MEASUREMENT NEWS

#15 - February, 1986

Editor: Pete Riegel - 3354 Kirkham Road - Columbus, OH 43221
614-451-5617 (home, not after 10 PM EST)
614-424-4009 (work, 7 to 4:30 ex 11-12:30)

Measurement News (MN) is distributed free to all members of the Road Running Technical Committee of TAC (everybody listed in NRDC News). Some foreign people are also included in the free distribution.

Subscriptions are available for $15 per year. Back issues are available for $2.50 each.

If you wish to reproduce or report on anything in MN, go ahead, but an attribution would be appreciated.

MN is our way to talk to one another, so that we all know what's going on. It also serves to provide guidance from the RRTC Vice Chairmen to the regional certifiers.

MN wants to make measurement as good as it can be. All opinions and grievances are solicited. No cows are sacred. If you have a new measurement technique, or if you think things should be done differently, send in your contribution to MN. Your opinion will be given space. Nothing changes until somebody tries!

Nice, clean typed stuff is most welcome, but send what you can.

* * * * * * * * * * *

A TAX ON CERTIFICATION?

P3-8

In this MN you'll find some letters dealing with a new situation. Ray Vandersteen, the Executive Director of Illinois TAC, wishes to have measurers send their courses directly to his office, with a fee. He retains some of this fee for IL TAC administrative expenses, and forwards the course to me for checking.

I don't like it because it adds to the time and correspondence involved in my certification activity. I prefer to deal directly with measurers and let them take care of things on their local level, such as notifying the race director when certification is complete. In addition, I don't think that taxing the races is likely to be seen as a friendly activity by TAC and RRTC.

Ray thinks it's a good idea because it produces much-needed revenue for his Association.

You'll see some correspondence inside dealing with this. Your thoughts on this are earnestly solicited.

BAUMEL VALIDATES THE UNIVERSE! SEE P. 31

SEE NIFTY MAP! P 21

SURFACE ROUGHNESS MAKES A DIFFERENCE! SEE P 19-30

"SHORTEST POSSIBLE ROUTE" VS "IDEAL LINE OF RUNNING"

It is correctly said that our current measuring line, the "Shortest Possible Route" does not really reproduce the path available to a runner, especially on sharp corners. Nobody can run one foot from the curb on a 12-foot radius turn at racing speed. It is argued that a more proper way to measure might be to ride at a certain speed, say 12 mph, and try to come within a foot of one point on each turn. This has a certain appeal, since the measuring arc will more closely match the one that a runner can follow.

The disadvantage of this is that different measurers will not be able to precisely duplicate the original path that is followed, because of aiming error, inability to duplicate the precise speed, and variations of riding curvature while rounding the turn at speed.

Some people feel that the tightness of our measuring line unjustly deprives a runner of the chance to run the ideal line, causing him/her to have to run farther than necessary.

Help is at hand. If you feel this way, you have the option to lay out arcs, of whatever radius you wish, at each corner, and to locate the centers and define the arcs as lines to be coned. This is a lot of trouble on race day, but it is a legal option for those who wish to give the runners the fastest possible course. And if the locations of the cones are defined, the route is checkable by another measurer and meets TAC standards.

This was done on the Olympic Marathon in places where runners had to round the ends of skinny median dividers. Large arcs were laid down, and they were coned on race day, in an effort to give the runners the shortest legal runnable course.

If you decide to try this, better have a lot of confidence in the race director to get things right on race day.

TRACK MEASUREMENTS

LDR track records must presently be set on either a 400 meter or 440 yard track, No other tracks can be used for record purposes. After reviewing my "Measuring a Track" article for this MN, Bob Letson commented "I cannot swallow the categorization of tracks for purposes of long distance runs. The track length should be calculated from the measured length. LDR is not track (i.e. 200m, 400m, etc.). People should receive credit for actual performance, not imagined performance."

Ken Young notes: "An uncurbed track cannot be certified for record purposes - only for 'recreational' use."

3354 Kirkham Road
Columbus, OH 43221
January 15, 1986

Ray Vandersteen - 111 W Butterfield Rd - Elmhurst, IL 60126

Dear Ray,

Our conversation of yesterday gave me a restless night. As you know, I am not happy with the idea of a TAC Association being the initial contact point for a measurer, as was done in IL when Len Evens was the Regional Certifier. Now that I am handling IL, I think it best if I do it as I handle my other territory - that is, to have measurers send their measurements directly to me for review. This has been found to facilitate the certification process all over the US.

I'm also disturbed at the idea that an Association should use the certification process as a fund-raising device. I agree that the Association's expenses may exceed its revenue, and that many people may put in time disproportionate to their reward, but I question whether using the certification process to gain revenue is wise.

Therefore I intend to make it known to IL measurers that my review services are available for $15 per course - the same fee I charge everywhere else. $5 of this goes to NRDC, because I am in sympathy with their goals. I do not regard this contribution as any more than my personal donation to them, nor do I require other regional certifiers to make a similar contribution, although I urge them to do so. Some do, some don't.

"Who's in charge here, anyway?" - an oft-posed question. In the case of certification, it's RRTC. I fear that if we in RRTC begin to use our powers to tax the runners, we may lose some of the respect we have worked to gain. I want RRTC to steer well clear of the political shoals so evident in other TAC activities.

As you may know, RRCA is now represented in RRTC by Harold Tinsley. The use of RRTC certification power to raise funds for TAC may be seen by RRCA as being detrimental to their interests. Maybe not. These are political issues to be thrashed out by others, and I don't want to be the principal thrasher.

RRTC is fortunate in that it is made up, for the most part, of like-minded individuals who have a mutual respect for one anothers' expertise in the technical aspects of measurement. They are largely apolitical and tend to bridle when supervision is imposed, so I try to lead in the East by example and persuasion, rather than by fiat. Their loyalty is, in many cases, like my own - to the runners who will use the courses that we certify. Most of them see no difference between a TAC course and any other - the affiliation of the race director has no relevance.

If you choose to continue to ask race directors in Illinois to send their courses and $25 to you for certification, I will not fight you. I simply intend to treat IL as I do all other regions - my services will be available at the standard rate.

This decision brings me some personal stress, because I like you and know that you are one of the good guys, and it pains me to act against your interests. I know IL TAC can use the money, and use it well. Your Association is one of the better ones in the East, at least in my experience. But I want to keep RRTC as it has traditionally grown to be - a group of people who serve all runners without favor or prejudice. I don't think using certification as a fund-raising vehicle is the proper direction to go.

If you choose to fight this, please be aware that it will not affect any of my services to measurers in IL, nor will it affect my eagerness to hear from you. I've enjoyed our association and want to keep it up. So go to it - I may fight you, but I won't get mad about it. Frustrated and pissed-off, maybe, but certainly not mad.

Best regards,

Pete

Peter S. Riegel
Vice Chairman, RRTC, TAC

xc:

Allan Steinfeld - 9 E 89th St. - New York, NY 10128
Paul Christensen - 3715 NE 18th St - Portland, OR 97212
Wayne Nicoll - 3535 Gleneagles Dr. - Augusta, GA 30907
Alvin Chriss - 11 Middle Neck Rd Rm 307 - Great Neck, NY 11021
NRDC - PO Box 42888 - Tucson, AZ 85733

THE ATHLETICS CONGRESS TAC ILLINOIS

GOVERNING BODY FOR ATHLETICS IN ILLINOIS

Illinois TAC

111 W. Butterfield Rd., Elmhurst, IL. 60126
Phone 312-833-7303

Ray Vandersteen
Executive Director

January 17, 1986

Peter S. Riegel
3354 Kirkham Road
Columbus, Ohio 43221

Dear Pete -

This is a somewhat revised version of the letter I wrote to you yesterday, prior to our phone conversation of January 15. I understand your position regarding the fee charges and if I were in your shoes I'm not certain I would disagree with you. But, I'm not in your shoes and, furthermore, I think my brand of sneakers will soon outsell yours. And well it should! So, if I understand our "agreement", we'll proceed as follows: you'll charge $15.00 for any measurer who contacts you directly; and Illinois TAC will stick with its announced fee schedule ($25 to TAC Clubs/TAC-Sanctioned Races and $35 to others).

So long as TAC is the organization primarily identified with the certification system, I believe that the fee should reflect this kind of primary identification. In Illinois, I think more can be done for certification through a close association with TAC. And, in the long run, I believe this will prove to be true on a national scale, too.

Even if all the certification people were as efficient and conscientious as you are, there would still be a problem with the RRTC operating purely as a technical arm of the "running community". The publicity and promotion, and the financial support now given the whole operation by TAC would probably not be there if it were not for the TAC connection. Associations, in particular, need to get more involved--so long as they do not in any way interfere with the technical end of the business.

All of which brings us around to the question of who receives the measurers' applications. For now, I'd like to continue to receive them here at the Illinois TAC Office---for the following reasons:

(1) for the identification reasons suggested, above
(2) because there's already a fair amount of information out there to that effect
(3) because course measurers don't always accurately and honestly communicate with race directors and/or sponsors re measurement submissions; and when the latter call this office for information, I want to be able to tell them if the application has, in fact, been submitted
(4) In the not-too-distant future, you may appoint someone else as a final certifier in Illinois. And, then, there would be yet another change in direction for measurers/race directors.

For now, the loss of time (a week or less) doesn't equal all the positive reasons for continuing the present communications flow. If things do not remain stable or if the time lag should increase for any reason, we can always make a change later.

Finally, please address the issue of the processing fee in your next "letter" to RRTC members. For those Associations (or Final Certifiers) who are recycling their fees back into the "business", the $25.00 limit is ridiculously low. For Illinois, the monies collected from fees don't cover a fourth of what is directly spent on certification. We really can't afford to do more in '86 if we can't pass at least some of the increase on to the consumer. Most consumers don't mind paying the fee if they get the service. And, the larger the fee (within limits, of course) the greater the service "orientation" of those providing it. More and more people in the business (race directors, sponsors, course measurers) are beginning to accept this "connection". I hope you can bring along yourself and the RRTC. I'll make my pitch with the TAC Association officers/administrators.

