred for various reasons (for example, I will discuss Tom McBrayer's case later in my section about "solid-wheeled" bikes). One of the experienced measurers was overheard to remark that he doesn't believe in measuring within the concrete "curb aprons" or "gutters" which are often found adjacent to curbs.

Our Phoenix test course included such curb aprons, extending about 50 cm into the street from the vertical curb-faces. The correct measuring line, 30 cm from the curb-face, was therefore always *within* the curb aprons when hugging the inside edges of curves. Any measurer who avoided the curb aprons was considerably farther than 30 cm from the vertical curb-faces.

Actually, it would be extremely instructive if, at a seminar like this, some of the corners were painted with lines showing the correct measuring path, 30 cm from the curb. In fact, I once participated in a measurement where this was done. This was my June '92 validation of the Fujitsu 8 km in San Jose, where Tom Knight (the original measurer) had painted such markings at some of the corners. Possibly, those markings helped the four measurers (Tom Knight, Tom Benjamin, Paul Oerth, and myself) obtain agreeement within 2 m on the 8 km course. (See data in July '92 *MN* p 32, and written report in Sept '92 *MN* pp 36–40. I notice, however, that my validation report made no mention of Tom's 30 cm marks!)

Another obstacle on the Phoenix test course consisted of many large plants (not cactus, fortunately!) growing near the curbs, with branches projecting into the street. Some of the more fearless measurers returned from their bike rides with scratched arms and legs, proving their willingness to battle this shrubbery at close range. Riders who were more squeamish about colliding with these plants would have obtained higher measurements.

By the way, while this shrubbery problem is fun to discuss, there is also a real philosophical question: Should the measurer crash right through these plants, even though no sensible runner would do so? Actually, measurers must realize that, prior to race day, somebody may *trim back* these unruly plants. Therefore, the measurer should be guided only by the curb locations, and should ignore the encroaching shrubbery.

Our median measurement was obtained by Pete Riegel. Five of the measurements were tightly clustered around this median, from JFD at 7419.6 m to BB at 7421.1 m (which is a range of only 1.5 m or 0.02%). We would like to assume, *but have no proof*, that all of these measurers rode paths fairly close to the correct line 30 cm from curbs.

Turning to our lower measurements, there were four tightly clustered results (BL1,DL,DS, FC), between 7417.1 m and 7417.7 m. These people may have ridden slightly closer than 30 cm from curbs (perhaps they were about 20 cm from curbs at street corners). Possibly, there was some ambiguity in Pete's instructions for the "normal" course rides. Some people interpreted this as "ride as close as possible to 30 cm." Others interpreted it as "ride as you normally do." Some measurers normally ride closer than 30 cm, where feasible, for greater safety in course layout.

The very lowest measurement of 7415.85 m was obtained by John Disley. This is slightly less than my own "circus" measurement of 7415.96 m. Knowing that in my "circus" ride, my front tire was actually scraping the curb at street corners, my first thought was that Disley must have ridden *much* closer than 30 cm in his "normal" ride. There is, however, another possible explanation:

Disley experienced a very large *calibration variation* during his "normal" measurement. His constant dropped from about 11065 counts/km at pre-calibration to about 11051 counts/km at mid-calibration. From these numbers, all we *really* know is that his measurement was somewhere between 7411.05 m and 7420.65 m. The "Average Constant" calculation picks the value right in the middle. This is based on the assumptions that tire size varies linearly between pre- and post-calibration, and that the course measurement is centered in time between pre- and post-calibrations (assumptions which are often violated).

My guess is that Disley's tire size probably varied in a highly *non*-linear manner. Perhaps it was expanding rapidly immediately after pre-calibration but then remained more steady. If so, the most accurate value for Disley's measurement is not the midpoint of the range (from 7411.05 to 7420.65 m), but is closer to the upper end of that range; e.g., maybe it agreed well with the four measurements (BL1,DL,DS,FC) clustered between 7417 and 7418 m.

Larger vs. Average Constant – Connection with Validation

We have seen that John Disley experienced a large calibration variation. In this particular case, the most accurate result was probably closer to "smaller" constant than "larger" constant. But in general, when large calibration changes occur, the most accurate result *could* be anywhere in this range. Use of "average" constant is accurate only in a *statistical* sense, but not necessarily in individual cases. To insure that laid-out courses are not short, the only *safe* choice is the *larger* constant—which is the standard USATF layout procedure.

I should add that attempts to deal with calibration changes systematically by interpolation (using time, temperature, or elapsed distance as independent variables) are probably hopeless, as actual patterns of calibration change seem to defy rational explanation. In this seminar, JD and JFD both measured in the morning and obtained large changes between pre-cal and mid-cal, while observing smaller differences between mid-cal and post-cal. AB also measured in the morning, but his mid-cal to post-cal change exceeded his pre-cal to mid-cal variation. In the afternoon, BB obtained a fairly large pre-cal to mid-cal variation, although KW observed practically no change. BB and KW both rode rented mountain bikes, and in fact, KW rode the same bike on which JFD had previously obtained very large calibration changes during the morning.

(Note: By the above, I do not mean to imply that tire size is a supernatural phenomenon. However, it probably depends on numerous other variables such as: the exact materials the tire is made of, its inflation level, the rider's weight, recent usage history of the tire, etc.)

In analyzing this Phoenix seminar, Pete Riegel has discussed the implications if some of the measurements are considered as "layouts" and others as "validations." I will show that the results look pretty good if the "layout" measurements are calculated by *larger* constant.

In Figure 7, I plotted all the measurements by both Average and Larger constant. I have also drawn lines indicating a 0.15% difference. This is the key tolerance in the USATF validation system. The layout process includes a 1.001 factor, which adds 0.1% to the nominal distance. Then, the validation process rejects courses only when they measure 0.05% short of the nominal distance (This is known as "allowance for error in the validation measurement"). As an example, a nominal "10 km" course is laid out at 10 010 m, and is rejected only if the validation finds it shorter than 9995 m. Thus, there is a 0.15% separation between the layout point and the rejection point for validation.

Considering only the *Average* constant results in Figure 7, there are ten pairs of measurements differing by more than 0.15%. These are all cases where the higher measurement, regarded as a "layout" would *fail* if the lower measurement is regarded as a "validation."

However, if layouts are done using *Larger* constant, we need only consider pairs where one measurement (the "layout"), computed by larger constant, is more than 0.15% higher than a second measurement (the "validation"), computed by average constant. When viewed this way, *everybody's* "layout" would pass validation by everybody except John Disley. (And even with Disley as validator, *only one* of the "layouts" would fail.)

Regarding Disley's measurement, recall that it had a serious accuracy problem due to large calibration variation. We ought to ask ourselves: Would we accept a validation result if it rejects a course *and* there is so much calibration variation in the validation measurement?

What I have shown is that even though the total range of our measurements was larger than I might like, the situation regarding validation looks pretty good—*providing* that we use **all** of the safety factors in the USATF procedure. And this includes Larger Constant!

The debates about larger constant are very strange. When calibration change is small, it makes little difference whether larger or average constant is used, so nobody cares which method is used. When calibration change is large, it does make a difference. This is when people complain about larger constant. However, this is precisely the case where accuracy is most uncertain, so the extra safety provided by larger constant is most beneficial.

One also frequently hears the argument: "I don't need larger constant because I'm a skilled rider." Unfortunately, large non-linear calibration changes have no respect for riding skill.

In May '94 Measurement News pp 11–12, Pete Riegel suggested a protocol for evaluating results of the 1996 (Atlanta) Olympic Marathon measurement. I see no problem with Pete's method of sorting among different measurements (medians on each segment). However, I disagree with Pete's method of calculating individual measurements. He suggested Average constant. I strongly urge *Larger* constant. (I also suggest at least one intermediate calibration session, to reduce the intervals between pre-cal and post-cal.)

