AN INVESTIGATION OF THE VALIDITY OF CERTAIN PRACTICES IN STOP WATCH TIMING

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THESIS

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AN INVESTIGATION OF THE VALIDITY OF CERTAIN PRACTICES IN STOP WATCH TIMING

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CHAPTER I

INTRODUCTION

<u>Importance of Precision in Stop Watch Timing</u>

Stop watches are used by officials in many modern sports, especially those involving speed. In sports like wrestling and boxing, precision is not a factor of utmost importance, while in others, swimming and track for example, precision is a matter of primary concern. It is frequently necessary to run preliminary "heats" in both track and swimming meets. Frequently it is necessary to time the first several contestants in each heat in order to determine who is to swim or run in the finals of the event. In addition to the importance of precise timing in the heats, occasionally official records are involved.

It has been realized for many years that the accuracy of stop watch timing is limited by a number of factors. It is also recognized that electric or mechanical timing devices reduce the errors in timing speed events. A number of such devices have been developed but as yet they are impractical for use in the average high school or college situation. As a result, even though it is fully realized that stop watch timing is inaccurate, stop watches are usually used in timing athletic events such as swimming races, certain track events, rope climbing, ice skating, skiing, etc.

It is customary for several timers equipped with stop watches accurate to a tenth of a second to mark the times of the contestants. The method of determining official times from the times marked by the timers is an important factor. Certain practices are required by the rules adopted

by the National Collegiate Athletic Association and the National Amateur Athletic Union for various speed events. A typical example is taken from the 1948 A.A.U. Official Track and Field Handbook. The rule is as follows:

RULE VII
Timekeepers

1. There shall be three official timekeepers who shall time every event. In case two of their watches agree, and the third disagrees, the time marked by the two shall be official time. If all watches disagree, the time marked by the watch giving the middle time shall be the official time. Time shall be taken from the flash of the pistol.

2. Should alternate timekeepers be provided, they shall perform like duties, but the time recorded by their watches shall only be accepted in the event of one or more of the watches held by the official timekeepers failing to mark the time, in which case they shall be called upon in such order as may be previously decided upon, so that on all races, where possible, three watches shall record the time.

3. If only two of the three watches record the time of an event, and they fail to agree, the longest time of the two shall be accepted as official time.

The N.C.A.A. and A.A.U. rules require that stop watch times marked by timers in swimming and track events be handled in exactly the same manner as specified in the rule quoted above.

Purpose of the Investigation

The validity of the above practice as well as other similar practices of handling stop watch time is questionable. The purpose of this investigation is to compare the validity of several of these practices. The officials of each of the sports are interested in using the most valid methods of determining

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[1] The Official Track and Field Handbook. (New York: The Amateur Athletic Union of the United States, 1948), Pp. 158-9.

official times from the marked stop watch times. The need for such a study seems obvious in view of the fact that the popularity of track and swimming events at all levels is increasing. The most valid techniques in marking times and the most valid methods of handling the times marked should be employed.

Survey of the Literature

Several articles have appeared in the literature in regard to the inaccuracies of stop watch timing. E. K. Rumberger[2] reported the results of an experiment conducted to show the extent of these errors. In his experiment, the data were gathered in a laboratory situation. Timers marked the times between two successive appearances of a red signal flash. "True" times were recorded on a kymograph and compared with the stop watch times for each trial. The average errors of individuals ranged from 0.051 to 0.261 seconds. Individual errors as great as 1.01 seconds were reported. It was not stated whether or not the times recorded by the stop watches were faster or slower than true times. This study substantiates the claims that stop watch times are quite inaccurate. The particular experiment is of only limited value in so far as this study is concerned since the situation was unlike an actual track situation.

In 1932, C. H. Fetter[3] published an article in the *Bell Telephone Quarterly* in which the errors of stop watch timing are briefly discussed. He describes the construction and uses of a photographic-electric timing

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[2] E. K. Rumberger, "The Accuracy of Timing with a Stop Watch," *Journal of Experimental Psychology*, 10:60-61, February, 1927.

[3] C. H. Fetter, "A New Way of Splitting Seconds," *Bell Telephone Quarterly*, 11:293-300, October, 1932.

device developed in the Bell Telephone Company laboratories for timing track events. The times recorded by this device and the official Olympic times recorded on a number of events in the 1932 Olympic games are quoted for comparative purposes. The deviations between official and camera times recorded by this piece of apparatus ranged from - 0.1 to 0.08 seconds. In the six cases cited, the official times were longer than camera times in four cases and shorter in only two. The device, though apparently very accurate, is impractical for use in the average high school or college.