Sincerely,

Ray

Ray Vandersteen

Post notes: Since TAC and the certificaion business now have a very close identification, TAC is going to be perceived as responsible for certification. And, if the final certifiers are going to continue to operate, organizationally and politically, through TAC's RRTC, they cannot avoid the TAC connection. So, we're bound to one another whether we like it or not.

More to the point, the alternative solutions are probably not in the best interests of either position. If TAC were to divorce itself from the certification business (as the governing body, I don't believe it can!), the financial and PR support would probably dry up--not only for the technical/measurement end of the operation, but for everything presently done by the NRDC, too. On the other hand, if TAC were to lay on too heavy a political hand, we would probably lose all our technical help--at least all our good help.

So, we've got to find a way for the two views to co-exist. Ideally, I believe that TAC should handle publicity and promotions (and certification fees!) and the final certifiers should take care of the purely technical end of the operation. There probably should be a maximum charge for what any Association could levy for certification processing, but within these limits I believe each Association should establish its own fee schedule (as is done with club fees and, starting in '87, with TAC-Card fees)---and that the final certifiers should not undercut those charges.

Specifically, as regards Illinois: if your position "wins" the debate, our Association will not be able to increase its support of the certification business or of the NRDC. We believe that the "product" consumer should pay for the services rendered. Illinois TAC plans to more than match that consumer return with monies from other sources, because we believe that the Certification technical people (whether "TAC oriented" or not) and the NRDC deserve more support from us than they're getting now. Don't you agree?!

1-17-86

PETE - GOT YOUR LETTER TODAY. I'VE SENT A COPY OF MY LETTER TO ALL THOSE YOU XC'd YOUR LETTER TO. LET'S HOPE THE DEBATE WILL CONTINUE IN THE FRIENDLY FASHION THAT WE'VE BEGUN IT.

R.

The Athletics Congress of the USA

The Governing Body for Athletics in the United States including Track and Field, Long Distance Running and Race Walking for men and women and boys and girls at all age levels.

WAYNE B. NICOLL
3535 Gleneagles Drive
Augusta, Georgia 30907
(404) 860-0712

January 28, 1986

Ray Vandersteen
Illinois TAC
111 W. Butterfield Rd.
Elmhurst, IL 60126

Dear Ray,

Many thanks for a copy of the January 17th letter you wrote to Pete Riegel regarding your debate over the processing of course certification applications within the Illinois TAC.

I am a TAC National Certifier for a four state region (GA,AL,TN,SC). I was appointed by Pete and in many respects of the certification effort, I am a Riegel clone. I do, however, have a particular interest in organizational design - that is, how men organize themselves to accomplish particular tasks. I hold a masters in Public Administration and was repeatedly called upon in my military career to head task forces to tailor or redesign military units to face new tasks and challenges. Hopefully I can do as you ask and continue this debate in a "friendly fashion".

It took a long time to draw me into the TAC ranks. I remained aloof for years, complaining about the AAU and later TAC bureaucracy, but I finally realized that constructive change would come only when our best people pitched in and made it happen. I harbor a certain amount of reluctance to accept organizational growth in the size of TAC becauee it is certain to generate many of the poorer characteristics of bureaucracies. In fact, I am not sure that the current design of TAC with the TAC Associations as the grass roots nuclear unit,is really the way to go. I would prefer to see it designed along functional, rather than territorial,lines.

You are one of the few executive directors of a TAC Association that I know about. To maintain an office and any part time or full time employees is expensive overhead, so I understand your concern over funding of your operation. As an executive director, I see your job as primarily an administrator. You make sure TAC cards, club memberships, and sanctions are distributed and collected properly. You serve as an information souree on the latest problems, like TAC TRUST and liability insurance. You communicate with both administrative and athletic committees on matters of mutual concern. The job is really managerial or administrative in nature.

At the 1985 TAC Convention a number of permanent special committees were voted into existence and among them was the Road Running Technical Committee (RRTC). This legislative action established the RRTC as the TAC body firmly and unquestionably in control of matters of race course certification,including the establishment of application fees. To my knowledge there has never been a move to make course certification a ermanent committee at the association level.

If there are any so called association certifiers, the designation should be dropped because the RRTC, with full authority to do so, is organized along regional lines of their own choosing.

I have a little trouble with a couple of your statements about costs and the "product". You say that a certification application fee of $ 25.00 is ridiculously low. I have set a fee of $ 10.00 for any race course or calibration course that I process in my four state region. I find that perfectly adequate to cover my operating expenses as a volunteer certifier. It covers mailing, reproduction and telephone costs and filing of records. I suspect you may be confusing certification with measurement. There is no requirement for a TAC official to measure any race course, unless it is a part of TAC validation to examine race management procedures where a National or World Record has allegedly been set. The costs of course measurement are borne by the race management and their sponsors. They must buy their manual, Jones Counters, and pay for gasoline, paint, police escort, etc. required to complete the job, or they can hire an experienced measurer to do the job. It is not a cost that Illinois TAC must bear. And what is the "product" you are giving them? You can refer all certification inquiries to Pete (or to his designated reviewer in Illinois). You could be helpful and maintain a supply of measurers manuals and Jones Counters in your office to be used to speed the learning process but you can easily leave the technical side of review and certification of course applications to the designated reviewers. I do not believe you have a legal basis for extracting an association course certification fee from a race director.

Somehow the RRTC has been portrayed as a feisty, independent bunch of mavericks who will do as they damn well please. That is not true. We are a high-spirited, closely knit, very communicative, efficient and responsive group of men and women dedicated to the enhancement of road racing through accurate measurement and timing techniques.

We are constantly searching for and identifying capable people that we can bring into the RRTC and allow us to spread the workload. I have already relinquished Florida from my region to a certifier I personally trained. I hope someday to have trained certifiers operating in Alabama, South Carolina, and Tennessee, three states in which the association and state boundaries are the same. The result is that the regional certifier will become more closely allied with the association. It may be so routine in the future that the RRTC may not be needed, but for now it is and has a highly technical mission that it should be able to accomplish with cooperation from the local associations.

I strongly support your desire to locate and document the calibration courses in your association. We issue a national certificate to any new calibration course and maintain the certificate at the regional level. All new race course maps must include the cal course identification number. I am constantly searching for old cal courses that still exist. We scan old certified courses on the lists and then try to find the race director or measurer of the race course in hopes of finding the cal course. When I locate one I check it with the calibrated bicycle. If the counts compare favorably to cal courses I know are correct (I keep the tire pressure and temperature information on my calibrations) then I certify it. I have de-certified one calibration course that was not correctly laid and have re-measured several others. If we conduct a regional measurement clinic, we often lay a calibration course as part of the instruction.

Thank you again for your letter.

Sincerely,

Wayne B. Nicoll

xc: Pete Riegel
Paul Christensen
Allan Steinfeld
Alvin Chriss
NRDC

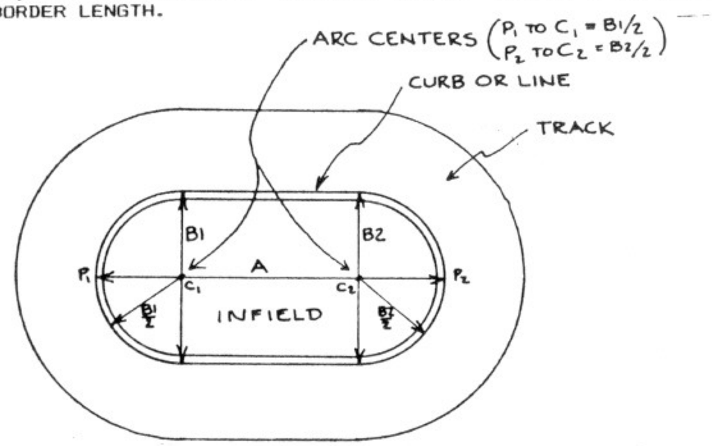
MEASURING A TRACK

If you are ever required to establish the length of a full lap on a track, the following is a suggested way to do it. It works for tracks that are made up of parallel straightaways with circular-arc ends. For any other geometry, use another method. The method assumes that the legal path is 30 cm from the curb or 20 cm from the track side of the boundary line, or inner border.

When you start you may not know the length of the track, and may have to determine whether it is supposed to be a 400 meter or a 440 yard track.

1) Determine the length of the inner border (MEASURED BORDER LENGTH) (curb or line) of the track.

Curbed Tracks - Use a steel tape and measure around the track side of the curb. If the curb is elevated or round, and can't be measured, use the following "Uncurbed Tracks" method to determine MEASURED BORDER LENGTH.



Uncurbed Tracks - See diagram. Measure the width of the infield at each end of the straightaway, close to where the track begins to curve. Be sure the end points of the measurement are on the straightaway on the side of the line toward the track surface. Establish the mid-point of each of these distances on the ground. Then measure the length of the infield from end to end, being sure to stay in line with the two mid-points established earlier, and being sure, again, that the end points of the measurement are on the track side of the line.

For each distance taped, average the measurements obtained and use these averages in the next step. Use the following formula to determine MEASURED BORDER LENGTH:

$$\text{MEASURED BORDER LENGTH} = 2A + 0.570796\ (B1+B2)$$

2) If you taped around a curb you can skip this step. If you used the length-width method, now check that the geometry is correct. Using the ARC CENTER as a center, check to see that the curved portion of the border is a constant distance from the center. If it isn't, this method won't work and you have a troublesome "special case".

3) Decide the TYPE OF TRACK. If the track is normal, the MEASURED BORDER LENGTH should be very close to one of the following NOMINAL BORDER LENGTHS.

TYPE OF TRACK	NOMINAL BORDER LENGTH
Curbed 440 yard track	1313.82 ft
Uncurbed 440 yard track	1315.88 ft
Curbed 400 meter track	398.12 m = 1306.17 ft
Uncurbed 400 meter track	398.74 m = 1308.20 ft

4) Convert your measurement to proper units. If the track is 400 meters, use metric units (meters). If the track is 440 yards, use feet.