In the present Phoenix seminar, the median of the *Average* constant results differed from the median *Larger* constant result by 1.24 m. That was on a 7.42 km course, so we might expect about a 7 m difference on a 42.195 km course.

Normal and "Circus" Riding

To properly evaluate differences between measurement, we must know how curvy the course was. I estimate that the total curve angle consisted of about 21 radians (≈ 1200°) of street corners and about 9 radians (≈ 500°) of gradual curves, for a grand total of about 30 radians (≈ 1700°). Here's how I estimated these figures: Of sharp street corners, there were 14 such corners—which would add up to 1260° (≈ 22 rad) if all the corners were 90°, but some were a bit less than 90°, so I estimate a slightly lower total of 1200° (≈ 21 rad). For gradual curves, my map measurement yields a total of 487° (≈ 8.5 rad). [Note: I measured this from the aerial photograph on the cover of Jan '94 *MN*—not from the hand-drawn map Pete handed out.] I've increased this figure slightly to about 500° (≈ 9 rad) in case I missed some curvature in my map measuring.

The total curve angle of about 30 rad means that a 1 m difference in clearance from curbs should translate to a 30 m difference in total measurement. Fortunately, our measurements didn't span *that* big a range; nevertheless, the range was actually about 14 m (and I refer here only to the "normal" rides—I haven't introduced "circus" riding yet). This suggests that the riders with the highest measurements were probably, on average, about 45 cm farther from the curb than those with the tightest measurements.

If we assume that the tightest riders were about 20 cm from the curb, this means that the loosest riders must have been about 65 cm from the curb (which is quite believable if we assume that these riders stayed entirely in the asphalt, avoiding the curb aprons).

Now, let's consider "circus" riding. Suppose that an ideal rider is 30 cm from the curb in "normal" riding. Let's assume that in "circus" riding, he reduces this clearance to 2 cm. (I don't assume *zero*, because the tire has finite width!) Then in our course's total 30 rad of curves, his measurement would be reduced by 30×0.28 m = 8.4 m. This is, mathematically, the maximum possible reduction that a perfect measurer could achieve.

Actually, I don't expect most measurers to achieve this much reduction, because of the difference between street corners and gradual curves. It is very easy to reduce the clearance on curbed street corners by "scootering" the bike (See next section on riding technique). However, it is much more difficult to reduce clearance on the gradual curves. Therefore, although a 28 cm reduction in radius is feasible on the street corners, the reduction on gradual curves might be only, say, 5 cm. This would lead to a total reduction in measured distance of $(21 \times 0.28 \text{ m}) + (9 \times 0.05 \text{ m}) \approx 6.3$ m.

In fact, Table 3 shows that most of the measurers with "normal" rides close to the median obtained reductions of around 5 to 6 m in "circus" riding. People who rode tighter than 30 cm in their "normal" rides could not reduce their measurements this much. Conversely, measurers with "normal" rides higher than the median had more room for improvement.

This leaves us with Jean-François Delasalle, the clear "winner" of the circus competition, who obtained a *huge* reduction of 14 m, which is much greater than predicted. It does seem quite appropriate that Jean-François should win this contest. After all, he is the author of the trick-riding instructions reprinted in Nov '93 *MN* pp 39–40. Nevertheless, it seems to me that JFD's reduction was greater than mathematically possible.

Recalling that JFD experienced large calibration variations (although not as big as Disley's), could it be that JFD's anomalous reduction in circus riding was an artifact of those calibration changes? I don't think this is the explanation. Even if we look at the *Larger* constant results in Table 3, JFD's circus ride is a whopping 12.3 m less than his normal ride.

I will now speculate on how JFD *could* have achieved his 14 m reduction in the circus ride. I noted earlier that it is easy to reduce the curb clearance at street corners by "scootering." A measurer who was really serious about obtaining the minimum possible measurement may have considered scootering the gradual curves as well. However, that would have been extremely time-consuming and uncomfortable, especially in view of the projecting shrubbery discussed earlier. A far easier way to keep one's front wheel in direct contact with the curb would be to dismount and *walk* the bike through the gradual curves.

Now, when you dismount and walk a bike, you unweight its tires, and *significantly* increase the tire size (by about 0.85% according to some old data I collected about 11 years ago). Walking a bike during a course measurement is normally harmless if the walked stretches are short enough; and in "layout" measurements, the error is always in the "safe" direction (You get a longer race course). However, effects are quite noticeable if the walked distances are long enough. For example, walking (instead of riding) for a distance of 1 km may reduce the measured distance (or lengthen a laid-out race course) by 8.5 m.

Thus, JFD *could* have obtained his 14 m reduction through some combination of bike walking (which reduces the measurement even with *no* change in measured path), and actual reductions in curb clearance. Please note, however, that I have made no attempt to verify whether JFD *actually* walked his bike.

Notes on Riding Technique

We sometimes talk about skilled riders measuring closer than 30 cm from curbs. While this is sometimes true, measuring *at* 30 cm is non-trivial. Beginning measurers often ride much *farther* than 30 cm from curbs, until learning the correct skills.

One of the most important skills is "scootering" at curbed street corners. (Amazingly, this is not mentioned in our *Course Measurement* manual!) By "scootering," I mean slowing down and putting your inside foot on the curb for balance, while remaining seated on the bike and keeping your outside foot on its pedal (at bottom of travel). The inside pedal must be up; otherwise, it would crash into the curb when the front wheel is only 30 cm from the curb.

It is nearly impossible to successfully measure a curbed corner at 30 cm while *continuously riding* the bike. An extremely skilled cyclist may *sometimes* achieve this feat by coasting (with the inside pedal up), but this is far less reliable than the scootering method.

When scootering a corner, it is fairly easy to measure at any clearance you want. (So if you wish to come *closer* than 30 cm, you may do so.) When scootering very tight corners at close clearances, you may sometimes find that your *back* wheel bumps the curb. You may choose to ignore this, or you may reach back and pull the rear end of the bike away from the curb.

Many measurers could probably benefit from some practice at scootering 30 cm from the curb: Locate a street corner with a vertical curb-face. Get a ruler and draw the correct measuring line (30 cm from curb) on the pavement. Then get on your bike and practice scootering with your front wheel on this line.

While street corners are easy to measure by scootering, I know of no analogous trick for *gradual* curves on curbed streets. The pedals of a bike typically project about 20 cm from its center-line. However, if you are hugging the inner edge of a curve, with front wheel 30 cm from the curb, then the clearance between your inside pedal and the curb is *even less* than 10 cm, due to the geometry of a turning bicycle. Successful riding, with so little clearance between your inside pedal and curb, requires excellent cycling skills and very steady nerves. (And even so, I wonder how many measurers really accomplish this.)

I know that I am probably *not* a good enough cyclist to achieve this feat. In practice, my front wheel may be around 35 to 40 cm from the curb while riding gradual curves. Sometimes I may compensate for this by intentionally measuring tighter at street corners. For example, if I think I was 40 cm from the curb in a gradual 90° curve, I can compensate by measuring 20 cm from the curb at a 90° street corner.

Note on Solid-Wheeled Bikes

One of the bikes at this seminar had some type of non-inflated wheel. This was a bike brought by Bob Letson. Curiously, it seemed to produce inferior-quality measurements.

Two measurements were made with Letson's solid-wheeled bike. Letson used it himself for his Saturday measurement, although he had used a different bike (with conventional high-pressure tires) for his Friday measurement. Also, Tom McBrayer used the solid-wheeled bike for his one measurement (which was actually performed on Friday May 20, at which time McBrayer and Letson were riding together).