In 1933, T. K. Cureton and D. E. Coe[4] reported the findings of a series of experiments on the nature and magnitude of errors involved in timing a sprint race. The method used in collecting the data was quite similar to actual track conditions. Actual race situations were reproduced with groups of three timers marking the times of runners over 30 and 100 yard distances. The times of each timer were compared with the true time as recorded by an electrical timing device. A total of 64 timers were reported to have had an average error of - 0.302 seconds with a range of errors from - 0.01 to - 1.07 seconds. In every case, the times recorded by the stop watches were faster than true times.

In the discussion, the authors considered the following as sources of error: Extent of flash of the starting pistol, timers reacting to sound rather than to the flash of the pistol, timers reacting to smoke rather than the flash, varying resistances of stop watch starting mechanisms, position of the watch in the hand of the timer, mechanical errors within the individual watches, acuity of vision of the timers, the

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[4]T. K. Cureton and D. E. Coe, "An Analysis of the Errors in Stop Watch Timing," <u>Research Quarterly</u>, 4:94-109, May 1933.

reaction times of the various timers, timers reacting to minimal queues of movements of other timers or sounds of other watches, experience of the timers, and the tendency of most timers to acticipate the finish. It was concluded that the greatest error was due to reaction delay in starting the watches. This, combined with the fact that most timers tend to anticipate the finish, was thought to account in great part for the results reported.

In a recent report, Franklin Henry[5] discusses the possibility that current practices of estimating true times from stop watch times are invalid. In his study, he reports the results of an experiment involving the handling of stop watch times. The primary objective of the study was to determine the loss of precision by discarding discrepant data. The experimenter timed 10-second intervals with a stop watch using the movements of the sweep second hand of an electric clock as a stimulus. Henry was not directly interested in the sources of the errors but rather in the validity of various methods of handling the data.

A total of 150 serial times were recorded, the true time in each case being 10 seconds. The mean time of the 150 trials was 9.99 seconds and the standard deviation 0.162. After grouping the data in pairs, triplets, and quintuplets, he handled them in a variety of ways. When the middlemost score for each triplet was taken as official time he found the standard deviation to be 0.112 as compared with a standard deviation of 0.084 when the average of all three times was taken. The average of the two most discrepant times in each triplet had a standard deviation of 0.087

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[5] Franklin Henry, "The Loss of Precision from Discarding Discrepant Data," Research Quarterly, 21:145-152, May, 1950.

which is much smaller than the average of the two closest times, which gives a standard deviation of 0.131. He found that when the average of all five times in each quintuplet was computed the standard deviation was lowest of any other method, 0.064. From these reported standard deviations it can be concluded that under the conditions of his experiment the most valid method of computing true time from three stop watch times is to take the average of all three. When five times are available, the most valid method is to take the average of all five. Rejecting discrepant data led to increased error, which is in agreement with statistical theory.

It cannot be concluded from this study, however, that the same results would have been obtained if the times had been marked by several different timers under typical track conditions. As was shown by Cureton and Coe,[6] there may be a constant error involved when times are recorded under actual conditions. It is possible that such an error, if it exists, would have an effect on the results of a similar study. In the laboratory situation used in the study reported by Henry, many of the errors discussed by Cureton and Coe were not involved.

The literature to date seems to indicate that stop watch timing is inaccurate to varying degrees depending upon the situations. There is reason to question the validity of the practices required by the A.A.U. and the N.C.A.A. rules for handling stop watch times. To the best knowledge of the writer, no one has made a statistical study of the validity of methods of handling times marked by several stop watch timers under typical track or swimming conditions.

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[6] Cureton and Coe, <u>loc. cit.</u>

<u>Organization of the Remainder of Thesis</u> The methods of collecting and treating the data are described in Chapter II. Chapter III contains the results of the statistical treatment of the data. These results are discussed in Chapter IV. The summary, conclusions, and recommendations are found in Chapter V, the final chapter.

CHAPTER II

METHODS OF PROCEDURE

<u>Method of Collecting Data</u>

An actual race situation was reproduced for purposes of collecting the data for this study. An outdoor, 50 yard straightaway lane was marked off. A chalk line marked the starting line and starting blocks were placed in position behind it. An official finish line was constructed. Each runner was started with a gun and was timed by five timers and an electric timing device. The times marked by each of the five stop watches and the true time as recorded by the electric timer were recorded for each trial.