5) Once you have decided the TYPE OF TRACK, add the following ADDITION to the MEASURED BORDER LENGTH to obtain the MEASURED LENGTH OF ONE LAP.

TYPE OF TRACK	ADDITION
Curbed track	6.184 ft or 1.885 m
Uncurbed track	4.123 ft or 1.257 m

MEASURED LENGTH OF ONE LAP = MEASURED BORDER LENGTH + ADDITION

Examples

1) Curbed Track - You tape around the curb and obtain the following MEASURED BORDER LENGTH :

1st - 1313.80 ft
2nd - 1313.78 ft   Average = 1313.79 ft

This track is probably supposed to be a 440 yard track, since 1313.79 ft is quite close to 1313.82 ft. The proper ADDITION is 6.18 ft.

MEASURED LENGTH OF ONE LAP = 1313.79 + 6.18 = 1319.97 ft.

(Note that the track measures a bit shy of 440 yards. Don't worry about it. Some tracks do measure out a bit short. Just call it as you get it.)

2) Uncurbed Track - You obtain the following measurements:

B1 - 1st - 239.54 ft		
2nd - 239.56		Average B1 = 239.55 ft
B2 - 1st - 239.51 ft		
2nd - 239.49		Average B2 = 239.50 ft
A - 1st - 516.35 ft		
2nd - 516.39		Average A = 516.37 ft

MEASURED BORDER LENGTH = 2(516.37) + 0.570796(239.55 + 239.50)
= 1306.180 ft

Since 1306.180 ft is quite close to 1306.179, the track is probably a 400 meter track. Converting to metric, 1306.180 ft = 398.124 m.

The proper ADDITION for an uncurbed 400 meter track is 1.257 m.

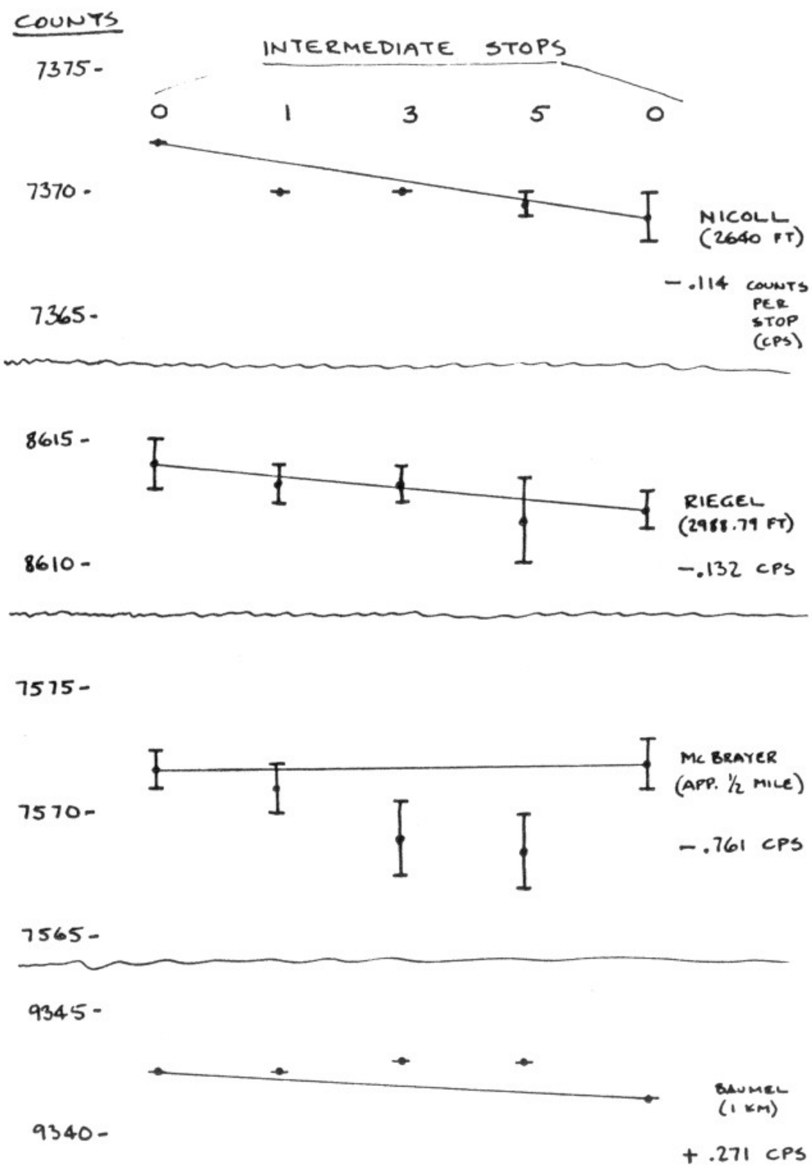
MEASURED LENGTH OF ONE LAP = 398.124 + 1.257 = 399.38 meters.

Whoa! What's wrong? - this is almost a meter short! Then you notice some small holes in the asphalt, indicating that a curb is to be installed over the line. With the curb in place, the track becomes a CURBED track, and the proper ADDITION is 1.885 meters. In this case:

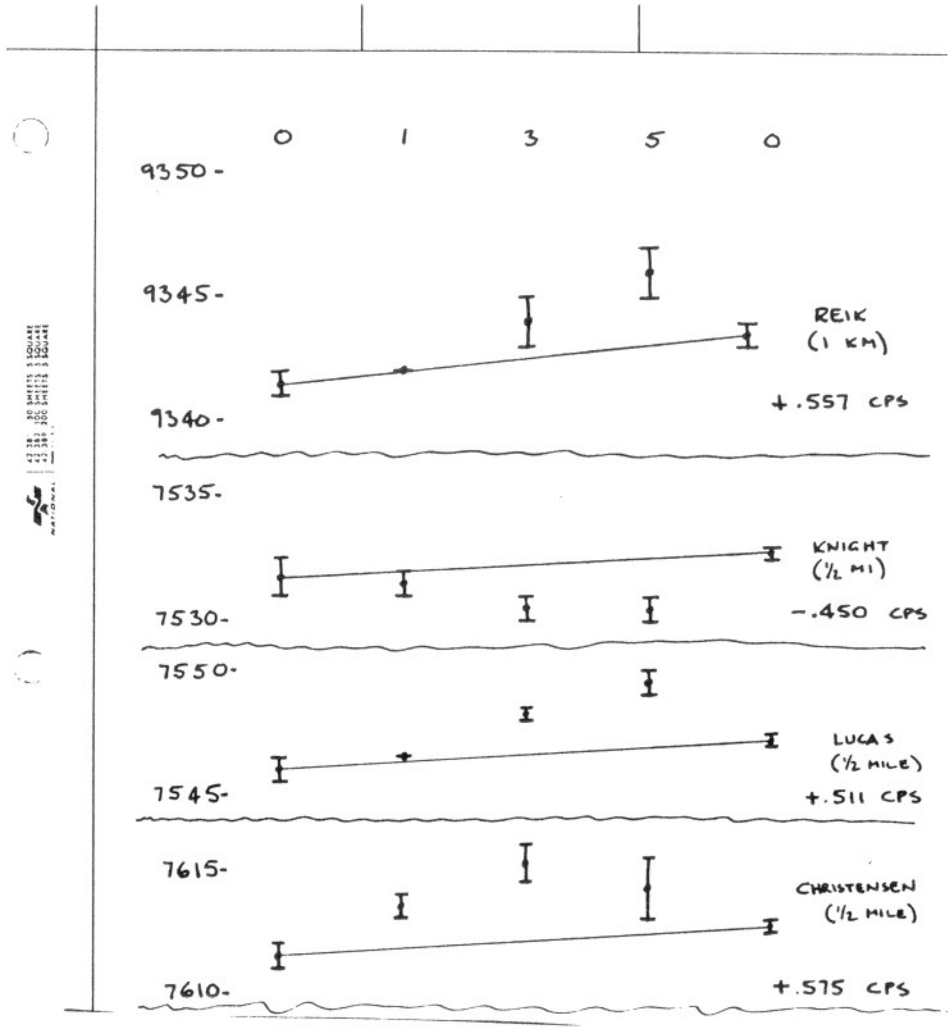
MEASURED LENGTH OF ONE LAP = 398.124 + 1.885 = 400.01 meters. As a curbed track, this track is clearly OK. It would be wise to see that the curb actually conforms to the line when installed.

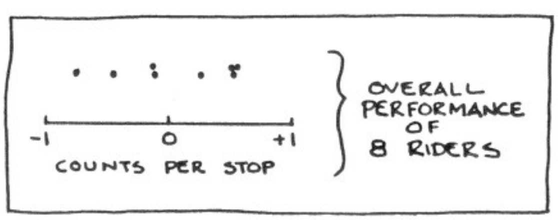
Radius check: You have your helper hold the end of the tape at the ARC CENTER, and you check the arc at several places. The distance is always the same within an inch or so. This indicates that the curve is a true circular arc, and your measurements are OK. Bob Letson reports "The set of radials measured for the Olympic stadium (presumably an expertly engineered curb) varied by about one inch. At best, the determination is approximate, and may have an error of maybe 6 inches/lap."

STARTUP WOBBLE DATA



Eight people responded to the call. See Oct '85 MN. It's not too late! Results will be updated as they come in.