The Friday measurements performed by Letson and McBrayer were intended as preliminary scouting rides, to familiarize them with the course. Unfortunately, McBrayer then developed knee trouble, and did no more bike riding that weekend. Letson did perform a complete set of measurements on both Friday and Saturday.

In comparing Letson's Friday measurements with his Saturday measurements, it is curious that he obtained significantly lower results in his original (preliminary scouting) rides. This is exactly opposite to expectations. The difference was probably that he used high-pressure pneumatics on Friday, but rode his solid-wheeled bike on Saturday.

McBrayer obtained one of the highest measurements of any experienced measurer. This occurred for two reasons: First, Tom's only measurement was the preliminary scouting ride with Letson, and at this time, McBrayer *wasn't trying* to get a tight ride. But part of the problem was also the solid-wheeled bike: Tom told me that this bike was "not as responsive," and resulted in a "less-accurate ride."

These observations may not apply to non-inflated wheels in general. However, it is interesting that they parallel my own experience ten years ago with a type of non-inflatable insert called an "Eliminator." I used Eliminators for about a year, from 1984 to 1985, but eventually quit after deciding that they reduced my ability to control the bike, thereby reducing the quality of measurements. At the time, nobody believed my claims, so I am glad to see some similar evidence from the data at this seminar.

SUMMARY

After all the text I've written, I will try to keep this brief. However, I think it will be useful to bring together some of the key recommendations from this long (admittedly rambling) report. I will list these points in outline form:

Recommendations for *Course Measurement* Manual
Explanation of Construction-Style Hook-Ring (Figure 3)
Simplify Tape Tension recommendations (Use manufacturer's intended tension if you know it. If not, use 50 N ≈ 5 kgf ≈ 11 lbf).
Reword to avoid "long tape" and "skinny tape" fallacies.
Provide Advice on Riding Technique – Scootering Method.

Recommendations for Future Seminars
If another "Tape Comparison" exercise is performed, then:
Use Correct Tension for all tapes.
Improve Resolution—read fractional tape graduations.
Mark Calibration Course Endpoints Unambiguously (with nails).
Paint 30 cm lines (showing correct measuring path) at some corners.
Better preparation if inexperienced measurers will be present.*
Include a Wrap-Up Session at end of Seminar.*

Recommendation for Olympic Marathon Measurement
Use Larger Constant!

The above outline includes two points, marked by asterisks, that do not correspond to any statements in the preceding text. With regard to inexperienced measurers, different arrangements are appropriate for experienced or inexperienced people. Experienced measurers benefit from independent measurements, as performed at this seminar, producing lots of nice data that we like to analyze. However, beginners benefit much more from *riding together with experienced measurers*, so that the new measurer can *observe* and *be observed by* experienced people. For this seminar, I don't know how much planning was done to help the three Mexicans. As it turned out, the entire role of "instructor" fell to Doug Loeffler.

My comment about a "Wrap-Up Session" actually resulted from my phone conversation with Doug Loeffler. It seems that at the end of measuring, everybody was in a hurry to finish up, so they could hike up the mountain or whatever. Seminars should always finish with a communal session so we can compare data and see how things turned out.

The above recommendations for the *Course Measurement* manual should be added to other changes that we know must be made whenever the book is next reprinted. For example, we know that in the Application for Certification of Calibration Course, we must eliminate the line about "Credentials or Experience." And in Appendix D, we must update the definition of point-to-point course (which still refers to an old version of Rule 185.5), etc., etc.

With regard to this Phoenix seminar, I certainly found it very informative, and had a lot of fun, and enjoyed doing all the additional analysis described in this report.

Bob Baumel

J.F DELASALLE
BP 25
80800 Corbie
FRANCE

JFD

to Pete RIEGEL

1994 July 4 th

Dear Pete,

I really enjoyed the welcome and the organization of the seminar in Phoenix.
That was an excellent way of meeting other measurers and seeing that the method of the calibrate bicycle with the Jones counter is used correctly in many countries.
Out of the 16 people taking part in the seminar I only knew two persons (John Disley and yourself) but I knew that many good measurers would be there because the Jones counter has been used in the USA for a very long time. I have managed to make this method known in France only since 1990 and we also have several very good measurers here now.
The results that were obtained on the very nice course of Felix didn't really surprise me.
However a few remarks can be done as far as I am concerned.

1. The fact that each one had to measure the length of the calibration course and make his own calculations afterwards seems a good idea because it allows to see what the conclusion of one measurer would be "if he was alone on this course" in the real conditions of work.
However I have always been more interested in the comparison of the results of the straight line on a bicycle and for that everyone has to use the same lenght of the calibration course.
One can see that for most people the results show very little difference in fact but a few calculations or judgment mistakes can be seen.

2. What was the length of the calibration course?
- Nobody has the answer but I think it is probably around 332,13 - 332,15 (values that have been found most often).
-We could see that the ways of marking the ground with the steel tape could vary according to the habits of each measurers (sticking paper with a personal mark in most cases). This is of no great importance if the marks are thin and precise (One person = one way).

However the temperature brings three problems :
2 -1. The choice of the tape.
I did it on purpose to bring with me a 50 m plastic tape to show its extreme distension : so we proved that they must never be used to lay out a calibration course.
The plastified fiberglass tape (from Rodolfo) also distends too much but less than the plastic one : it can only be used around 20 °C but not in extreme temperatures.
Besides all the steel tapes must be used : we had been recommanding their use, we proved that one must use them only.

2-2.Taking the temperature.
In the extreme cases it creates a problem and our behaviours proved to be different sometimes.
I must admit that it was the first time I was laying out a calibration course with a 50°C temperature on the ground under bright sun.
In the shade and on the ground the thermometer indicated 10°C less.

JFD

Most measurers used the average of the ground temperature between the sun and the shade (this is what I did myself) but some measurers took the temperature in the shade on the foot path or at 10 cm from the ground or even in another way.
What is the best solution? I am waiting for your suggestions..

2-3. Calculation of the thermic correction factor.
Some ignored it or forgot it : this is a mistake (probably out of inexperience).
However the IAAF/AIMS books only show an approximative chart of the correction to do : for me it is not enough.
One must calculate with the "magical formula" the distension of the tape when one doesn't have the chart of the thermic correction factor.

3. The standard measurement of the course and the study of the group results.
The group results seemed good enough, but I think that no method allows to classify the measurers themselves.
The complex figures according to the variations compared with the medium value of the group for each split of the course are too complicated and anyway there are distorded with the very composition of the group : if there are many beginners in the group the medium value will be higher than is an homogeneous group of equal experience measurers.
The figures of "accuracy" and "precision" would have some value only if one knew the real distances to be compared but no-one knows the real distance of each split...
As for me I'm used to analyse the results of a group of measurers globally (and no split by split).
I don't like the split by split study : they are intermediate marks only which are used to detect the stupid mistakes but for me the global result of the measurer is the most important since it shows his own conclusion of his own work and his own interpretation of the whole course.

