A New Method Of Pacing

(BASED ON NON-FUNDED RESEARCH)

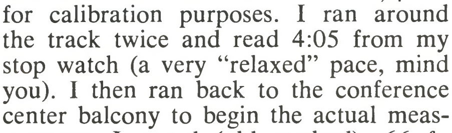
BY Dr. BEN BUCKNER From the ACSM Bulletin, May, 1981.

Pacing has been used by surveyors for centuries to measure distance. Generally, we think of pacing as counting one's steps or strides between two points and converting this count to familiar units through some prior calibration of the number of such units per pace.

At the Surveyors' Teachers Conference held in June 1980 in Colorado, there were several contests held to estimate distances to various terrain objects. One of these was the distance to the big "A", painted on the side of a hill approximately 3 mi. away. Most of the surveying teachers stood on the balcony of the conference building and did a lot of eye-balling and other judgment methods to arrive at the distance. Nobody apparently thought of pacing the distance. Well, maybe it entered someone's mind, but he probably quickly reconsidered due to the distance and drudgery involved with the "old" concept of pacing.

My method of measuring the distance, using the "new" concept of pacing is described herein. On the morning the contest was announced, I had noted the rectangular pattern of the street system during a morning run. This run served as a general reconnaissance of a pacing route to that hillside. Maps certainly could have been used for this, and even for scaling the distance, but they weren't readily available. I figured there was surely an east-west and north-south set of component streets which would arrive at the base of hill "A" and proceeded the next morning (at 5:30 a.m.) to pace the distance.

First, I ran the 2 mi. from the dormitory to the university track. This served to get the instrument "warmed up". I had to assume that the track was ¼ mi. for calibration purposes. I ran around the track twice and read 4:05 from my stop watch (a very "relaxed" pace, mind you). I then ran back to the conference center balcony to begin the actual measurement. I paced (old method), 66 ft. west of the balcony to have a suitable starting point, then ran south, then west, then south again, etc., each time using the stop watch to measure the time interval for each component. This involved a point-to-point zig-zag traverse, each component being a departure or latitude, with time being the direct measurement unit. But, the desired terminal point was not the base of the hill but the center of the big "A" on the hillside. So, I had to arrive at a method to estimate a short distance over steep and rugged terrain. Any large error in this would spoil any accuracy I had in my pacing. It would be foolish to climb the hill. Running it was next to impossible. So, I stood at the base, extended my arm and noted how many fingers covered the base of



Principle of Jacob's Staff.

the "A", using the principle of the Jacob's staff described in Kiely's book on **Surveying Instruments.** I then began to "close" my traverse by running back east. When I arrived at the first change in direction, almost directly east of the "A", I again noted how many fingers it took to cover the base of the "A" with arm extended. These data were used later to estimate the last, inaccessible leg of the traverse.

Returning to the starting point via the same route, I again used the stop watch and recorded each component time in my "field book". The forward and return traverse leg times (minutes and seconds) are as follows:

	Forward		Return	
	South	West	North	East
	1:15	4:39	0:46	3:45
	3:04	17:14	2:14	16:11
	2:18	4:06	3:05	4:38
	0:42		1:16	
Sums	7:19	25:59	7:21	24:34

The values are in measurement order as shown by the arrows. Very close agreement (indicating precision in the method) is seen. For example, the 1:15 and 1:16 agree, 3:04 and 3:05 agree, etc. In fact, the north-south components show a very good closure and small discrepancies in individual duplicate measurements. Large discrepancies in the east-west components occurred in two places. The 17:14 and 16:11 should have agreed. Likewise, the 4:06 and 3:45 were over the same lines. But, a 10 mph wind and an approximate 3 percent grade over part of these lines accounts for the difference. Being an experienced distance runner and having quantified these effects on pacing in the past provided means to adjust or apply systematic corrections to these values.

After returning to the start point, the pace was recalibrated on the track, with a time of 4:08 being observed for ½ mile. This recalibration is good surveying practice and, in this instance, was advisable in order to consider several possible effects on the instrument due to the altitude, jet lag, and the resulting associated fatigue. For lower accuracy, and at a location closer to home, I may have neglected this precision in calibration since I run about 9 mi. a day and have developed a feeling for pace through almost constant monitoring over known distances. Also, being akin to Superman, I do not usually get tired over such short distances, so recalibration would not

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affairs of the Eskimo people. He presented a paper detailing their appearance, origin and life-style in the 1894 Annual Report.

Having been appointed Surveyor and Engineer for the City of Hamilton in 1888, he served his adopted city well in the years that followed. He finally established a practice with James J. MacKay, O.L.S. The partnership became a noted one, specializing in municipal surveys. This practice was eventually carried on under the name of MacKay & MacKay.

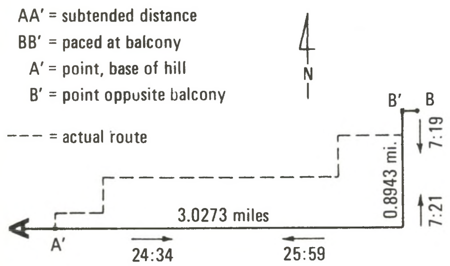
Amidst his professional activities, he found time to serve as alderman and controller between 1914-18.

Many years of Mr. Tyrrell's active life were spent in meridian surveys, base line surveys and township subdivision in north-western Canada. For the Ontario government, Mr. Tyrrell spent the year 1912 exploring the Nelson, Hayes and Severn Rivers, and 1934-37 traversing much of the shoreline of the Bruce Peninsula and the shoreline of Edmund's Township on Lake Erie.