AVERAGE = 0.057 CPS
STD DEV = 0.469 CPS

(see Bob Baumel's writeup. Next page. My method and his are identical.)
Pete

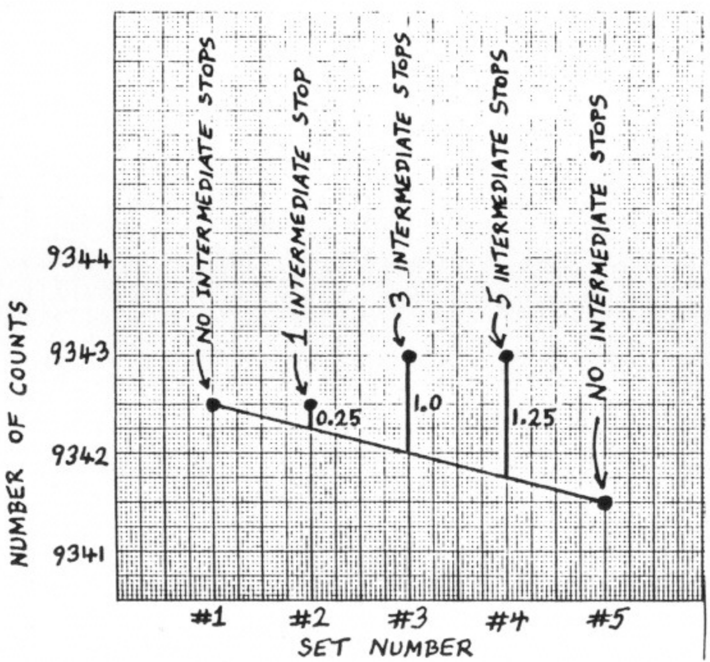
21 Oct 1985

Dear Pete,

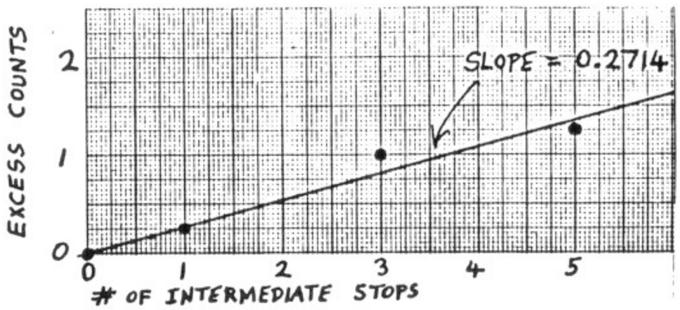
My enclosed data does seem to show a wobble effect, although it is quite small (only about half what I got in my short cal course experiment back in Apr 83) and is also mixed with a temperature effect. Although the effect is small, I did fortunately get very consistent data. My 1st and 2nd rides of each pair always gave the same number of counts (at least to the resolution to which I read the counter).

Since I don't know how you intend to analyze this data, I present my own analysis below. The crucial aspect of the analysis is in removing the temperature effect. There is one other place later on (in fitting a line to some data points) where I make another somewhat arbitrary choice, but that affects the final answer by less than 10%.

In the following graph, the abscissa denotes all my sets of rides in chronological order. The intent here is for the horizontal axis to correspond more or less to a time axis. The vertical axis simply shows the numbers of counts obtained in each set of rides. (Note: if my 1st and 2nd rides of a set had differed, I would have averaged them in order to obtain a single point from each set).



In the above plot, the straight line connecting the points from the 1st and 5th sets provides interpolated values of my "normal" constant (i.e., with no intermediate stops) during the middle 3 sets when I did make intermediate stops. By subtracting the interpolated "normal" constants from the counts actually obtained in those middle 3 sets, I obtain estimates of the excess counts due to the intermediate stop-starts.



The graph above shows these "excess" counts as a function of the number of intermediate stop-starts. Note that when the number of intermediate stops is zero, then the number of excess counts MUST, by definition, be zero. With this in mind, I chose to fit these data points, not by a standard least squares straight line (which would have 2 adjustable parameters, i.e. slope and intercept), but instead with a least squares straight line constrained to pass through the origin (hence only one adjustable parameter, i.e. the slope). The slope of this line is given by:

$$\text{Slope} = \frac{\Sigma xy}{\Sigma x^2} = \frac{9.5 \text{ counts}}{35} = 0.2714 \text{ counts}$$

This slope is interpreted as the excess number of counts due to each additional stop-start. This figure of 0.2714 counts is equivalent to a wobble distance of 2.9 cm (using my constant of about 9342 counts/km). That should be further rounded to 3 cm, considering the resolution of this experiment.

Recall that from my Apr 83 short cal course experiment, I estimated my wobble distance as about 6 cm (a figure later used by Tom Knight when analyzing the results of the NY Marathon validation). Perhaps my starts are smoother now than they were in 1983. But that wouldn't be a fair conclusion. In a letter I wrote on 5 Mar 83 to Ted Corbitt (you probably have a copy in your files), I reported on two still earlier short cal course experiments. One experiment on 8 Nov 80 yielded an estimated wobble distance of 3 cm, while the other on 2 May 82 resulted in an estimated wobble distance of 8 cm.

The correct conclusion is probably that the wobble distance of any one individual can be highly variable. I hope that you get responses from a lot of people, so we can get an idea how much variation there is between different individuals. I wouldn't be surprised if some of the data exhibits a NEGATIVE wobble distance. (I thought I saw such an effect in some of the calibration data from the Olympic marathon measurement, although I'm sure that many more effects were operating in that case in addition to the wobble effect).

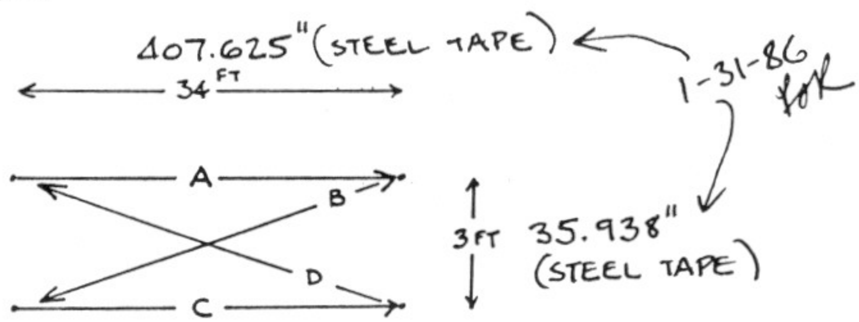
Bob

DO WE MEASURE AS WE CALIBRATE?

In November 1982 I attempted a crude experiment to check this. I obtained the help of 9 other engineers at Battelle (where I work) and we did some measuring on a smooth, level floor paved with 1 foot square tiles. We used a Rolatape MeasureMaster wheel which read in feet and inches, with a wheel circumference of 1 foot. Readings were estimated to the nearest 1/4 inch. A brief summary was reported in the very first MN, with none of these details.

I reasoned that the measurers could measure straighter when they had a line to follow than when they had to estimate a straight path on a diagonal, and I designed the experiment to check this.

The measurements consisted of two of the long side of a 34 x 3 foot rectangle, and two of the diagonal. They were taken as shown in the following diagram:



Measurement Data Obtained - Inches

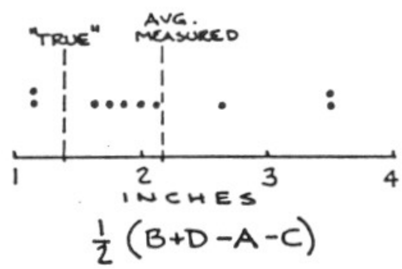
	A	B	C	D	.5(B+D-A-C)
FR	408	409	407.75	409.5	1.375
HW	409	412	408	412	3.5
JH	408.75	410.5	408	410	1.875
DR	407.75	409	407	409	1.625
DH	407.75	409.25	408	410	1.75
FW	407	411.25	407.5	410.25	3.5
RG	407.5	410.25	408	409.5	2.125
WA	407.5	409.5	407.5	409.5	2
TP	408.5	411.75	408.5	410.5	2.625
DE	408.75	409.5	408	410	1.375

avg measurement = 2.175
std dev = .789
std dev of the mean = .249

"true" distance = 1.59

Note that the "true" distance of 1.59 inches (for the diagonal length minus the side length) does not change much even if fairly gross errors exist in the dimensions of the 34 x 3 rectangle. Try some numbers using Pythagoras. You'll see.

Without getting excessively statistical, I will say that the experiment showed that the measurers measured less straight when forced to estimate a straight line between points than when they could follow a line. This should be fairly obvious, if you imagine yourself on a road with equal calibration courses on each side. Do you think you could ride the diagonal as straight as the calibration course itself, which follows the road edge?



What this means, if bikers do the same as measuring-wheelers, is that we usually lay out a course slightly shorter than we intend to. In other words, our 10ks that we lay out at 10010 meters are more likely somewhat shorter - perhaps in the 10005 to 10007 range, and which varies depending on the measurement circumstances. It also means that we tend to overestimate course lengths when we validate.

Have fun with the data!

Pete Riegel 1-30-86

TEMPERATURE CORRECTION FACTORS FOR STEEL TAPING

TAPED LENGTH FEET	TEMPERATURE, DEGREES F 20	30	40	50	60	70	80	90	100
500	-.15	-.12	-.09	-.06	-.03	.01	.04	.07	.1
1000	-.31	-.25	-.18	-.12	-.05	.01	.08	.14	.21
1500	-.46	-.37	-.27	-.17	-.08	.02	.12	.21	.31
2000	-.62	-.49	-.36	-.23	-.1	.03	.15	.28	.41
2500	-.77	-.61	-.45	-.29	-.13	.03	.19	.35	.52
3000	-.93	-.74	-.54	-.35	-.15	.04	.23	.43	.62
3500	-1.08	-.86	-.63	-.41	-.18	.05	.27	.5	.72
4000	-1.24	-.98	-.72	-.46	-.21	.05	.31	.57	.83
4500	-1.39	-1.1	-.81	-.52	-.23	.06	.35	.64	.93
5000	-1.55	-1.23	-.9	-.58	-.26	.06	.39	.71	1.03
5500	-1.7	-1.35	-.99	-.64	-.28	.07	.43	.78	1.14

Example #1 - You have just laid out a tentative half-mile calibration course. On your first measurement you set two points which measured exactly 2640 feet apart. On your second measurement you measured the length at 2639.84 feet. The average measured distance was thus 2639.92 feet.