In a group of measurers there are always two extremes:
- Beginners or inexperimented measurers or measurers with technical problems : it's the extreme of the longest results, most often due to bad trajectory, too far away from the kerb or the corners. Usually these measurers will only need a little practice to improve very quickly. However some measurers in this group can sometimes have results that are apparently accurate or short : for example when their calibration is even worse than their trajectory (constant increases a lot, trajectory increases a little, so the result of the distance decreases) or that their equipment is very bad (a tire losing air increases the post constant, so the result of the distance decreases).
- The other extreme consists of very short results (or too short results?) : most often they come from measurers who are anxious to compare their results with others or who try to be the shortest possible intentionally in fear of being badly appreciated.
In fact it is for them like competition that they try to be very short, but to measure 30 cm from the obstacles is difficult enough to apply in reality and strictenough for the runners whose real trajectories are always longer than those measured (without cutting of course).
I do not think that John's result is connected to this fact. I can only explain it with the difficulty of measuring in the American gutters, that are 40 cm wide !!... John would jut out after each bend in order to ride on the tarmacadam road in the streight lines, when most of us would wobble a long time in the gutter in the small 10 cm externe wide line. Let us not forget that all of us calibrated our bicycles on the tarmacadam calibration course.
I think that John's result is the best of all and we must pay tribute to his great experience.

Nevertheless I am used to analysing a group result by discarding the extreme values of the group with my method of 0.05% discording system that is to say plus or less 0.05% compared to the medium value of the group (this corresponds to a 0.1% margin) then conclude by calculating with the remaining measures the average of three measures (the medium value and the 2 immediatly lower values to the medium).

This given for the course of Felix a result of 7419.17 m and I think that this value is good JFD enough.
The measurers that have a result showing a difference of more than 0.1% must ask themselves the question and try and know why. All the others are OK and it is not necessary to try and classify then.
According to me one should classify the measurers only when doing games like the contest test of the offset test. This shows the experience, the appreciation and also a bit of luck too I think (this is part of the game and of the competition).

4. The tight measurement of the course.
There as well it was a little like a game in order to avoid measuring too short in the standard measurement I think.
In fact only the results of the standard measuremant are important.
The tight measurement was only a game : I am sorry I won it...
I think that a few people must have throught that I had practiced cutting or that I had made mistakes in my calculations : I can certify that this is wrong. I was also surprised by my result - very short. I had mathematically calculated that the difference of measurement between 30 cm or 0 cm of the kerbs would make us find a distance between 8 and 9 meters shorter during the tight measurement.
My own result is 14 meters shorter!!.
I can only explain part of it :
- my standard measurement maybe a little too long (cf J.Disley's result) however it is within the average of the results of the other measurers.
- I am very skilled with using a bike (cf 4 x 4 test, 5 m slowest test, etc...) and I often practice on trails and for the trial. This has allowed me to always be able to ride close to the kerb in the bands : my tire was always touching the kerb but in that care I couldn't pedal and had to push with my feet on the ground to go ahead. Don Shepan was with me during the tight measurement and he saw me do it. I think it is better that way (rarher then get off the bike in the bands : this decreases the calibration constants of a least 1 count/kg when the rider is not on his bike and therefore it lenghtens his measure).

This is my results between tight and standard measurements by splits.
X = O,6 x 3.14159 / 4 = 0.471238 m by 90° corner

	Theoric tight	JFD tight
S - SF	4,5 x = - 2,12 m	- 3,50 m
SF - R1	2 x = - 0,94 m	- 1,21 m
R1 - R2	6 x = - 2,82 m	- 4,61 m
R2 - SF	6 x = - 2,82 m	- 4,65 m
total	18 x = - 8,70 m	- 13,98 m

I think that those who have too small a difference between their tight and standard measurements must also ask themselves the question of knowing which of the two is not quite accurate:
-if it is the thight : no problem
-if it is the standard : this can be annoying.

5. OFFSET TEST
I had no idea what type of game that was but I enjoyed it very much.

Personnaly I never use such translations during real measurements with my bicycle (a 12 meter wide road!) but only for very short distances as far avoiding a car that is parked (about two meters).
My estimation was not too bad but I think that the winner B.Baumel has an extraordinary good eye and also a bit of luck.
Aiming to the next centimeter from a distance of 12 meters without any mark is prodigious (I can do it with a bow on a wellknown target but not without sights).
I would also have been interesting to ask each measurer to calculate with the help of triangulation measures what was the good answer. I think it is a good test to find out what the minimum knowledge in geometry of the future measurement experts is.

I will stop here because I have been long enough.

I hope that the others will not take as much space in the final seminar report.

Best wishes.

Jean François

PHOENIX - 22.05.94 - STUDY BY SPLIT (Standard measurement)

CALIBRATION COURSE = 332,14 m

	John DISLEY	Doug LOEFFLER	Dave YAEGER	Félix CICHOCKI	Don SHEPAN	Bob BAUMEL	Peter RIEGEL	Bob LETSON	J. François DELASALLE	Tom Mac BRAYER	Mike WICKISER	Andy BEACH	Luciano RAMIREZ	Rodolfo MARTINEZ	Marcial TELLEZ	Karen WICKISER
S/SF	2 957,14	2 957,79	2 958,21	2 958,26	2 958,34	2 958,64	2 959,44	2 959,46	2 959,50	2 959,91	2 960,00	2 960,08	2 960,50	2 962,51	2 963,19	

	John DISLEY	Doug LOEFFLER	Don SHEPAN	Marcial TELLEZ	J. François DELASALLE	Félix CICHOCKI	Dave YAEGER	Bob LETSON	Peter RIEGEL	Bob BAUMEL	Tom Mac BRAYER	Andy BEACH	Mike WICKISER	Rodolfo MARTINEZ	Luciano RAMIREZ	Karen WICKISER
SF/R1	1 029,30	1 030,05	1 030,07	1 030,07	1 030,11	1 030,22	1 030,37	1 030,42	1 030,44	1 030,45	1 030,50	1 030,74	1 030,94	1 031,48	1 032,61	

	Doug LOEFFLER	John DISLEY	Félix CICHOCKI	Don SHEPAN	Bob LETSON	J. François DELASALLE	Peter RIEGEL	Dave YAEGER	Andy BEACH	Bob BAUMEL	Mike WICKISER	Tom Mac BRAYER	Karen WICKISER	Luciano RAMIREZ	Marcial TELLEZ	Rodolfo MARTINEZ
R1/R2	1 548,02	1 548,11	1 548,23	1 548,33	1 548,78	1 548,81	1 548,98	1 549,05	1 549,50	1 549,65	1 550,80	1 550,85	1 551,21	1 551,52	1 551,61	1 552,23

	Don SHEPAN	Félix CICHOCKI	J. François DELASALLE	John DISLEY	Doug LOEFFLER	Bob LETSON	Peter RIEGEL	Dave YAEGER	Bob BAUMEL	Mike WICKISER	Andy BEACH	Rodolfo MARTINEZ	Luciano RAMIREZ	Tom Mac BRAYER	Karen WICKISER	Marcial TELLEZ
R2/F	1 881,06	1 881,10	1 881,26	1 881,36	1 881,81	1 881,85	1 881,89	1 882,39	1 882,44	1 882,88	1 882,89	1 883,10	1 883,29	1 883,75	1 884,54	1 884,97

SUM OF MEDIUM SPLIT 7 421,32

SUM OF 1/3 SPLIT 7 419,04

	John DISLEY	Doug LOEFFLER	Don SHEPAN	Félix CICHOCKI	J. François DELASALLE	Dave YAEGER	Bob LETSON	Peter RIEGEL	Bob BAUMEL	Andy BEACH	Mike WICKISER	Tom Mac BRAYER	Karen WICKISER	Luciano RAMIREZ	Rodolfo MARTINEZ	Marcial TELLEZ
TOTAL	7 415,92	7 417,68	7 417,79	7 417,81	7 419,69	7 420,02	7 420,51	7 420,76	7 421,11	7 423,22	7 424,41	7 425,01	7 426,00	7 427,92	7 429,32	7 429,74