The timing device[1] used in this experiment was designed and constructed by Robert Clark, a graduate Electrical Engineering student at Michigan State College. It consisted of a starting switch operated by the muzzle blast of the starting gun, an electric chronometer which was started by the action of the starting switch, and a photo-electric cell unit at the finish line that stopped the chronometer when the beam was broken. The chronometer was calibrated to a hundredth of a second and was powered by a synchronous motor. The starting switch was highly sensitive and operated by the muzzle blast of the starting gun. It was located approximately ten feet from the starting line. The starting gun used was an open muzzled, .22 calibre, eight-shot revolver. When the runner was ready, the starter called out "Guns up". This acted as a

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[1] For a diagram of the timing device used, see Appendix "A".

preparatory command for both the timers and the runner. A few seconds after the command, the starter fired the gun in such a way that the flash was visible to each of the timers and at the same time the blast would operate the switch. At 50 yards, on most occasions it was possible to see the flash of the gun.

The runners were cautioned to avoid "jumping the gun". In the event that a runner did jump the gun, the entire trial was discarded. They were also told that it was not necessary for them to run "all-out" on each trial but were requested to run at a relatively fast and even pace for the last 15 yards of the race. To prevent breaking the photo-electric cell beam prematurely, at the finish each runner carried his arms over his head or behind him. The runners consisted of students enrolled in service courses at Michigan State College and other volunteer groups. The runners ran one at a time.

At the finish line, official standards for holding finish line yarn were erected. The yarn was drawn taut between the standards approximately four feet above the chalk marked finish line. As was previously stated, the photo-electric cell unit was located at the finish line. It was placed so that the beam was direcly over the chalk line and approximately one foot beneath the yarn. The chronometer and the rest of the electrical apparatus with the exception of the starting switch were also located near the finish line.

About fifteen feet from the finish line and parallel to it on one side was placed a three step judges stand. On the opposite side, about the same distance from the finish line, a natural slope served the same purpose as the stand. Three timers took positions on the stand and two took positions on the slope. The timers chosen had had considerable experience in timing physical events. The same five timers were used throughout the entire experiment and were issued the same watch for each session. Meylan watches calibrated to one tenth of a second were used. Each timer was in such a position that both the starting gun and the finish line were clearly visible. Timers were instructed to start their watches at the flash of the gun, or, in the event that they failed to see the flash, at the first sight of smoke. They were instructed to stop their watches when any part of the runner's body crossed the finish line. In each case, this was the torso of the runner. Timers were requested to refrain from looking at their stop watch times and were told that in no case were they to attempt to compensate for their errors in the event they discovered they were making errors. Each was considered competent, honest, and conscientious.

For each of the trials, the writer acted as recorder, reading and recording the times marked by the five stop watches and the electric chronometer. These data were recorded on prepared work sheets. When any of the watches failed to mark the time, the trial was discarded. The interval between trials varied depending upon the time necessary to record the times, reset the electric timer, reload the gun, runners to get set, yarn to be restrung, etc. All of the data recorded were gathered in three sessions of approximately one and one half hours each. The student who designed and built the timing device operated it at each session.

<u>Possible Sources of Errors</u>

In addition to the possible sources of errors discussed by Cureton and Coe,[2] certain errors may have been present in the timing device. Since the chronometer was

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[2]Cureton and Coe, <u>loc. cit.</u>

operated by a synchronous motor, changes in frequency in the power source would cause errors. The power company supplying electrical power to the fieldhouse at Michigan State College where the experiment was conducted assured the writer that there were no fluctuations in frequency during the hours when the experiment was in progress. The Electrical Engineering Department estimated the maximum error of the electrical apparatus (relays, etc.) as considerably less than 1/60th of a second. A possible source of error was the starting switch. The starting gun was held approximately one foot from the switch. The average .22 calibre blank cartridge contains .24 grams of powder. The Smithsonian Physical Tables quote the rate of travel of explosive waves in air for a charge of powder this size to be 1102 ft./sec. This being the case, the flash would be seen and the switch operated simultaneously for all practical purposes. Although it is possible that a larger calibre gun would have produced a flash more easily seen, the .22 was not replaced since a gun of this calibre is used in most high school and college meets. In the report by Cureton and Coe,[3] it was stated that a personal correspondence from Kirby indicated that the flash and first smoke of a pistol shot appeared within 1/250th of a second of each other. This was determined through experiments involving motion pictures of a gun being fired.