During the taping the temperature averaged 94F

Using the chart - 94F is closer to 90F than to 100F. 2640 feet is closer to 2500 feet than to 3000 feet. The correction factor is thus .35 feet.

Your actual distance is thus 2639.92 + .35 = 2640.27 feet. It is a bit over 1/2 mile. You should shorten it by 0.27 feet (3 1/4 inches) to obtain an even 1/2 mile.

Example #2 - Layout of a 1000 meter (3280.84 feet) calibration course. Temperature = 23F.

1st (layout) measurement =	3280.84 ft
2nd (check) measurement =	3281.04 ft
Average measurement =	3280.94 ft

Correction factor (for 20 F and 3500 ft) = -1.08

Corrected length = 3280.94 - 1.08 = 3279.86 feet

The course is just short of a kilometer.

For a 1000 meter calibration course, the distance should be increased by 3280.84 - 3279.86 = 0.98 feet = 11 3/4 inches.

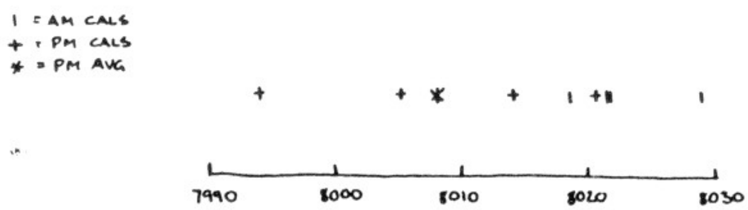
STROH'S 8K - NEW ORLEANS
9-9-85
C.J. MOUTON

COUNTS ON COURSE 78154 / 78172 > 0.023%

1/2 MI CAL COURSE

80° - 10 AM AM CALIBRATION	METERS	93° - 1 PM PM CALIBRATION	METERS
7857	8004.1	7881	7979.7
7854	8007.2	7855	8006.2
7847	8014.3	7870	7990.9
7854	8007.2	7862	7999.0

14 M WAS ADDED TO THE COURSE AFTER LAYOUT



METERS AFTER 14 M FINAL ADJUSTMENT

IN SPITE OF TERRIBLE CALIBRATION RIDES, THE SYSTEM SEEMS TO HAVE WORKED. OF COURSE, THE QUALITY OF THE COURSE RIDE MUST BE SUSPECTED IN VIEW OF THE UNSTEADY CALIBRATION. I BELIEVE IT WAS PROPER TO CERTIFY THIS COURSE (JEANSONNE DID)

A TRUE-LIFE SUBMITTED MEASUREMENT

EFFECT OF SURFACE ROUGHNESS ON THE ACCURACY OF BICYCLE MEASUREMENTS

by Bob Baumel

1986/01/11

Introduction

The calibrated bicycle method is based mainly on one key assumption: That if a bicycle records a certain number of counts when covering a given distance on the calibration course, then it will record the same number of counts for an identical distance on the race course. We have known since the pioneering work of Bob Letson that this principle is violated (albeit in a fairly systematic way) when one surface is paved and the other unpaved (see recent discussion in "Measurement News" #13 and #14). But we would still very much like to assume that bicycles behave consistently on all PAVED surfaces. Unfortunately, I have now observed consistent differences, on the order of 4 counts/km, between two different (but both quite common) paved surfaces. That's enough to make a difference of 4 to 5 meters in a 10 km race course, which can be quite significant (especially in a validation context). These results suggest that we may have been guilty of erecting an elaborate edifice of rules regarding certification and validation of race courses without being fully aware of the limitations of our methods of course measurement.

I first observed a surface-roughness effect in Oct 84 during a measurement in Oklahoma City. I wrote that up in Nov 84 ("Are 'ELIMINATORS' less accurate on Rough Road Surfaces" -- 84/11/03). At that time I was comparing rides on calibration courses in Ponca City and Oklahoma City (several days apart), based on the somewhat dubious assumption that my "Eliminator" non-inflated innertubes would maintain a stable measuring constant over a period of several days. I also made the assumption (which I now know to be false) that any surface-roughness effect I had observed was nothing more than a specific problem of Eliminator brand innertubes.

I have now investigated the subject of surface roughness much more systematically by laying out a second calibration course very near my pre-existing one in Ponca City. Both my old and new calibration courses are shown in the map on page 3. The measurements used for laying out both courses are described in Appendix A. The old course on Hubbard Road is actually TWO parallel courses (one along the southern edge of the road for West-to-East rides, the other along the northern edge for East-to-West rides). My new course is just a single course along the extreme western edge of the (paved) west shoulder of Highway 77. As shown on the map, the riding distance between the east end of the old course and the south end of the new course is only about 702 meters. This proximity makes it easy to do comparative rides of the old and new courses. In fact, this report will present eleven such sets of comparative bicycle data collected by myself and my wife Marcia.

Surface Descriptions for Old and New Calibration Courses

The old calibration course on Hubbard Road (measured Mar 83) has a type of paved surface that is generally quite typical of roads in this area. It has a rough "coarse-grained" surface including numerous pebbles or rock fragments, roughly a centimeter across, that project up out of the surface. This texture is evidently due to the low-cost method by which it is "resurfaced" from time to time; i.e., gravel, and maybe some tar, is spread over the road and allowed to become embedded due to the action of passing vehicles. (One consequence is

that the edges of the road, where my calibration courses are located, actually have rougher surfaces than the central portion of the road which is worn smoother by vehicle action. It would be interesting to do some cal rides closer to the center of the road, but traffic density is high enough that I probably wouldn't survive such an experiment). Aside from its rough texture, the low-quality paving on Hubbard Road has a distinct tendency to develop cracks and potholes. The county usually manages to get these potholes patched within several weeks or months after they appear (I'm lucky that the course is located outside the limits of Ponca City, as the city is even worse than the county in this regard), but these asphalt patches introduce another level of surface irregularity above and beyond the normally rough surface of this road.
As mentioned in my Nov 84 report mentioned previously, the two courses on Hubbard Road are not in equally poor condition; the southern course (for West-to-East rides)is definitely WORSE in terms of cracks and patched segments. This seems to be reflected in our bicycle data which show a rather clear difference between the W-E and E-W rides on Hubbard Road (aside from the still larger overall difference between the Hubbard Rd and Highway 77 courses).

My new calibration course (measured Aug 85) is located on a new stretch of Highway 77 that was just built within the past couple of years. It was evidently built using more effort, and better quality materials, than Hubbard Road or most other roads in this area. It has a finer-grained surface. Most importantly, this surface has been pressed very FLAT. It's the sort of surface that is very pleasant to ride a bicycle on. Unfortunately, this increased riding comfort shows up in the data taken with the Jones counter: Bicycles record fewer counts on the Highway 77 kilometer than on the Hubbard Road kilometer.

Methodology

Appendix B shows all the bicycle counts from each of the 11 occasions when Marcia or I did comparative rides of the two courses. Our standard pattern (natural in view of the geometric arrangement shown on the map) was to do:

1) some "precal" rides on the old course
2) some calibration rides on the new course
3) some "postcal" rides on the old course.

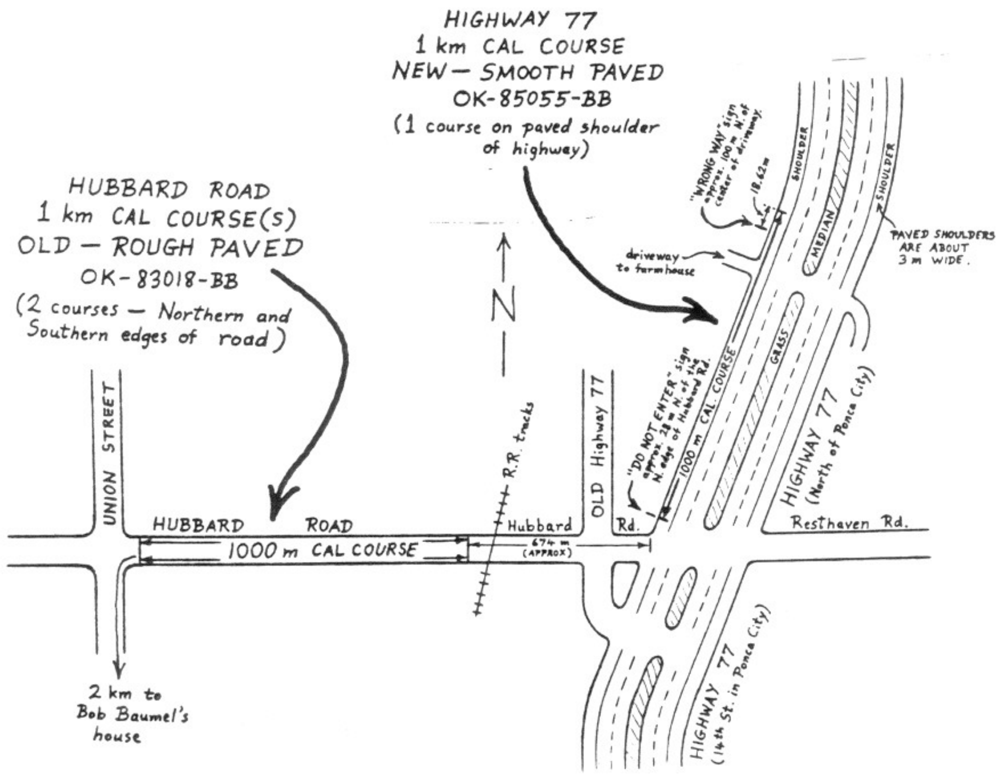
Reference to the map should also explain why on many (although not all) occasions, the "precal" and/or "postcal" on the old course consisted of an odd number of rides. Note that each occasion automatically included at least 2 km of warmup riding before beginning the experiment (i.e., the distance from my house to the west end of the old cal course).

The eight sets of data collected by myself were taken using three different arrangements of tires/tubes, namely:

1) Air tubes at more or less normal pressure. These tires are rated at 690 kPa (kilopascals), or 100 psi for those of you not yet thinking in metric.
2) Air tube (in front wheel) at reduced pressure of 500 kPa.
3) Eliminator airless tube (in front wheel).