MEDIUM RESULT

MEDIAN 7 420,76

-.05% 7417.85

+.05% 7424.47

1/3 RESULT 7 419,69

	AVERAGE	MEDIUM	1/3
S/SF	2 959,53	2 959,46	2 958,34
SF/R1	1 030,52	1 030,42	1 030,11
R1/R2	1 549,72	1 549,05	1 548,78
R2/F	1 882,53	1 882,39	1 881,81
TOTAL	7 422,30	7 421,82	7 419,04

AVERAGE OF 3 MEDIUM RESULTS 7 420,79

RANGE OF MEDIAN ± .05%

NEW MEDIAN

AVERAGE = 7419.17

JFP

PHOENIX - 22.05.94 - STUDY BETWEEN STANDARD AND TIGHT RIDING

CALIBRATION COURSE = 332,14 m

	J. François DELASALLE	John DISLEY	Don SHEPAN	Peter RIEGEL	Mike WICKISER	Dave YAEGER	Bob BAUMEL	Bob LETSON	Félix CICHOCKI	Andy BEACH
S/SF Tight	2 956,00	2 956,54	2 956,98	2 957,24	2 957,24	2 957,30	2 957,52	2 957,77	2 957,93	2 959,41
S/SF Standard	2 959,50	2 957,14	2 958,34	2 959,44	2 960,00	2 958,21	2 958,64	2 959,46	2 958,26	2 960,08
Diff.	-3,50	-0,60	-1,36	-2,20	-2,76	-0,91	-1,12	-1,69	-0,33	-0,67

	J. François DELASALLE	Don SHEPAN	John DISLEY	Peter RIEGEL	Bob BAUMEL	Dave YAEGER	Bob LETSON	Mike WICKISER	Félix CICHOCKI	Andy BEACH
SF/R1 Tight	1 028,90	1 029,39	1 029,52	1 029,57	1 029,58	1 029,59	1 029,79	1 029,98	1 030,05	1 030,24
SF/R1 Standard	1 030,11	1 030,07	1 029,30	1 030,44	1 030,45	1 030,37	1 030,42	1 030,94	1 030,22	1 030,74
Diff.	-1,21	-0,68	0,22	-0,87	-0,87	-0,78	-0,63	-0,96	-0,17	-0,50

	J. François DELASALLE	Félix CICHOCKI	Don SHEPAN	Peter RIEGEL	Dave YAEGER	Bob LETSON	John DISLEY	Mike WICKISER	Bob BAUMEL	Andy BEACH	Karen WICKISER
R1/R2 Tight	1 544,21	1 546,73	1 546,91	1 546,99	1 547,04	1 547,36	1 547,54	1 547,73	1 548,04	1 548,33	1 549,49
R1/R2 Standard	1 548,81	1 548,23	1 548,38	1 548,98	1 549,05	1 548,78	1 548,11	1 550,60	1 549,65	1 549,50	1 551,21
Diff.	-4,60	-1,50	-1,47	-1,99	-2,01	-1,42	-0,57	-2,87	-1,61	-1,17	-1,72

	J. François DELASALLE	Peter RIEGEL	Don SHEPAN	Dave YAEGER	John DISLEY	Félix CICHOCKI	Andy BEACH	Bob LETSON	Mike WICKISER	Bob BAUMEL	Karen WICKISER
R2/F Tight	1 876,61	1 879,36	1 879,55	1 880,27	1 880,34	1 880,39	1 880,46	1 880,61	1 880,65	1 880,88	1 881,96
R2/F Standard	1 881,26	1 881,89	1 881,06	1 882,39	1 881,36	1 881,10	1 882,89	1 881,85	1 884,54	1 882,44	1 884,54
Diff.	-4,65	-2,53	-1,51	-2,12	-1,02	-0,71	-2,43	-1,24	-3,89	-1,56	-2,58

TOTAL	J. François DELASALLE	Mike WICKISER	Peter RIEGEL	Don SHEPAN	Dave YAEGER	Bob BAUMEL	Bob LETSON	Andy BEACH	Karen WICKISER	Félix CICHOCKI	John DISLEY
TIGHT	7 405,71	7 415,60	7 413,16	7 411,82	7 414,20	7 416,02	7 415,53	7 418,43	7 421,70	7 415,10	7 413,93
STANDARD	7 419,69	7 424,41	7 420,76	7 417,79	7 420,02	7 421,18	7 420,51	7 423,22	7 426,00	7 417,81	7 415,92
DIFF.	-13,98	-8,81	-7,60	-5,97	-5,82	-5,16	-4,98	-4,79	-4,30	-2,71	-1,99

JFD

PHOENIX - 22.05.94 - CALCULATED COURSE LENGTH (Tight Riding)

CALIBRATION COURSE = 332,14 m

	J. François DELASALLE	Don SHEPAN	Peter RIEGEL	John DISLEY	Dave YAEGER	Félix CICHOCKI	Bob LETSON	Mike WICKISER	Bob BAUMEL	Andy BEACH	Karen WICKISER
CAL											
C5	3 866,00	3 288,00	3 200,50	3 667,00	3 183,00	3 126,00	3 735,00	3 125,50	3 225,00	3 236,00	3 857,00
C6	3 865,00	3 288,50	3 201,50	3 667,00	3 183,00	3 127,00	3 734,00	3 125,50	3 227,50	3 236,00	3 859,00
C7	3 865,50	3 287,50	3 200,00	3 666,00	3 188,00	3 126,00	3 734,00	3 125,50	3 224,50	3 236,00	3 858,00
C8	3 865,00	3 288,50	3 200,50	3 667,00	3 183,50	3 127,00	3 734,00	3 125,50	3 226,00	3 235,00	3 860,00
C9	3 863,00	3 286,50	3 200,50	3 667,00	3 181,00	3 127,50	3 733,00	3 125,50	3 225,00	3 233,00	3 857,00
C10	3 862,00	3 288,00	3 201,00	3 668,00	3 182,00	3 127,00	3 733,00	3 125,50	3 226,00	3 234,00	3 858,00
C11	3 863,00	3 287,00	3 200,00	3 667,50	3 182,00	3 126,00	3 733,00	3 125,50	3 225,00	3 234,00	3 857,00
C12	3 863,00	3 288,50	3 200,50	3 667,00	3 182,00	3 126,00	3 734,00	3 125,50	3 225,00	3 235,00	3 861,00
AVE.	3 864,06	3 287,81	3 200,56	3 667,06	3 182,44	3 126,56	3 733,75	3 125,50	3 225,50	3 234,88	3 858,38
CSTE	11 645,47	9 908,77	9 645,82	11 051,75	9 591,20	9 422,80	11 252,74	9 419,60	9 720,98	9 749,23	11 628,33

69

COUNTS											46 400,0
S/SF	34 424,0	29 300,0	28 525,0	32 675,0	28 364,0	27 872,0	33 283,0	27 856,0	28 750,0	28 852,0	
SF/R1	11 982,0	10 200,0	9 931,0	11 378,0	9 875,0	9 706,0	11 588,0	9 702,0	10 008,5	10 044,0	
R1/R2	17 983,0	15 328,0	14 922,0	17 103,0	14 838,0	14 574,5	17 412,0	14 579,0	15 048,5	15 095,0	18 018,0
R2/F	21 854,0	18 624,0	18 128,0	20 781,0	18 034,0	17 718,5	21 162,0	17 715,0	18 284,0	18 333,0	21 884,0
TOTAL	86 243,0	73 452,0	71 506,0	81 937,0	71 111,0	69 871,0	83 445,0	69 852,0	72 091,0	72 324,0	86 302,0