Mr. Tyrrell died at the age of 81 in Hamilton in 1945. •

ordinarily have been essential, except for the desire for better accuracy to win the contest (competitive urge).

After considering various "best values" for actual probable pace for each component considering hills, wind, fatigue, and other round-off factors, the following departure and latitude values were computed, as shown in the sketch, each distance being computed using the pace divided into the time for each leg.



For example, the 0.8943 mi. was computed using 7:20 for time and 8.2 minutes/mile pace by the Pythagorean theorem A'B' = 3.1566 mi. Using the east-west leg measuring 3:45 and 4:06 times and the subtended finger data and similar triangles, a distance of 0.40 mi. was estimated for AA'. Assuming no significant difference between this and a hypotenuse of the triangle and, likewise, neglecting slope and assuming that AA' was also along the desired line AB, the total sum came to 3.157 + 0.40 + 0.0125 = 3.5695 mi. The distance, converted to chains, is 285.56, the units requested by the contest sponsor. But, this is to the base of the "A" and it was assumed that the desired distance was to the center of the "A", so a final estimate of 287 chains was made using a judgment as to its probable size, and considering significant figures. The "true" value used by the contest sponsor was 286 chains and so I won, estimating only one chain high. Later, it was learned that he had only scaled it from a map anyway and did not know whether that was to the center or to the base of the "A". I may even have been closer to the true value.

An estimate was also made of the distance uncertainty. Considering possible high and low variations in the pacing of various components, propagating these according to random error theory, with an error estimate of the subtended portion added using the same theory, an estimate of +— 3 chains was made, or 1 part in 100 — not too precise, but probably better than the "old" pacing method over distances greater than a few hundred feet and better than estimation as winning the contest attests to.

One prerequisite to using the specific method described — throw away the cigarettes, run every day, and skip those heavy lunches. With this method, **you** are the instrument.

After presenting this new pacing method to the group, it was rumored that I may be called in as consultant to calibrate EDM or simply be used in lieu of. What the heck, I run every day anyway, so I'll sell the services cheap. The method may be considered by some as in the same category as Prof. Milton Schmidt's legendary "contour hound," but it is actually sound in theory and application. Read on, please.

Readers who have plodded this far through this article may have been lulled into thinking that it was written only for amusement, but if you know the author, he cannot resist making a plug for education and professionalism when the opportunity exists. Throwing all modesty aside, it must be considered that the above measurement, from its selection through its final result and error estimate, required both education and practical experience in surveying.

First of all, simply considering methods other than estimation is a mark of an educated surveyor. Then, realizing that untested methods might work, being willing to try the unproven, and simply selecting a feasible method for a particular job comes from the broad and open mind that education helps develop (ingenuity, if you want to call it that). Background in several aspects of surveying were involved in this problem, most coming from textbook or theoretical study and some from practice. The necessity of calibration is overlooked by many people involved in measurement. It wasn't neglected here. Error sources such as instrumental, natural, and personal were all considered, including the wind, hills, slope, fatigue, and calibration itself. Professional judgment was used in applying corrections for systematic errors, but the initial recognition of the need to apply such adjustments came from the knowledge that they **do** exist in any measurement, coupled with the recognition of the need to study the data to look for such errors.

Without a study of surveying history, the principle of the Jacob's staff, a medieval instrument, may not have been used. Certainly, trigonometry and basic traverse theory were used. Recognizing that any measurement can be made indirectly, rather than always directly between points, comes from use of such methods in practice. A knowledge of land systems was used in the initial selection of the method. Had this been Boston instead of Ft. Collins, the land system would not have yielded the cardinal directions necessary for the traverse legs, since it was recognized that Colorado is on the public lands system. Public lands knowledge was used in another way. After observing that various values for pace yielded between 1.98 and 2.09 mi. for the lone E-W length, it was realized that the line must be across two public land survey sections and 2.03 average seemed to be a good value, even without considering error theory and pacing variations, since such sections are usually slightly long rather than short or nominal. A "preponderance of evidence" was being accumulated to add confidence in the method.

It might also be pointed out that the decision to neglect slope and the difference between hypotenuses and long legs at AA' and BB' was not made until their possible effects were checked. While showering after the run, for example, the slope effect was estimated by mental calculation using a percent slope estimated from how the grade "felt" while running it and the formula $v^2/2\ell$ as recalled from memory. Similar quick checks on significance of many measurement errors can, of course, be made in practice if one remembers the sources and the formulas. Knowing what to investigate and how to do so expeditiously is part of the "art" of surveying.

Actually, this type of pacing is not really new. It is used in principle in EDM, distance being measured indirectly by speed of light. It was used even in ancient times. In fact, the first accurate estimate of the earth's circumference involved calculations using a base line measured by the known speed of a camel caravan! Again, recognition of such historical facts can lead to better surveying today. How else can such knowledge be gained through reading and education?

The above success at an insignificant game, for which only a T-shirt was the prize (it says "I'm on the Level"), can be realized in practice where it counts, applying theoretical and practical knowledge and background gained through a combination of practical experience and formal education. Used in the solution was background in basic surveying math, surveying measurement theory, land systems, and confidence and willingness to attempt new methods, all of which are ingredients of professional-level work. Most important was a demonstration of expertise in the art and science of measurement — that area of professional practice which forms the only reason for existence of surveying. Surveying can become fun, both as a game and a practice, when you understand and enjoy the art and science of measurement.

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