My motivation for testing air tubes with reduced pressure was the thought that a softer tire might better be able to "smooth out" the variations in surface roughness. I expected the surface-roughness dependence to be greatest with the Eliminator and least with the reduced-pressure pneumatic. Such an effect did not clearly emerge in the data, as I obtained very similar results with all three tire arrangements. (There is some evidence that use of the air tube with reduced pressure might have decreased the count spread between the W-E and E-W rides on the old course, although not the overall difference between the old course and new course. In any case, I would not recommend using a

OLD & NEW CALIBRATION COURSES — PONCA CITY, OKLA.



pneumatic with lower-than-rated pressure since I think it can cause more erratic temperature behavior of the tire -- as I observed in the Aug 83 measurement of the Tulsa Run, for which a Knight diagram was published in Pete Riegel's Measurement News #7 in Dec 83).

All three of Marcia's data sets were collected with air tubes, although her first set was taken using a badly worn set of tires which she used at a reduced pressure of 515 kPa. (Actually, the wear on those tires was rather strange, as they were barely over a year old. We speculated that the rubber had degraded due to the action of sunlight while the bike was parked at work, as the damage was mainly just on one side). Marcia's other two sets were taken using new tires inflated to more or less normal pressure.

The raw data listed in Appendix B come from three different calibration courses (i.e., the W-E and E-W courses on Hubbard Road, and the new course on Highway 77). The differences in counts obtained on those three courses correspond mainly to genuine differences in bicycle behavior on the three courses, although some small portion was certainly due to slight differences in length among the courses. To remove the effect of differing course length, I have computed "corrected" counts/km (listed in Appendix C and displayed graphically in Appendix D) based on the actual EDM-measured lengths of all three courses. As noted in Appendix A, the old Hubbard Road course was EDM-measured in Apr 83, but was checked again on Aug 10, 1985 -- the same day as the new Highway 77 course was laid out by EDM. The Apr 83 and Aug 85 EDM measurements of the old course were in excellent agreement, but for computing corrected counts/km, I chose to use the EDM measurements of all three courses performed on 85/08/10. Actually, the total spread in length among all 3 courses is only 3.7 cm, corresponding to about one-third of a Jones count. (Note that in a normal measurement, I wouldn't worry about these minute differences, but would just treat any of the courses as an exact kilometer).

Another feature of my data analysis in Appendices C and D is that I've separated out the W-E and E-W rides on the old course. There are three reasons for this:

1) The W-E and E-W courses on Hubbard Road are not exactly the same length (the W-E course is 3.1 cm longer according to the 85/08/10 EDM measurements), so I needed to compute corrected counts/km separately for the W-E and E-W rides.
2) Consistent differences were observed between riding the W-E and E-W courses on Hubbard Road.
3) In many of these data sets the "precal" and/or "postcal" on the old course consisted of an odd number of rides, so a straight average of all precal rides (or all postcal rides) would be unfairly weighted toward either the W-E (or E-W) course.

I have not similarly separated out the S-N and N-S rides on the new course since I have not seen any consistent difference between those two directions. It is nevertheless interesting that in the raw data shown in Appendix B, fairly definite differences between S-N and N-S rides on the new course can be seen in the data from certain riders on certain days. These differences are generally related to the wind direction on the particular day.

My graphical display in Appendix D is designed to help identify effects of changing temperature during the experiment, and to (at least approximately) permit you to visually remove that effect. I did this by drawing a vertical (or diagonal) line connecting the W-E precal and W-E postcal on the old course, and a similar line connecting the E-W precal and E-W postcal on the old course. I could not draw any such lines for data set #1 which was a rather limited set (with no E-W precal rides and no W-E postcal rides). And I could draw only one such line for set #4 which had no W-E postcal rides.

Discussion of Data

Now let's turn to the actual bicycle data. The following discussion is probably most easily followed by referring to the graphical displays in Appendix D, while occasionally turning to the raw data listing in Appendix B for certain items that aren't shown on the graphs.

The overall difference between riding the new and old calibration courses is best seen in data sets #1, #3, #5, #9, #10 and #11. I've included set #1 in this list even though it is less complete than the other sets. Set #1 was obtained on the afternoon of 85/08/10 after having just laid out the new cal course that morning, and includes only four isolated calibration rides spread out over a 1.75 hour period. (Most of those 1.75 hours were spent collecting other data that I would use in drawing my map of the new cal course to put on its certificate).

Marcia's three data sets (#2, #4 and #6) do not show quite as clean a pattern as my own data. One problem with all three of Marcia's sets is that, in an effort to avoid riding during the hottest part of the day (in Oklahoma in August), she did all her rides in the morning -- at times when the temperature was rapidly INCREASING. The effect of increasing temperature is quite clear in the graphs of Appendix D where my diagonal lines (connecting the precal and postcal on the old course) slope downward to the left in all three of Marcia's sets (#2, #4 and #6). By the way, the graph for set #3 (one of my own sets using an Eliminator) looks as though the temperature was decreasing, but this was not the case. The temperature was actually quite steady in set #3. Furthermore, Pete Riegel and I have both found the behavior of Eliminators to be almost totally uncorrelated with temperature changes. Actually, the increasing riding constant (from precal on the old course to postcal on the old course) seen in set #3 is just the usual tendency of Eliminators to squash down during a measurement.

Returning to Marcia's data, we note that in her first attempt at data collection (set #2), there was a relatively large spread among her four rides on the new cal course (actually the largest spread observed in any of the 11 data sets in this report). I think that the problem here was Marcia's unfamiliarity with the new cal course, as this was her first attempt at riding it. Although Marcia had participated in the EDM measurements of 85/08/10, she didn't share my own intimate familiarity with the new course (as she hadn't been present when I did my initial scouting rides and decided where to locate the new course). She admitted after collecting set #2 that she wasn't sure exactly where on the highway shoulder she should have been riding. Note (Appendix B) that the last of Marcia's four rides on the new course in set #2 was also the one giving the lowest count. It could be that she wasn't properly riding the course in the first three of those rides. Note also that the difference between this 4th ride on the new course and Marcia's rides on the old course (set #2) was similar to the differences between the new and old courses in my own data.

In Marcia's 2nd attempt (set #4), she was hampered by a very strong wind from the East-Southeast. Consequently, she grew tired, and quit after her first E-W postcal ride (before doing any W-E postcal rides which would have forced her to face that wind again). In spite of several deficiencies in set #4 (i.e., wind effect, temperature increase, and incomplete data), this set seems to show about the same difference between the old and new cal courses as my own data.

For Marcia's 3rd and final attempt (set #6 on 85/08/24), a new problem arose. The new cal course, which had been chosen because of its nice smooth surface, was no longer so nice and smooth. Numerous big clumps of mud had appeared all over the new course. Examination of tire tracks revealed what had probably happened: It seems that some drunk Okie in a pickup truck had been doing slalom rides between the highway shoulder and the off-road unpaved surface during a rainstorm the previous night! Due to the resulting crud all over the new course, the new course was now not so different from the old course. Marcia's data in set #6 indicates less difference between the old and new courses, although there was a very big difference between her W-E and E-W rides on the old course. It would be interesting to know what the wind was doing on the morning of 85/08/24, but I have no record of that information.

I tried collecting some data myself on 85/08/24 (the day that the crud appeared on the new cal course). One difference between my rides and Marcia's is that while the clods of mud had been quite fresh when Marcia rode that morning, they were more dried and caked due to the sun (therefore harder) when I rode in late afternoon. My observed difference between the old and new cal courses (set #7) was only about half what I had seen when the new course had been clear I tried again a week later (set #8 on 85/09/01). The clods of caked mud were then smaller, but still present. And the difference in my bicycle counts between the old and new courses was greater than a week earlier, but still less than when the new course had been free of all this crud. After that, I didn't collect any more data until 85/10/12 (set #9), at which time the crud was gone, and my data again seemed similar to what it had been before the crud appeared.

Further Analyses

The data displayed in Appendix D seem to indicate a consistent pattern of calibrations roughly 4 counts/km lower on the new (smooth) course than on the old (rough) course. This difference seems to be nearly the same with all three tested arrangements of tires/tubes (i.e. Eliminators, pneumatics at normal pressure, and pneumatics at reduced pressure).

The data also show a difference between W-E and E-W rides on the old course in a very consistent direction (always more counts in the W-E rides), although the actual magnitude of this effect is more variable, ranging from 0 to 3 counts/km. This magnitude varies from one occasion to the next, and also seems to be somewhat smaller when using pneumatic tires at reduced pressure.

The difference between the W-E and E-W rides is probably due to the poorer state of repair of the southern edge of Hubbard Road relative to its northern edge as mentioned earlier. Another conceivable explanation for systematic differences between riding the two directions of a cal course is elevation difference between its endpoints. In fact, the East end of the Hubbard Road course is about 4.7 m higher than its West end (see Appendix A). But I don't think this explains the observed bicycle data. I noted in my Nov 84 report that the Pennsylvania Avenue cal course in Oklahoma City has a big enough average grade (about 1%) that I thought maybe I could see it in my bicycle data. But the lesser grade of the Hubbard Road course in Ponca City (less than 0.5%) was probably too little to affect the data. Furthermore, I have found that in my riding, I tend to get fewer counts for a given distance when heading uphill than downhill. This is in exactly the WRONG direction to explain the observed difference between W-E and E-W rides on the Hubbard Road course!

The variability of the W-E vs. E-W difference on Hubbard Road is probably due to wind variation. This is another subject discussed in my Nov 84 write-up, although I have now become much more aware that the effect of wind differs for different riders. I personally tend to get fewer counts riding into a headwind than with a tailwind (just as I get fewer counts riding uphill than downhill). For example, in data set #8, the wind was from the South, and I got fewer counts riding N-S than S-N on the new course (see Appendix B). It seems, however, that wind has exactly the opposite effect on Marcia's riding. For example, in data set #4, the wind had a component from the South, but Marcia got MORE counts riding N-S than S-N on the new course. Actually, judging by cases of wind effect I've encountered in certification applications I've reviewed, I suspect that Marcia's pattern is more common than my own pattern.

