INLAND WATERS BRANCH

DEPARTMENT OF THE ENVIRONMENT

A Short Note on the Speed Calibration of the Geodyne Model 920 Current Meter

H.S. WEILER

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The Geodyne Division of EG&G International manufactures the Model 920 Tape Recording Current Meter. With the meter, it supplies a standard speed-calibration table. Comparison of this table with direct calibrations shows that the standard table produces large errors in the measurements, especially at low speed. Analysis of these errors leads to the conclusion that the standard table should not be used; rather, a table formed from fitting least-square curves to direct calibration data would give much greater accuracy in speed measurements.

Résumé

La Division Geodyne du EG&G International, construit le Modèle 920 du moulinet à bande enregistreuse. Avec le moulinet, la Division fournit aussi une table standard de vitesses (calibrage). Une comparaison entre cette table et les mesures de calibrage direct montre que la première est entachée d'importantes erreurs, en particulier lorsque l'on a affaire à de faibles vitesses. L'analyse de ces erreurs conduit à conclure que la table standard ne devrait plus être utilisée; par contre, une table établie par superposition des courbes de moindres carrés aux données du calibrage direct donnerait une plus grande précision dans les mesures de vitesse.

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INTRODUCTION

The Geodyne Division of EG&G International, manufacturer of the Model 920 Tape Recording Current Meter, provides tables of standard calibrations for temperature, current speed, time (in hours), and conductivity, as a function of octal number. However, use of the speed calibration table supplied by Geodyne Division can lead to some serious errors in measurement. This note considers these errors, and their effect on the measurements.

CALIBRATION DATA

The Savonius rotor speed sensor used in the EG&G Model 920 Current Meter has received a fairly extensive series of direct calibrations (Hankins, 1963; Fofonoff and Ercan, 1967; UNESCO, 1970). These results are consistent enough so that the (static) calibration curve can be considered well known for practical purposes, with the studies of Fofonoff and Ercan providing the most extensive set of direct calibration data.

FITTING OF LEAST-SQUARE POLYNOMIALS TO THE FOFONOFF-ERCAN (F-E) CALIBRATION RESULTS

The EG&G Model 920 Current Meter records speed by counting pulses from the pickup coil used to determine the rate of rotation of the Savonius rotor. The rotor has 16 small magnets attached evenly to the rotor, so that 16 pulses per revolution of the rotor are generated. The gate time for the pulse counter is 4.375 seconds, giving a calibration factor of 16 x 4.375 = 70 pulses for a speed of one revolution per second. Since the total number of pulses counted during the gate time is recorded on the magnetic tape in the current meter, all results are converted to "pulses per gate time", N, e.g., 1 r.p.s. = 70 pulses.

For studies in the Great Lakes, and smaller lakes, the speed range from 0 to 100 cm/sec is adequate to measure all but a small percentage of current speeds. This range only was considered in comparing the calibration data of Fofonoff and Ercan (here regarded as standard and henceforth called F-E) and the calibration table supplied by Geodyne Division, as well as the results of Hankins. Since the speed range from 0 to 10 cm/sec is of primary importance in lake currents (encompassing about two thirds of all the speeds measured), the F-E calibration data were used directly from Tables I and II of the F-E Report and a least-square curve fitted to the actual calibration points, with the speed U cm/sec being considered a function of N, the number of pulses recorded in 4.375 seconds. At zero angular speed, the speed was set to 0.0 cm/sec, and all points from the F-E tables which had speeds less than 1.5 cm/sec were omitted as being too unreliable.

This procedure was then used to obtain similar least-square calibration curves for the ranges 7 to 48 and 48 to 110 cm/sec, corresponding to N ranges of 0 to 10, 10 to 84, and 84 to 200 pulses per gate time. These ranges correspond to the range used by Fofonoff and Ercan to calculate the coefficients in their calibration equations [12] and [13] (Fofonoff and Ercan, 1967).