At the finish line, the photo-electric cell unit beam was approximately one foot below the yarn and directly over the chalk line. It is possible that a runner could have a body lean great enough that a part of his torso would cross the finish line before the beam was broken. To produce a difference of two inches, a body lean of 10° with the ground

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[3]Cureton and Coe, loc. cit.

would be necessary. It was estimated that no runner was leaning more than 10° when the finish line was crossed. The average runner was traveling at a speed of approximately 225 inches per second. At this speed, a difference of two inches would be equivalent to less than 1/100th of a second.

The portion of the beam that had to be broken in order to stop the chronometer varied depending in part upon the intensity of the sun. In the most extreme cases, the full bean, one inch in diameter, would have to be broken. This would introduce a maximum error of approximately 1/225th of a second.

With all errors operating at maximum, the total error would be approximately 1/45th of a second. The errors would cause the electric chronometer times to be longer than actual true time by something less than 1/45th of a second. It is extremely unlikely that the errors in the device on any single trial would approach this figure.

The stop watches were calibrated in tenths of seconds. Occasionally the sweep hand of a watch would stop between two graduation marks. It is questionable whether or not the watches are accurate to less than a tenth of a second, but when the hand stopped immediately between two marks, the times were recorded to 0.05 seconds. No attempt was made to read the watches to a more accurate time than a tenth of a second except in such cases as just mentioned when the hand stopped almost exactly between the graduation marks. At worst, this practice would not introduce an error greater than by reading the watches to the closest tenth of a second. An effort was made to reduce parallax errors by reading the watches from a point directly above and perpendicular to the hand on the watch.

<u>Method of Analyzing Data</u> Conventional statistical techniques were used to analyze the data. The error deviations between true time and the time marked by each of the timers for each trial was computed. The arithmetic mean and standard deviations were determined for each timer. The significance of the difference in means and variances among the five timers was determined using the critical ratio and "F" ratio tests respectively.

Estimates of true time were determined using three methods. Three timers chosen at random were designated as "official timers". An estimate of true time using the times marked by these three timers was determined by following the A.A.U. rules.[4] Using the same three times, another estimate was determined by computing the average of the three times for each trial. Finally, the average of all five times for each trial was taken as an estimate of true time. Using these three methods, three sets of estimates for each trial were recorded. Each of the estimates was compared with true time for each trial and the deviations from true time recorded. The mean and standard deviation was then computed for each method. The results determined by using the three methods were analyzed by comparing the means and standard deviations of the three methods.

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[4] <u>Cf. ante.</u>, p. 2.

CHAPTER III

RESULTS

<u>Comparisons of Individual Stop Watch Times</u>

The times recorded for each trial by each of the five timers were analyzed using conventional statistical techniques. The times marked by each timer were compared with true time for each trial. From these deviations (errors), a mean and standard deviation for each of the five timers were computed. The variance and the standard error of the mean were also computed for each timer. These values are given in Table I below.

TABLE I

CHARACTERISTICS OF THE DISTRIBUTION OF ERRORS* BY INDIVIDUAL TIMERS

Timer	Mean (sec.)	σ_M (sec.)	σ^2 (sec.)	σ
A	- .1095	.0055	.0030	.055
B	- .1373	.0083	.0069	.083
C	- .1461	.0108	.0116	.108
D	- .0773	.0082	.0067	.082
E	- .0491	.0105	.0110	.105

*Error refers to difference between true time and stop watch times. Minus sign indicates stop watch time is less than true time.

From these data, the significance of the difference of the means and variances was determined for each combination of the five timers by the critical ratio and the "F" ratio tests respectively. The correlations between "A" and "B" and between "C" and "D" were plotted. From the extreme scatter it was apparent that no significant correlation was present. Therefore, in computing the "t" values, the large sample formula was used without taking into consideration correlation. The "t" and "F" values may be found in Table II.

<u>Comparison of Estimates of True Time</u> Using the times of the three timers designated as "official timers", an estimate of true time for each trial was determined employing the A.A.U. method.[1] From the same three times, an arithmetic mean was computed as a second estimate of true time. A third estimate was computed by taking the average of all five times for each trial. Each of the estimates was compared with the true time for each trial and deviations computed. From these deviations were computed the mean, standard error of the mean, standard deviation, and the variance for each method of estimating true time. The values computed for each appear in Table III.