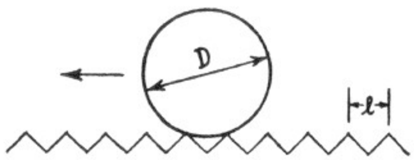
There are definite indications that lowering the tire pressure decreased the W-E vs. E-W difference on the Hubbard Road course. This difference was very small when Marcia used her worn tires at low pressure (set #2), and was virtually non-existent in my first trial with reduced pressure (set #5), although it was larger in my 2nd such trial (set #10). The difference between sets #5 and #10 was probably the wind, which I suspect was in such directions that my W-E vs. E-W calibration difference was reduced in set #5 while being amplified in set #10. In set #5 (afternoon of 85/08/18) the wind was much calmer than it had been that morning when Marcia collected set #4, but there was probably still SOME remnant of that strong East wind that Marcia had to fight. In set #10, there was probably some breeze from the West (which I didn't write down at the time, but did include in my field notes for set #11 a few hours later). These considerations suggest that in the complete absence of wind, my W-E vs. E-W calibration difference on the Hubbard Road course when using reduced tire pressure would be intermediate between the values observed in sets #5 and #10 (which is less than I generally observed using either Eliminators or pneumatics at full pressure).

If it is true that lowering the tire pressure reduced the difference between W-E and E-W rides on my old cal course, this suggests that using a softer tire might reduce the effect of relatively large-scale surface irregularities (such as patched potholes). On the other hand, the very consistent overall difference between my new and old cal courses, as observed with all tire arrangements, suggests that smaller-scale surface irregularities (such as embedded pieces of gravel projecting out of the pavement) have just about as much effect on soft tires as on hard tires.

The consistent overall difference of about 4 counts/km between riding my old and new cal courses is probably due to the differences in surface texture mentioned previously, although other explanations are possible. It would certainly be very embarrassing, after all I've written, if it turns out that I made some mistake in laying out the new cal course so that it's actually 40-50 cm shorter than intended. But that seems unlikely.

Another possible explanation that occurred to me recently concerns the effect of road camber. The two courses on Hubbard Road run along its edges where the road has some sideways tilt to permit water drain-off. Even though the new Highway 77 course is in a shoulder at the edge of a highway, it is really very flat. I made a few rough measurements of lateral tilt on 85/12/24, and the results were interesting: As expected, the new Highway 77 course turned out to have very little sideways tilt (generally less than 1 degree). But on the old course, I was surprised to find considerably more tilt (about 3-4 degrees) along its southern edge than along its northern edge (about 1 degree). Thus, these measurements seemed to correlate not only with the overall calibration difference between the new and old cal courses, but also with observed difference between W-E and E-W rides on the old course! These statements must be qualified by noting that the number of tilt measurements I made on 85/12/24 (a cold day with considerable wind chill) was really quite small -- probably not enough to be representative of the course. In any case, it should be understood that no matter which mechanism was responsible for our calibration differences between the new and old cal courses (i.e., surface roughness, or lateral tilt, or some combination), these calibration differences represent a significant source of error in the calibrated bicycle method.

In Dec 83, Pete Riegel did some geometric calculations to approximate the behavior of wheels rolling on both rough surfaces and surfaces with lateral tilt. For both calculations, he assumed the wheel shape to be a perfectly rigid torus. The rough surface he considered was an idealized "corrugated" surface as shown below:



On both surfaces, he determined that the wheel would undergo more revolutions than while rolling the same distance on a smooth flat surface. He derived the following formulas, which I have slightly modified to show fractional increase in the number of wheel revolutions (and I've also added lowest-order approximate versions of each formula):

Wheel rolling on Corrugated surface (corrugations of spacing ℓ)

$$\text{fractional increase} = \frac{D}{\ell}\sin^{-1}\left(\frac{\ell}{D}\right) - 1 \approx \frac{1}{6}\left(\frac{\ell}{D}\right)^2 \qquad (1)$$

[$\sin^{-1}$ in radians]

Wheel rolling on surface with Lateral Tilt (of angle ϕ)

$$\text{fractional increase} = \frac{d}{D}(1-\cos\phi) \approx \frac{\phi^2 d}{2D} \approx 0.0001523\,\frac{\phi^2 d}{D} \qquad (2)$$

[ϕ in radians] [ϕ in degrees]

In both formulas, D is the wheel diameter. In the second formula, d is the diameter of the tire cross-section.

Let's plug some numbers into the above formulas: I'll assume an effective wheel diameter (D) of 680 mm (equivalent to a riding constant of 9362 counts/km), and a tire cross-section diameter (d) of 28 mm. For riding on a surface with corrugations spaced 3 cm (or 30 mm) apart, equation (1) predicts a fractional increase of about 0.000325 which, for our assumed flat surface riding constant of 9362 counts/km, implies an increase of about 3 counts/km on the corrugated surface. Note that this is of similar magnitude to the actual observed difference between rides on my old and new cal courses. As for lateral tilt, equation (2) predicts that for tilt angles of 1, 3 and 4 degrees, the increases in riding constant would be about 0.06 counts/km, 0.5 counts/km and 0.9 counts/km respectively. These results suggest that the effect of lateral tilt is far too small to account for any significant portion of the difference between rides on the new course and the E-W rides on the old course. But it may be able to explain at least part of the observed difference between W-E and E-W rides on the old course.

How much faith can we put in the above calculations, recalling that they are based on the very unrealistic assumption that the bike wheel is rigid? (In reality the wheel contacts the ground, not at a mathematical point, but over an extended generally oval-shaped region). I have some comments on each calculation:

Lateral Tilt calculation: This one might not be too far off. Even though I have not been able to supply a correct treatment that fully accounts for wheel deformation, my instinctive feeling is that such a treatment would result in numbers similar to those from Pete's formula. If true, this would be rather comforting, as it would imply that bicycles may be capable of reasonably accurate measurements around curves (since in principle, riding a curved path on a flat surface ought to be more or less equivalent to riding a straight path on a surface that tilts sideways). Note that the ability of bicycles to measure accurately around curves has never really been tested.

Corrugated surface calculation: This one is more shaky. For one thing, the corrugation spacing of 3 cm that I plugged into Pete's formula is just a number that I pulled out of a hat and bears little relation to the surface of Hubbard Road. The derivation of equation (1) makes two assumptions that are both certainly wrong: First, that the wheel contacts the ground ONLY at certain points projecting out of the surface and nowhere between (which would certainly be violated if the projecting points are more than a few centimeters apart, especially if they project only a couple of millimeters above the surrounding road surface). And secondly, that the tire deforms no more than normally in the vicinity of the projecting points (in spite of the large forces concentrated at those points). In spite of these limitations, Pete's formula does at least lend some plausibility to the idea that the observed riding differences on my old and new cal courses could be due to surface roughness.

In connection with these geometric analyses, I am unable to resist commenting on a statement by Al Phillips published in Measurement News #14. Referring to a proposed explanation for the gravel/pavement calibration difference, Al wrote, "It would really need a physicist's attention to be absolutely sure but I think the figures are in the ballpark." I found this statement amusing since I actually AM a physicist. Yet, although the subject has intrigued me for quite a few years, I still haven't succeeded in meaningfully calculating the kinematics and dynamics of a rolling bicycle wheel (based on a realistic model including wheel deformation).

Implications

I have presented my results as the difference between riding two different calibration courses. In practice, of course, one surface could be a calibration course while the other is a race course to be measured. This situation is surely quite common. I suspect that most measurers go to some length to locate their cal course on a nice smooth road. At the same time, in an effort to avoid traffic, race courses are often located on secondary roads or park roads, which tend to have rough surfaces. In this situation (smooth cal course and rough race course) the effect on course layout will be for the course to come out shorter than intended (perhaps by 4 or 5 meters for a 10 km course), even if the measurer is highly skilled.

Naturally, the consequences are most serious in validation measurements, where a great deal can depend on whether the course is found to be longer or shorter than the advertised race distance. If the validator calibrates on a smooth surface when checking a race course on a rough surface, this gives the course an advantage, as the measurement will overestimate its true length. But this is reversed when the race course is smooth and the cal course is rough; in that case a race course which is really adequately long can be found short by the validation.

We can at least take some comfort in my finding that the surface-roughness effect seemed to be about the same for all tested tire arrangements. This seems to imply that as long as the Validator calibrates on the SAME cal course as was used by the original measurer, then assuming both to be skilled riders, their measurements should be in close agreement (even if both are WRONG)! Of course, validators DON'T always use the same cal course as was used for the original course layout. And even if they do, the situation is inherently unsettling since we would like to believe that our measurements represent an objective reality rather than an artifact of a particular measuring technique. If we are measuring something objective, then it should be possible to check it by a totally different measuring technique (such as careful survey measurements by surveyors who thoroughly understand our SPR concept).

Another observation that is perhaps a little comforting is that, on the whole, no individual source of error in the calibrated bicycle technique has been found to be much bigger than about half the 0.1% short course prevention factor (the one main exception being poor riding, which can contribute errors MUCH bigger than 0.1%). On the other hand, a number of individual sources HAVE been found to contribute errors on the order of 0.05% (which means that several such errors in combination could well add up to more than 0.1%). In Jan 84, I proposed the "larger constant" method of course layout because I realized that, due to variations in temperature patterns and the timing of precal--measurement--postcal, the traditional calculation of the Day's Constant as the Average of precal and postcal will often lead to errors on the order of 0.05%. (Note that the larger constant method doesn't make the measurement any more accurate, but simply provides more confidence that the laid-out course won't be found SHORT).
Now, as described in the present report, I have found that variations in bicycle behavior on different common paved surfaces can also produce errors on the order of 0.05%. There are, of course, many other sources of error in the bicycle technique including: errors in taping a calibration course (sometimes 0.02% or more), random variations in riding (often around 0.01% to 0.05% even among good riders), temperature differences other than those due to weather changes (for example, the race course might be on shaded park roads while the cal course is out in the hot sun; or one surface might be a darker color than the other causing it to be hotter in sunny conditions), effects of wind and hills (I've often seen large differences for cyclists riding the two directions of a cal course. Depending on race course geometry, its measurement might be, for example, predominantly downhill or with the wind).