METRES											
S/SF	2 956,00	2 956,98	2 957,24	2 956,54	2 957,30	2 957,93	2 957,77	2 957,24	2 957,52	2 959,41	
SF/R1	1 028,90	1 029,39	1 029,57	1 029,52	1 029,59	1 030,05	1 029,79	1 029,98	1 029,58	1 030,24	
R1/R2	1 544,21	1 546,91	1 546,99	1 547,54	1 547,04	1 546,73	1 547,36	1 547,73	1 548,04	1 548,33	1 549,49
R2/F	1 876,61	1 879,55	1 879,36	1 880,34	1 880,27	1 880,39	1 880,61	1 880,65	1 880,88	1 880,46	1 881,96
TOTAL	7 405,71	7 412,82	7 413,16	7 413,94	7 414,20	7 415,10	7 415,53	7 415,60	7 416,02	7 418,43	7 421,70

JFD

PHOENIX - MESURAGES MULTIPLES D'UN MEME CIRCUIT - PAR UN MEME MESUREUR

JF DELASALLE - Tableau chronologique

BASE D'ETALONNAGE DE PHOENIX (332.14 m)

	JFD 1 22-Mai-94 8h30 - 30 °	JFD 2 22-Mai-94 9h00 - 35 °	JFD 3 27-Mai-94 14h45 - 48 °	JFD 4 27-Mai-94 15h15 - 50 °	JFD 5 27-Mai-94 16h00 - 48 °	JFD 6 28-Mai-94 5h30 - 20 °	JFD 7 28-Mai-94 6h10 - 22 °	JFD 8 28-Mai-94 7h00 - 31 °
ETALONNAGE								
C1	3 870,00	3 870,00	3 824,00	3 823,00	3 822,00	3 833,50	3 831,50	3 831,00
C2	3 869,50	3 869,50	3 824,00	3 824,50	3 822,50	3 834,00	3 832,50	3 831,00
C3	3 870,00	3 870,00	3 824,00	3 823,50	3 822,50	3 833,50	3 832,50	3 831,00
C4	3 869,50	3 869,50	3 824,00	3 824,00	3 823,00	3 833,50	3 832,00	3 831,00
C5	3 866,00	3 866,00	3 823,00	3 822,00	3 823,00	3 831,50	3 831,00	3 828,00
C6	3 865,00	3 865,00	3 824,50	3 822,50	3 823,50	3 832,50	3 831,00	3 828,50
C7	3 865,50	3 865,50	3 823,50	3 822,50	3 823,50	3 832,50	3 831,00	3 829,00
C8	3 865,00	3 865,00	3 824,00	3 823,00	3 823,50	3 832,00	3 831,00	3 829,00
MOYENNE	3 867,56	3 867,56	3 823,88	3 823,13	3 822,94	3 832,88	3 831,56	3 829,81
CONSTANTE	11 656,02	11 656,02	11 524,35	11 522,09	11 521,53	11 551,48	11 547,52	11 542,25
PULSES								
S/SF	34 518,0	34 496,0	34 106,0	34 095,0	34 092,0	34 189,0	34 180,0	34 174,0
SF/R1	12 016,0	12 007,0	11 875,0	11 875,0	11 872,0	11 908,0	11 903,0	11 899,0
R1/R2	18 055,0	18 053,0	17 856,0	17 848,0	17 848,0	17 896,0	17 894,0	17 896,0
R2/F	21 933,0	21 928,0	21 677,0	21 683,0	21 681,0	21 735,0	21 730,0	21 721,0
TOTAL	86 522,0	86 484,0	85 514,0	85 501,0	85 493,0	85 728,0	85 707,0	85 690,0
METRES								
S/SF	2 961,39	2 959,50	2 959,47	2 959,10	2 958,98	2 959,71	2 959,94	2 960,78
SF/R1	1 030,88	1 030,11	1 030,43	1 030,63	1 030,42	1 030,86	1 030,78	1 030,91
R1/R2	1 548,99	1 548,81	1 549,41	1 549,02	1 549,10	1 549,24	1 549,60	1 550,48
R2/F	1 881,69	1 881,26	1 880,97	1 881,86	1 881,78	1 881,58	1 881,79	1 881,87
TOTAL	7 422,95	7 419,69	7 420,29	7 420,61	7 420,28	7 421,39	7 422,11	7 424,03

JFD

PHOENIX - MESURAGES MULTIPLES D'UN MEME CIRCUIT - PAR UN MEME MESUREUR

JF DELASALLE - Tableau analytique

BASE D'ETALONNAGE DE PHOENIX (332,14 m)

	JFD 2 22-Mai-94 9h00 - 35 °	JFD 3 27-Mai-94 14h45 - 48 °	JFD 5 27-Mai-94 16h00 - 48 °	JFD 4 27-Mai-94 15h15 - 50 °	JFD 6 28-Mai-94 5h30 - 20 °	JFD 7 28-Mai-94 6h10 - 22 °	JFD 1 22-Mai-94 8h30 - 30 °	JFD 8 28-Mai-94 7h00 - 31 °
METRES								
S/SF	2 959,50	2 959,47	2 958,98	2 959,10	2 959,71	2 959,94	2 961,39	2 960,78
SF/R1	1 030,11	1 030,43	1 030,42	1 030,63	1 030,86	1 030,78	1 030,88	1 030,91
R1/R2	1 548,81	1 549,41	1 549,10	1 549,02	1 549,24	1 549,60	1 548,89	1 550,48
R2/F	1 881,26	1 880,97	1 881,78	1 881,86	1 881,58	1 881,79	1 881,69	1 881,87
TOTAL	7 419,68	7 420,28	7 420,28	7 420,61	7 421,39	7 422,11	7 422,85	7 424,04

	JFD 5	JFD 4	JFD 3	JFD 2	JFD 6	JFD 7	JFD 8	JFD 1
S/SF	2 958,98	2 959,10	2 959,47	2 959,50	2 959,71	2 959,94	2 960,78	2 961,39

	JFD 2	JFD 5	JFD 3	JFD 4	JFD 7	JFD 6	JFD 1	JFD 8
SF/R1	1 030,11	1 030,42	1 030,43	1 030,63	1 030,78	1 030,86	1 030,88	1 030,91

	JFD 2	JFD 1	JFD 4	JFD 5	JFD 6	JFD 3	JFD 7	JFD 8
R1/R2	1 548,81	1 548,89	1 549,02	1 549,10	1 549,24	1 549,41	1 549,60	1 550,48

	JFD 3	JFD 2	JFD 6	JFD 1	JFD 5	JFD 7	JFD 4	JFD 8
R2/F	1 880,97	1 881,26	1 881,58	1 881,69	1 881,78	1 881,79	1 881,86	1 881,87

Somme des médianes de chaque secteur **7 420,92**

Degré d'estimation au

1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8
12,50%	25%	37,50%	50%	62,50%	75%	87,50%	100%
7 418,87	7 419,67	7 420,50	7 420,92	7 421,51	7 422,00	7 423,12	7 424,65

	MOYENNE	MEDIANE	1/4	1/8 SOSS
S/SF	2 959,86	2 959,50	2 959,10	2 958,98
SF/R1	1 030,63	1 030,63	1 030,42	1 030,11
R1/R2	1 549,32	1 549,10	1 548,89	1 548,81
R2/F	1 881,60	1 881,69	1 881,26	1 880,97
TOTAL	7 421,41	7 420,92	7 419,67	7 418,87

Moyenne des 3 totaux médians **7420,76**

JFD

FC

xxxxto Pete Riegel May 24, 1994
from Felix Cichocki

Dear Pete,

I hope everything was as you had desired.. Mary Ann and I enjoy do this sort of thing.. It was fun, informative, and beneficial to see and work with other measurers.. I am certainly open to hosting this sort of thing here again.. I even had such an enjoyable time hiking Camelback Mountain with the group on Sunday that I went again Monday after work.. Found out that they had 2 rescues last week due to hikers going where they should not and ending up on shear cliffs and could not get out.. By the way, 35:30 to the top.. I'm sure your Grand Canyon trip was memorable.. I hope everyone enjoyed their time here in Arizona..