For the lowest speed range, the best fit was obtained with a fourth-degree polynomial curve, of U as a function of N. Higher degrees did not improve the fit. The standard deviation was 0.18 cm/sec for the fourth degree and higher, and for the first to the third degrees, 0.28, 0.25, and 0.21 cm/sec respectively. The coefficients C in the equation

$$U = C_1 + C_2N + C_3N^2 + C_4N^3 + C_5N^4 \qquad (1)$$

were as follows, for the range 0 to 7 cm/sec (N = 0 to 10)

$C_1 = 3.3182.10^{-2}$

$C_2 = 1.6798$

$C_3 = -3.2943.10^{-1}$

$C_4 = 3.8378.10^{-2}$

$C_5 = -1.5490.10^{-3}$

The results of this fit are shown in Figure 1 (with the F-E calibration points shown as dots) and the coefficients for all orders shown in Table 1. Table 1 shows also the standard deviation of the speed from the least-square curve (1), as well as the maximum deviation (max. dev.) from the least-square curve.

The other two ranges, as well as a combined range (7 to 100 cm/sec), were treated in similar fashion, with least-square polynomials being fitted up to the fifth order. The results of these least-square fits are shown in Figure 2, and the various coefficients are outlined in Table 1 (up to the 5th order). From the data, the following is apparent:

(1) No improvement in fit for any of the curves occurred beyond the fourth order.

(2) For the range 7 - 48 cm/sec, the standard deviation decreases very little as the order of the least-square polynomial; a linear calibration curve (σ = 0.4 cm/sec) would be acceptable. Maximum deviation from the least-square curve here was 0.9 cm/sec at 44 cm/sec.

(3) For the range 48 - 100 cm/sec, a third-order curve gave a better fit than a first-order (linear) curve (σ = 0.72 cm/sec vs 0.79 cm/sec); this could be considered useful in minimizing errors from computations; however, the decrease in error is of marginal significance.

TABLE 1

Values of Coefficients (C) of Least-Square Curves
Fitted to F-E Calibration Data

$$U = C_1 + C_2N + C_3N^2 + C_4N^3 + C_5N^4 + C_6N^5$$

U = speed in cm/sec

N = pulses per gate time (4.375 sec)

Order	σ*	C_1	C_2	C_3	C_4	C_5	C_6
				Range: 0 - 7 cm/sec			
1	0.28	1.131	0.5754				
2	0.25	0.787	0.7652	-1.815(-2)			
3	0.21	0.320	1.202	-1.198(-1)	6.410(-3)		
4	0.18	3.318(-2)†	1.679	-3.294(-1)	3.838(-2)	-1.549(-3)	
5	0.18	-1.767(-2)	1.895	-4.978(-1)	8.585(-2)	-7.023(-3)	2.195(-4)
				Range: 7 - 48 cm/sec			
1	0.39	1.334	0.5559				
2	0.36	1.134	0.5838	-3.052(-4)			
3	0.35	0.884	0.6203	-1.432(-3)	9.092(-6)		
4	0.35	0.995	0.5974	-2.324(-4)	-1.299(-5)	1.308(-7)	
5	0.34	1.347	0.5042	6.923(-3)	-2.331(-4)	3.026(-6)	-1.360(-8)
				Range: 48 - 100 cm/sec			
1	0.79	4.197	0.5213				
2	0.74	-2.481	0.6215	-3.640(-4)			
3	0.72	1.667	0.1766	2.980(-3)	-8.153(-6)		
4	0.72	4.096	-0.5813	1.167(-2)	-5.154(-5)	7.972(-8)	
5	0.72	-4.005	2.5882	-3.714(-2)	3.185(-4)	-1.301(-6)	2.032(-9)

* - Standard deviation in cm/sec.

† - Throughout Table 1, figures in parenthesis denote that the value of the coefficient C is to be multiplied by 10 to the power of the figure indicated, e.g., C_1 (range 0 - 7 cm/sec, fourth order) = 3.318(-2) = 3.318×10^{-2}.