To determine whether or not the differences in the means of the errors and variability of the errors were significant among the various methods of estimating true time, critical ratio and "F" ratio tests were applied. To find the "t" values in this case, since correlation was present, it was taken into consideration. The large sample formula was employed. These ratios, in addition to other necessary statistical values for computing these ratios, are given in Table IV.

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[1]*Cf. ante.*, p. 2.

TABLE II

COMPARISONS OF MEANS AND VARIANCES OF THE ERRORS* OF INDIVIDUAL STOP WATCH TIMES

Timers Compared	Difference in Means (secs)	σ Diff.	t	P_t	F	P_F
A vs B	.0278	.0099	2.79	0.003	2.30	less than 0.02
A vs C	.0366	.0121	3.02	0.001	3.86	less than 0.02
A vs D	.0322	.0098	3.28	0.0005	2.23	less than 0.02
A vs E	.0604	.0118	5.12	0.0000	3.66	less than 0.02
B vs C	.0088	.0134	0.65	0.258	1.68	more than 0.05
B vs D	.0600	.0116	5.17	0.0000	1.03	more than 0.05
B vs E	.0882	.0134	6.58	0.0000	1.59	more than 0.05
C vs D	.0688	.0136	5.06	0.0000	1.70	more than 0.05
C vs E	.0970	.0151	6.42	0.0000	1.05	more than 0.05
D vs E	.0282	.0133	2.12	0.017	1.64	more than 0.05

*Errors refers to difference between true time and stop watch time.

TABLE III

CHARACTERISTICS OF THE DISTRIBUTION OF ERRORS* EMPLOYING THREE METHODS OF ESTIMATING TRUE TIME FROM STOP WATCH TIMES

Method of Estimating True Time	Mean (secs)	σ_M (secs)	σ^2 (secs)	σ (secs)
A.A.U. Method Using Three Official Times	.0753	.0066	.0044	.0663
Average of Three Official Times	.0762	.0061	.0037	.0608
Average of all Five Times	.1013	.0046	.0021	.0458

*Errors refer to difference between true time and estimates of true time.

TABLE IV

COMPARISON OF ESTIMATES OF TRUE TIME COMPUTED BY THREE METHODS

Methods Compared	Difference in Means of Errors	σ_{diff}	r	t	P_t	F	P_F
A.A.U. Method Using Three Official Times With Average of Three Official Times	.0009	.0067	.85	0.134	0.447	1.20	more than .05
A.A.U. Method Using Three Official Times With Average of all Five Times	.0260	.0035	.74	7.42	0.000	2.11	between .02 and .05

*Errors refer to difference between true time and estimates of true time.

CHAPTER IV

DISCUSSION OF RESULTS

Comparisons of Individual Stop Watch Times Apparently there is a significant difference among the mean errors of the five timers used in this experiment as was indicated by the large "t" values found. A difference among the standard deviation of the five timers was also obvious. It seems that there is considerable variability among individuals in their ability to time track events.

The sum total of all factors operating under the conditions of this experiment tend to cause an error in stop watch timing that is consistently in one direction, namely, faster than true time. Of the 505 times marked by stop watch timers in this experiment, 443 were faster than true times. The effects of these factors can also be seen in the mean errors of the five timers which ranged from - 0.0491 to - 0.1461 seconds. This confirms the earlier work of Cureton and Coe[1] who found that each of the 64 timers used in their experiment marked times faster than true time.

In the remainder of this discussion, the factors causing these errors and the errors are referred to as constant factors and errors. It is pointed out that they are not constant in the strict interpretation of the term but in the sense that they tend to cause stop watch times to be consistently faster than true times.

Cureton and Coe[2] offer a logical explanation for these constant

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[1] Cureton and Coe, *loc. cit.*

[2] *Loc. cit.*

errors. Since there is an initial reaction time delay in starting the watches and a general tendency for timers to anticipate the finish, the resulting marked times are faster than true times. It is possible that other factors may account in part for this error but the effects of the two factors mentioned above are apparently greatest. Though a full explanation is lacking, it is known that the sum total of the factors operating in timing track situations cause the marked times to be faster than true times in most instances. These constant errors are predominant in timing actual races. Neither Rumberger[3] nor Henry[4] made mention of such errors in their respective studies. The conditions under which their experiments were conducted apparently caused only variable or chance errors to affect the times. Though it was not stated by either author, it is assumed that stop watch times both faster and slower than true time were recorded and the errors varied about zero.