Attached is my version of everyone's data which I put in a Lotus 1-2-3 spreadsheet.. I'm sure others will do a more thorough analysis, but this is something quick for you to look at on your long plane ride home.. Here's a disk also (Windows version) if you would like to build from it.. Some comments on my data

1.. This does not contain any "tight" measurement info..

2.. This does not contain the second calibration - expecting to not use this data as the temps increased during the day and space on the paper was minimal..

3.. The "Total", which is the course length, is different on the spreadsheet than on some worksheets, like Disley, Delasalle, Baumel, and slightly for several others.. Rounding may be the answer for others but unknown for the named.. People's math would have been nice to see..

4.. Use of Temperature is interesting.. What temp should be used? Most people noted one, but when two, I used the larger or the one from direct sun.. I will do some study looking at the end result by varying the temp, but I suspect it is small..

5.. By the way, I recommend people experiment with the numbers using a spreadsheet.. I have found myself looking at the Jones Counter from different angles to see if it's .5 or .3, or what.. A person can get hung up on exactness in a area that has little consequence in the end, and computer testing can show this..

Regards,
Felix

(we have a print driver problem)

Measurement Seminar Results

Phoenix, Arizona

May 21 1994

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Don		43.5	91000.0	94290.5	3290.5	3289.625	S/F to S/F	40000.0	69323.0	29323.0	2957.62	
Shepan	1089.385	corrected	94290.5	97579.0	3288.5		S/F to #1	69323.0	79533.0	10210.0	1029.82	7415.99
	or	332.135	97579.0	100869.0	3290.0	counts/mete	#1 to #2	79533.0	94880.0	15347.0	1547.95	
	332.0445		100869.0	104158.5	3289.5	9914.384	$2 to S/F	94880.0	113525.0	18645.0	1880.60	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Felix		47	95430.0	98558.5	3128.5	3128.5	S/F to S/F	41093.5	68977.0	27883.5	2957.15	
Cichocki		corrected	98558.5	101687.0	3128.5		S/F to #1	68977.0	78687.5	9710.5	1029.84	7415.01
	or	332.121	101687.0	104815.0	3128.0	counts/mete	#1 to #2	78687.5	93280.5	14593.0	1547.64	
	332.0170		104815.0	107944.0	3129.0	9429.18	$2 to S/F	93280.5	111011.0	17730.5	1880.39	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
John		37	38000.0	41671.0	3671.0	3671.5	S/F to S/F	55800.0	88500.0	32700.0	2955.19	
Disley		corrected	41671.0	45344.0	3673.0		S/F to #1	16600.0	27982.0	11382.0	1028.62	7411.02
	or	332.135	45344.0	49015.0	3671.0	counts/mete	#1 to #2	27982.0	45101.0	17119.0	1547.09	
	332.0700		49015.0	52686.0	3671.0	11065.28	$2 to S/F	45101.0	65905.0	20804.0	1880.12	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Mike		25	2000.0	5125.5	3125.5	3125.5	S/F to S/F	17000.0	44882.0	27882.0	2959.97	
Wickiser	1089.625	corrected	5125.5	8251.0	3125.5		S/F to #1	44882.0	54593.0	9711.0	1030.93	7424.35
	or	332.137	8251.0	11376.5	3125.5	counts/mete	#1 to #2	54593.0	69199.0	14606.0	1550.58	
	332.1177		11376.5	14502.0	3125.5	9419.685	$2 to S/F	69199.0	86935.0	17736.0	1882.87	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Pete		43	15160.0	18362.0	3202.0	3202.125	S/F to S/F	58854.5	87208.0	28553.5	2958.78	
Riegel	1089.42	corrected	18362.0	21564.0	3202.0		S/F to #1	88400.0	98342.0	9942.0	1030.21	7419.11
	or	332.144	21564.0	24766.0	3202.0	counts/mete	#1 to #2	98342.0	113287.0	14945.0	1548.64	
	332.0552		24766.0	27968.5	3202.5	9650.42	$2 to S/F	113287.0	131444.0	18157.0	1881.47	

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	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Karen		31	885460.0	889318.0	3858.0	3858.25	S/F to S/F	903800.0				
Wickiser	1089.5	corrected	889318.0	893177.0	3859.0		S/F to #1		950200.0	46400.0	3990.17	7425.84
	or	332.122	893177.0	897035.0	3858.0	counts/mete	#1 to #2	950200.0	968238.0	18038.0	1551.18	
	332.0796		897035.0	900893.0	3858.0	11628.58	$2 to S/F	968238.0	990152.0	21914.0	1884.49	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
J.F.		43	465300.0	469170.0	3870.0	3869.75	S/F to S/F	574000.0	608496.0	34496.0	2957.82	
Delasalle		corrected	469200.0	473069.5	3869.5		S/F to #1	608496.0	620503.0	12007.0	1029.52	7415.46
	or	332.139	473100.0	476970.0	3870.0	counts/mete	#1 to #2	620503.0	638556.0	18053.0	1547.93	
	332.0500		477000.0	480869.5	3869.5	11662.66	$2 to S/F	638556.0	660484.0	21928.0	1880.19	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Doug		42	59000.0	62669.0	3669.0	3669.5	S/F to S/F	63000.0	95715.0	32715.0	2958.56	
Loeffler	1089.552	corrected	62669.0	66339.0	3670.0		S/F to #1	95715.0	107108.0	11393.0	1030.32	7419.58
	or	332.180	66339.0	70009.0	3670.0	counts/mete	#1 to #2	107108.0	123230.0	16122.0	1457.98	
	332.0954		70009.0	73678.0	3669.0	11057.76	$2 to S/F	123230.0	145044.0	21814.0	1972.73	

74

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Bob		46	672161.0	675896.0	3735.0	3734.25	S/F to S/F	690427.0	723729.0	33302.0	2959.21	
Letson	1089.425	corrected	675896.0	679630.0	3734.0		S/F to #1	723729.0	735324.0	11595.0	1030.33	7419.89
	or	332.157	679630.0	683364.0	3734.0	counts/mete	#1 to #2	735324.0	752752.0	17428.0	1548.65	
	332.0567		683364.0	687098.0	3734.0	11253.67	$2 to S/F	752752.0	773928.0	21176.0	1881.70	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Dave		40	43900.0	47083.0	3183.0	3183.375	S/F to S/F	59000.0	87380.0	28380.0	2957.58	
Yaeger		corrected	47090.0	50273.5	3183.5		S/F to #1	87380.0	97265.0	9885.0	1030.15	7418.45
	or	332.083	50280.0	53463.5	3183.5	counts/mete	#1 to #2	97265.0	112126.0	14861.0	1548.72	
	332.0060		53470.0	56653.5	3183.5	9595.668	$2 to S/F	112126.0	130185.0	18059.0	1882.00	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Bob		28.5	70940.0	74168.5	3228.5	3228.188	S/F to S/F	16460.0	45234.0	28774.0	2957.54	
Baumel		corrected	74168.5	77397.0	3228.5		S/F to #1	45234.0	55255.5	10021.5	1030.06	7418.42
	or	332.142	77397.0	80624.0	3227.0	counts/mete	#1 to #2	55255.5	70326.5	15071.0	1549.08	
	332.1090		80624.0	83852.8	3228.8	9729.026	$2 to S/F	70326.5	88634.0	18307.5	1881.74	