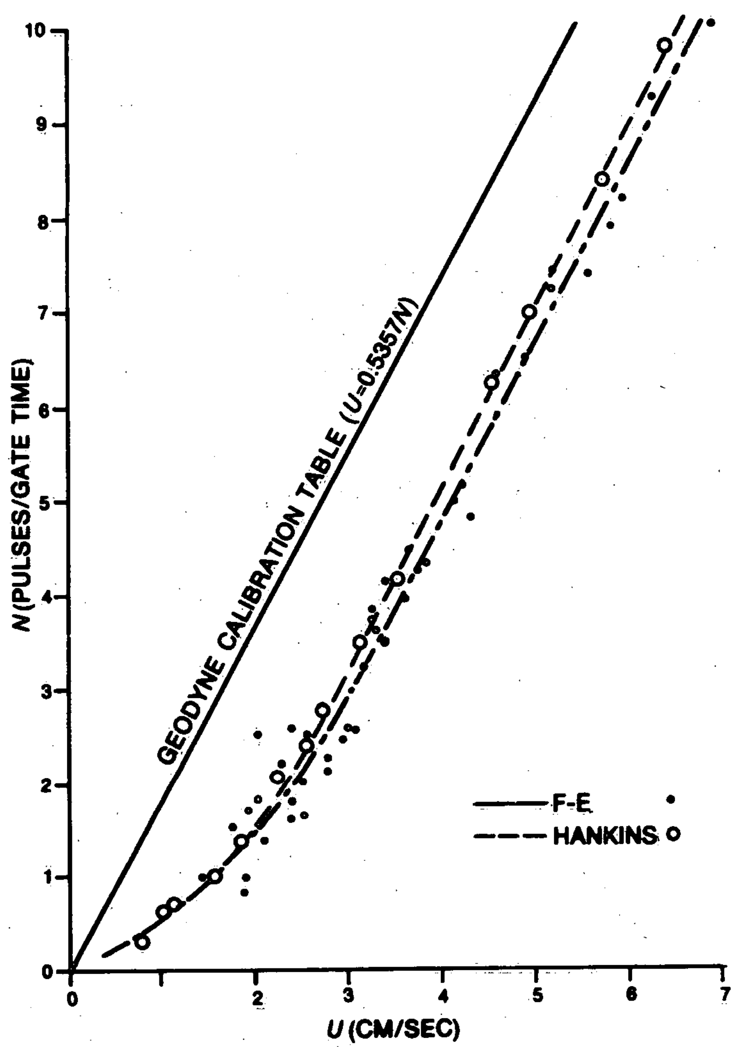

Figure 1. Speed calibration curves in the range 0 - 7 cm/sec.

(4) For the full range 7 - 100 cm/sec, the standard deviation falls between the standard deviations for the ranges 7 - 48 and 48 - 100 cm/sec, as should be expected. The best fit occurs at the fourth order (σ = 0.58 cm/sec). However, the standard deviation as a percentage of speed was more favourable at the lower end of the range if, rather than use the combined range, the whole range were split into the two ranges 7 - 48 and 48 - 100 cm/sec, i.e., 0.38 in 7.0 or 5.4%, as against 0.58 in 7.0, or 8.3%. The deviation of the actual calibration points from the least-square curve at the lower end of the range 7 - 100 was also somewhat less if the range were split into two instead of left as one. This meant that it would be more advantageous to approximate the F-E calibration results with two first-order curves in the ranges 7 - 48 and 48 - 100 cm/sec, rather than have a single curve for the full range 7 - 100 cm/sec.

COMPARISON OF THE F-E CALIBRATION DATA WITH THE STANDARD GEODYNE CALIBRATION TABLE AND HANKINS CALIBRATION DATA

Having fitted the least-square polynomials to the F-E data, the results of these were compared with the calibration table supplied by Geodyne Division for the Model 920 Current Meter. The fourth-degree polynomials in the range 0 - 7 cm/sec, the first-degree polynomials in the range 7 - 48 cm/sec, and the first-degree polynomials in the range 48 - 100 cm/sec were selected for comparison. The results, expressed as differences between the Geodyne and F-E calibrations, as well as percentages of the mean speed, are shown in Figure 3. (The three curves are presented in Figure 1 for the range 0 - 7 cm/sec to show detail in the lowest speed range).

Figure 3 shows that use of the standard Geodyne speed calibration table can lead to large errors, especially in the low speed range of the instrument. In the range 0 - 10 cm/sec, the speed from the Geodyne calibration is too low by 1.3 to 1.6 cm/sec or, expressed in percentages of the F-E calibrations, too low by 62% to 16%, a wide range indeed in this important speed area.