In the present study, the presence of the comparatively large mean errors cannot possibly be attributed solely to the errors in the timing device. The maximum error of the entire timing device was determined to be less than 1/45th of a second. The smallest mean error of the five timers was much larger than this error.

The constant errors are undoubtedly the greatest source of inaccuracies. In determining the accuracy of a stop watch time, it would normally be compared with true time. The relative accuracy of the five timers employed in this study is roughly indicated by the means of their errors.

The influence of the factors causing the constant errors may

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[3]Rumberger, <u>loc. cit.</u>

[4]Henry, <u>loc. cit.</u>

vary among individuals and within individuals. Timers do not anticipate finishes to the same degree, nor do several different timers anticipate the same finish to the same degree. This variance may be due to fatigue, lack of attention, or any number of factors. It has been demonstrated that these and other variable errors cause the errors of individual timers to vary about the mean of their errors, this mean consistently being in the same direction from true time. The extent of these variable errors is indicated by the standard deviations. The standard deviations for the five timers used in this study ranged from .055 to .108. The extent of these variable errors determines how consistent or reliable the timer is in marking times. A timer with a small standard deviation, despite the size of this mean error, would be considered a reliable timer.

Apparently accuracy and reliability are not positively correlated. In this study, timer "E" had the smallest mean error, .0491, and the second largest standard deviation, .105. Although quite accurate, "E" was not a consistent timer. Timer "A" had a mean error of .1095 and a standard deviation of .055. Although slightly less accurate than "E", he was considerably more reliable. Timer "C" was neither accurate nor reliable. His mean error was .1461 and his standard deviation .108. These respective values are the largest of any of the five timers.

Although it would be of great value to have this sort of information about timers, in the average situation, it is not available. If the information were available, there would be some question as to the type of timer that should be used in timing track events. If accuracy, as defined above, was desired without regard for reliability, timers who marked times as did timer "E" would be selected. If reliability was considered the important factor, although less accurate than timer "E", men who marked times as did timer "A" would be chosen. Of course the most desirable timer would be one who was both accurate and reliable.

Since this information is not usually known, it is probable that a group of timers employed to time a track meet would be similar to the group chosen to mark times in this experiment. The problem then becomes one of using a method of estimating true time from the stop watch times that will reduce the errors, both variable and constant. The principal problem of this study is to show the comparisons of several of these methods.

<u>Comparisons of Methods of Estimating True Time</u>

Since the times used to estimate true times are influenced by both variable and constant errors, the estimation would similarly be affected. The method could reduce either or both types of errors, and the ideal method would effectively reduce both. Using the method required by the A.A.U., times comparable to the individual times marked by timer "E" were estimated. The mean error of this method of estimating true time was relatively small, .0753, but the standard deviation was relatively large, .0663. Since the mean error of the estimations using the A.A.U. method was smallest of the three methods used, it may be said to be slightly more accurate. Conversely, since the standard deviation was larger than the standard deviation of either of the other two methods, it may be said that the A.A.U. method was slightly less reliable than the other two methods. This is further discussed below.

It so happened that the three official timers chosen at random had the smallest mean errors. Since the other two timers had larger mean errors, it was anticipated that the average of the five times would be less accurate. Had the three timers with the largest mean errors been designated as official timers, when the five times were averaged, the estimate would probably have been more accurate than either of the other methods. But with the three original official timers having the smallest mean errors, when the times of the other two timers were averaged in with the three, the mean error became larger and significantly different from the estimation using the A.A.U. methods. The mean error of the average of all five times was .1013. The standard deviation of the average of five times was .0458, which is significantly smaller than the standard deviation of the A.A.U. method.

The average of the three official times was slightly less accurate than the A.A.U. method, but not significantly so. The standard deviation was not significantly different from that of the A.A.U. method, but was slightly smaller which is in the same direction as that of the average of five from the A.A.U. method.

The problem of choosing the method of estimating true time would be similar to the problem of choosing which timers to use. In order to insure consistency throughout the country or even throughout a single meet, it would seem that an estimate computed by averaging all of the times marked would be most satisfactory. This sort of estimate would be particularly desirable in meets where qualifying heats are necessary. Even though the A.A.U. method of estimating true time was found to be the most accurate of the three methods used in this experiment (and under the above mentioned conditions), the average of five times was found to be a more desirable method on the basis of being fairest.