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	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Andy		43	79000.0	82237.0	3237.0	3237.25	S/F to S/F	94000.0	122873.0	28873.0	2958.83	
Beach	1089.2	corrected	82237.0	85474.0	3237.0		S/F to #1	122873.0	132927.0	10054.0	1030.31	7420.08
	or	332.077	85474.0	88711.0	3237.0	counts/mete	#1 to #2	132927.0	148041.0	15114.0	1548.84	
	331.9882		88711.0	91949.0	3238.0	9758.248	$2 to S/F	148041.0	166407.0	18366.0	1882.10	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Tom		28.5	466900.0	470635.0	3735.0	3734.75	S/F to S/F	484400.0	517716.0	33316.0	2959.92	
McBrayer		corrected	470635.0	474369.5	3734.5		S/F to #1	517716.0	529315.0	11599.0	1030.50	7424.96
	or	332.142	474369.5	478104.0	3734.5	counts/mete	#1 to #2	529315.0	546770.0	17455.0	1550.77	
	332.1090		478104.0	481839.0	3735.0	11255.69	$2 to S/F	546770.0	567973.0	21203.0	1883.76	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Luciano		42	29478.0	32663.0	3185.0	3184.5	S/F to S/F	16753.0	45165.0	28412.0	2960.77	
Ramirez	1089.563	corrected	32663.0	35847.0	3184.0		S/F to #1	45165.0	55055.0	9890.0	1030.62	7426.51
	or	332.183	35847.0	39037.0	3190.0	counts/mete	#1 to #2	55055.0	69945.0	14890.0	1551.66	
	332.0987		39037.0	42216.0	3179.0	9596.158	$2 to S/F	69945.0	88019.0	18074.0	1883.46	

75

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Mareal		41	89880.0	93180.0	3300.0	3288	S/F to S/F	79540.0	108891.0	29351.0	2961.43	
Tellez		corrected	93180.0	96468.0	3288.0		S/F to #1	108891.0	119094.0	10203.0	1029.45	7425.31
	or	332.081	96468.0	99750.0	3282.0	counts/mete	#1 to #2	119094.0	134463.0	15369.0	1550.69	
	332.0000		99750.0	103032.0	3282.0	9911.104	$2 to S/F	134463.0	153133.0	18670.0	1883.75	

	Calibration length		First Calibration									
	uncorrected	Temp C	Start count	Finish count	Difference	Average	Course	Start count	Finish count	Difference	Distance	Total
Rodolfo		42	3596.0	6808.0	3212.0	3212.75	S/F to S/F	19500.0	48178.0	28678.0	2961.86	
Martinez		corrected	6993.0	10206.0	3213.0		S/F to #1	104300.0	114285.0	9985.0	1031.25	7427.69
	or	332.145	10509.0	13723.0	3214.0	counts/mete	#1 to #2	114285.0	129311.0	15026.0	1551.89	
	332.0600		13807.0	17019.0	3212.0	9682.414	$2 to S/F	129311.0	147540.0	18229.0	1882.69	

FC

DS

3007 Ronna Drive

Las Cruces, New Mexico 88001

5 July 1995

Mr. Pete Riegel

3354 Kirkham Road

Columbus, Ohio 43221-1368

Dear Pete:

Comments on the Phoenix Seminar:

1. As a relatively new measurer, I and my wife were warmly welcomed by your group of seasoned measurers. We immediately felt very much at home.

2. The accommodations at the Resort Suites were very conducive to making friends and getting acquainted.

3. The comparison between my calibration course length measurement and yours was extremely close (1089.38 feet versus 1089.42 feet). Your techniques for quickly measuring the distance without sacrificing accuracy will be most helpful in the future. I am now convinced that pulling the chain straight and applying the 20 pound load is probably adequate. But if you have an 800 number for Lufkin, I would gladly call them to see what is recommended for this extremely heavy tape.

b. The standard offset course measurement I generated was as tight as some of the best measurements. I am pleased to learn this since this says my techniques and skills seem to be acceptable.

4. The new pavement on the seminar course tended to show and retain bike tracks. This was especially noticeable on diagonals. I was amazed to see the wide variation in tracks from one rider to the next. For example, at one location, most of the bikes left a dust trail across the new pavement. The width of all tracks as they crossed the center stripe at the midpoint of the diagonal may have been as much as 15 feet in width. But, the fairly large range in the course measurements has to be the result of riding the whole course very loosely and not due to deviations from straight lines on the diagonals.

5. I think some comments from you and the others on measuring in the concrete gutters would be appropriate. The concrete in the gutters would be cooler than the black asphalt (which would contribute to a shorter measurement). However, a runner easily senses the slightest grade separation between the concrete and the asphalt and will avoid that type of surface. Still, the 30 cm offset is the rule and it is located in the center of the gutter on many courses.

6. For me, the highlight of the seminar was your concurrence in allowing me to become a regional certifier (with assigned responsibility in NM). I look forward to our next discussion on this topic.

7. Congratulations to Felix for all the work he did on making the seminar a success.

Sincerely,

Donald R Shepan

Donald R. Shepan

DY

Dave Yaeger
19 Carondale Crescent
Scarborough, Ontario
M1W 2A9

July 5, 1994

Pete Riegel, 3354 Kirkham Road, Columbus, OH 43221-1368

Dear Pete,

Thanks for the photo of the Phoenix Measurement group. It was pleasure to meet and work with you.

I have been traveling since the measurement seminar and am now home for the summer. I have only undertaken a limited review of the data. Just enough to note that the range of measured lengths for the course was greater than the SCPF of approximately 7.4 m.

Some of the things I learned at the seminar were:

- I had been using a 20 lb pull on my 100 m steel tape. An inspection of the tape during the tape comparison session indicated that the tape was stamped for a 50 N - approximately 11 lb pull. Although not recorded in the table, the scale reading for my tape (#5) at 20 lb was 1.028 m - .003 mm more than at the 10 lb pull. Therefore my calibration course measurement which was done at 20 lb should actually be .034 m longer. This means that the courses I have been measuring are .1 m/km longer than necessary. Not significant - just an added measure of safety.
- The Canadian Measurement Handbook uses a temperature correction factor of 0.0000118 /°C. I will have this corrected to the standard value of 0.0000115/°C. The handbook factor provides an additional (but minuscule) "safety" factor.
- Feet and inches are hard to work with. I'll stick to metres.
- Estimating the offset was interesting. Not a lot of error there, however, it could add up if there was a number of them during a measurement.

I enjoyed the seminar and the opportunity to learn a little more about the various "errors" that are present in our measurements. Good luck with the number crunching.

Cheers,

Dave

ETM

USA Track and Field
Road Running Technical Council
Vice Chairman West
E. T. (Tom) McBrayer
4021 Montrose Blvd
Houston, Texas 77006-4956
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June 21, 1994

Pete Riegel
chairman, Road Running Technical Council
3354 Kirkham Road
Columbus, OH 43221-1368

Dear Pete:

It's difficult to image that much could be done to improve this event. My comments:

Location: Good for flight schedules; not so good for those driving (population density sity).

Accomodations: In a word, GREAT!

Course site/layout: If you built your own measurement layout, it would look like this.

Agenda: Covered basic measurement mechanics. The two "extras" (tape comparisons, eyeball offset) were nice touches.

Host: Five stars, two thumbs up! We know the results of Felix's effort; we can only imagine how much time was spent.

Possibilities:

1) How about an eastern location for '98? (Assuming we do this every four years, just like the Olympics);

2) Supplement these international seminars with low key, state/regional ones in alternate years.

Regards,