The difference between the Geodyne and F-E calibrations increases steadily up to 3 cm/sec in the speed range from 10 to 48 cm/sec, a result that visual inspection of Figure 36 in the report by Fofonoff and Ercan (1967) would lead one to expect. The percent error steadily decreases, however, from 16 to 6 percent in this range. Above 48 cm/sec, the F-E calibration has a slightly different slope (as can be seen from the first-order coefficients in Table I), and the F-E calibration curve slowly approaches the standard Geodyne curve. The absolute speed difference decreases also from 3 cm/sec to about 1.3 cm/sec at 108 cm/sec, with a percentage decrease from 6 to 1 percent in the same range.

Use of higher-order curves in the second and third ranges (7 - 48, 48 - 100 cm/sec), instead of first-order polynomials, did not change the results significantly; in the worst case (range 7 - 48 cm/sec), the difference between Geodyne and F-E calibration results increased.

A similar comparison of the F-E and Hankins calibration results showed that the difference between the two was not significant (4 - 5% maximum); the two can be considered similar within the estimated accuracies of the measurements.

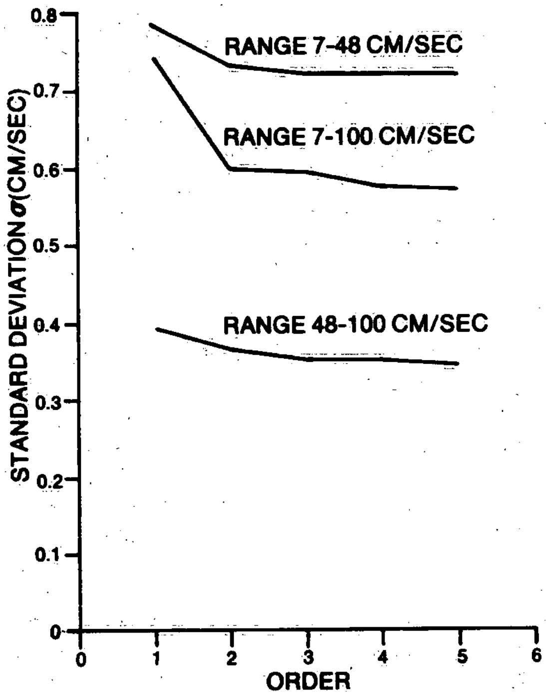

Figure 2. Standard deviation of least-square curve vs. order of curve.

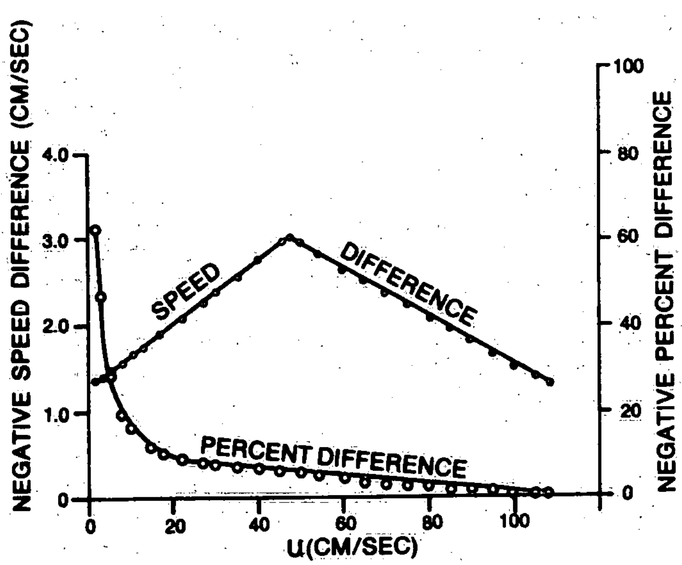

Figure 3. Difference between the Geodyne and F-E speed calibrations.

CONCLUSIONS

The above results showed that use of the standard speed-calibration table leads to quite serious errors in speed measurements, especially at low speeds. The error varies from a high of 62% at the starting speed of 1.8 cm/sec, to 2% at 100 cm/sec. In absolute terms, the Geodyne speed table is too low by 1.3 cm/sec to a maximum of 3 cm/sec in the range 1.8 to 48 cm/sec (decreasing thereafter).

In the light of these results, use of the standard Geodyne speed calibration table is not recommended. The use of the three-piece calibration curve in the ranges 0 - 7, 7 - 48, and 48 - 100 cm/sec, is recommended, using fourth, first and first order curves to calculate the speed calibration table of U vs N.

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