It is easy to be lulled into a false sense of security by examples in which several skilled riders get highly consistent results in a course measurement. But in most such cases, the measurements are far from independent. Usually, they were all done at the same time in the same weather conditions, and they all used the same calibration course. Even the choices of path to measure may not have been independent if the riders were in sight of each other. We must be careful not to assume that an entire procedure is very accurate just because we find that some portion of it can be done with high precision, when other aspects of the procedure are still based on untested assumptions.

Returning to my two calibration courses in Ponca City, I should note that, since laying it out in Aug 85, I have never used the new Highway 77 cal course for measuring a race course. All I've actually used it for were the experiments described here and an experiment on start-up wobble requested by Pete Riegel (see note accompanying set #10 in Appendix B. I used the new cal course for Riegel's experiment since I knew that I would get more consistent data that way). But when I've actually had to measure a race course, I used my old Hubbard Road cal course, since I knew that if I used the new cal course, I would end up making the race course about 0.04% or 0.05% shorter. And all the race courses that I'm likely to measure in this area have surfaces similar to that of the old cal course rather than the new cal course.

Acknowledgment

Various people helped collect the data presented in this report. John Sinton taped the Hubbard Road calibration course with me in Mar 83 and also participated in its EDM measurement in Apr 83. Rick Nopper operated the EDM instrument in both the Apr 83 and Aug 85 measurements. And my wife Marcia participated in the Aug 85 EDM measurements and also collected three of the sets of bicycle data shown in the Appendices.

Bob Baumel
86/01/12

3354 Kirkham Road
Columbus, OH 43221
January 22, 1985

Bob Baumel - 129 Warwick Road - Ponca City, OK 74601

Dear Bob,

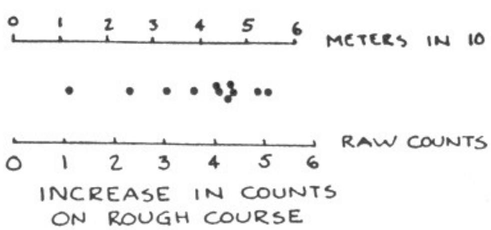
Got your experimental results on the effect of surface roughness yesterday, and I must say it's a nice job - that is to say, your usual product.

The only problem I have with it is that it is <u>way too long</u> for me to put the whole thing in MN. I thought of how to cut it down to two, or even four, pages, but was unable to come up with anything satisfactory. The nuggets of wit and wisdom seem to be uniformly distributed throughout it. So <u>I'll put the whole thing in MN</u>, with the exception of Appendices B through D. These I will replace with the following table and graph:

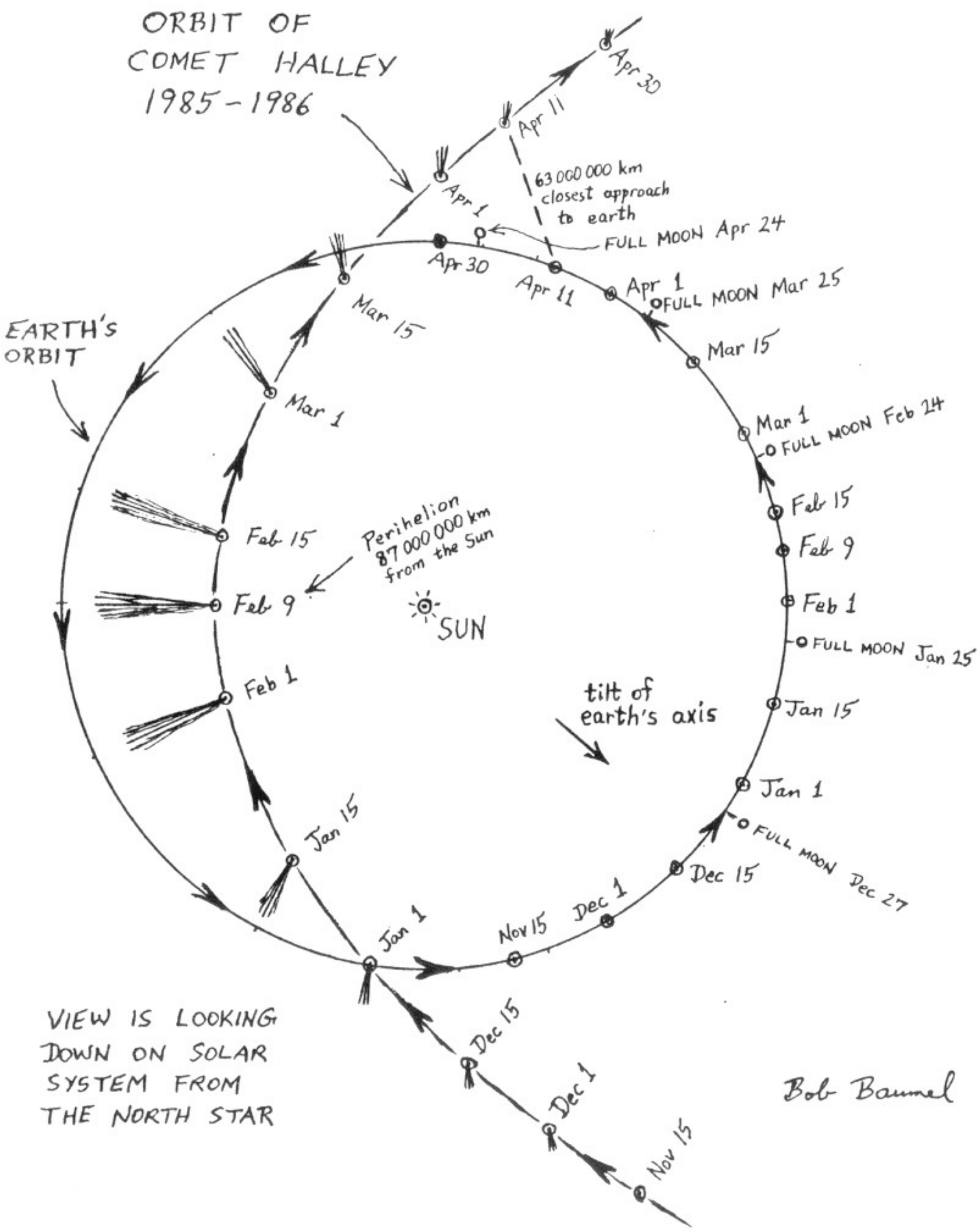
	Average Counts/kilometer					
	Old Rough Course		New			
Run	W to E	E to W	Course	Diff	Test Condition	Date
1	9345.4	9343.24	9339.25	5.07	normal pressure	85/08/10
2	9283.535	9283.19	9282.25	1.1125	low pressure	85/08/17
3	9458.025	9456.065	9452.62	4.425	Eliminator tube	85/08/17
4	9369.65	9365.94	9363.38	4.415	normal pressure	85/08/18
5	9360.525	9360.44	9356.12	4.3625	low pressure	85/08/18
6	9357.9	9354.565	9352.62	3.6125	clods-new course	85/08/24
7	9337.55	9335.915	9334.44	2.2925	" " "	85/08/24
8	9327.9	9326.69	9324.25	3.045	clods almost gone	85/09/01
9	9342.9	9340.815	9337.75	4.1075	normal pressure	85/10/12
10	9364.15	9362.69	9359.38	4.04	low pressure	85/10/20
11	9463.275	9460.94	9457.25	4.8575	Eliminator tube	85/10/20

Average = 3.7582 counts/km (4.01 m in 10 km)
Std Dev = 1.1853 counts/km (1.27 m in 10 km)

Avg "normal" = 4.53 counts/km
Avg "low pressure" = 3.17 "
Avg "Eliminator" = 4.64 "
Avg "clods" = 2.98 "



Pete


ORBIT OF COMET HALLEY 1985 – 1986
EARTH'S ORBIT
Apr 30
Apr 11
Apr 1
63 000 000 km closest approach to earth
FULL MOON Apr 24
Apr 30
Apr 11
Apr 1
FULL MOON Mar 25
Mar 15
Mar 1
FULL MOON Feb 24
Feb 15
Feb 9
Feb 1
FULL MOON Jan 25
Jan 15
Jan 1
FULL MOON Dec 27
Dec 15
Dec 1
Nov 15
Mar 15
Mar 1
Feb 15
Feb 9
Feb 1
Jan 15
Jan 1
Dec 15
Dec 1
Nov 15
Perihelion 87 000 000 km from the Sun
SUN
tilt of earth's axis
VIEW IS LOOKING DOWN ON SOLAR SYSTEM FROM THE NORTH STAR
Bob Baumel

THE ATHLETICS CONGRESS
TAC USA
RRTC
ROAD RUNNING TECHNICAL COMMITTEE
CERTIFIED ROAD COURSE #TX85001KL

THE ATHLETICS CONGRESS
TAC USA
RRTC
ROAD RUNNING TECHNICAL COMMITTEE
CERTIFIED ROAD COURSE #TX85001KL

LOGOS FROM KEVIN LUCAS.
WRITE TO HIM FOR
CLEAN COPY

RRTC
ROAD RUNNING TECHNICAL COMMITTEE
CERTIFIED ROAD COURSE #TX85001KL

THE ATHLETICS CONGRESS
TAC USA
RRTC
ROAD RUNNING TECHNICAL COMMITTEE
CERTIFIED ROAD COURSE #TX85001KL

TAC USA
RRTC
ROAD RUNNING TECHNICAL COMMITTEE
CERTIFIED ROAD COURSE #TX85001KL