The implications of this study are not in complete agreement with the results of Henry's.[5] The lack of agreement is probably due to the constant errors discussed above. Under the conditions of his experiment, apparently no constant errors were present. The stop watch times varied about true time. Therefore, a reduction in standard deviation was equivalent to a closer approximation to true time. He found that the average of three times was a closer estimate of true time than that computed using several other methods involving the same three times. He also found that the average of five times gave a closer approximation to true time that any other method involving five times. These results are not confirmed by this study.

The studies are in agreement at one point, however. Smaller standard deviations were found when the three or five times were averaged than were found when the A.A.U. method was used. This is also in agreement with statistical theory.

As was expected, the correlation between the estimates of the average of five times and those by the A.A.U. method was quite high, r = .74. Since the A.A.U. method and the method using the average of three times are quite similar, and since the three times used in each method were the same, an even higher correlation was found, r = .85. These correlations were used in computing the critical ratios.

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[5]Henry, loc. cit.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

<u>Summary</u> The primary purpose of this investigation was to compare the validity of several methods of estimating true time from stop watch times marked on runners. Subordinate problems were the investigations of the relationships existing among times marked by individual timers and between true time and stop watch times marked by the individual timers.

For purposes of collecting data, actual race conditions were reproduced. An outdoor, 50 yard straightaway lane was marked off using an official starting line and finish line. Runners who ran one at a time were started with a starting gun and timed by five experienced timers and an electric timing device. A total of 101 trials was taken using the same five timers and watches each trial. The true time and each of the five stop watch times were recorded for each trial.

The data obtained were analyzed using conventional statistical techniques. For each of the five timers, a mean error* and a standard deviation were computed. Times marked by individual timers were then compared. Considerable variability was found to exist among timers. Two types of errors seemed to affect the times: (1) Errors that tended to cause stop watch times to be consistently faster than true times; and, (2) Variable errors that caused a variation around the mean error for

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*Error refers to difference between true times and stop watch times.

each timer. Some of the timers had large mean errors but small standard deviations while others had small mean errors but large standard deviations. Using the size of the mean error as an indication of accuracy and the size of the standard deviation as an indication of reliability, it is apparent that there was no correlation between accuracy and reliability in stop watch timing in this study.

For each trial, three methods of estimating true time were used: (1) The A.A.U. method using three official times; (2) The average of the three official times; and, (3) The average of all five times. A mean error* and standard deviation were computed for each method. The A.A.U. method was significantly more accurate (having a smaller mean error) than the average of five times but was significantly less reliable (having a larger standard deviation). Had a different combination of timers been designated official timers, it is probable that the difference in mean errors would have been much smaller.

The A.A.U. method was found to be slightly less reliable and only slightly more accurate than the average of the three official times. It is important to note that in neither case were these differences significant.

<u>Conclusions</u> On the basis of evidence presented in previous chapters, the following conclusions seem justified:

1. There is considerable variability among stop watch timers both in regard to mean error (difference between true time and marked times) and standard deviation (chance errors).

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*Error refers to difference between true time and estimate of true time.

2. In addition to causing random errors, the sum total of factors involved in timing track races cause stop watch times to be consistently faster than true times. The major factors contributing to this "constant" error appear to be initial reaction delay starting the watch and the anticipation of the finish.

3. There does not seem to be any correlation between the extent and the consistency of the effects of these factors. A timer may be consistent and inaccurate or accurate and inconsistent.

4. The A.A.U. method was not demonstrated to be significantly more reliable or accurate than the average of the same three times used in computing the A.A.U. estimate.

5. The average of all five watches as an estimate of true time was found to be <u>significantly</u> more reliable (having a smaller standard deviation) than the A.A.U. method.

<u>Recommendations</u> The following recommendations are made for additional studies in stop watch timing.

1. If a photo-electric cell unit is used as a part of the timing device, a shielding tube extending for several feet from the cell (receiving unit) would minimize the interference of the sunlight.

2. Any apparatus used at the finish line as a part of the timing device should be at the same height as the yarn at the finish line.

3. The data collected for this study could be used in determining the relative validity of other methods of estimating true time or in applying the same methods with different combinations of timers.

4. It would be of value to compare the true times and stop watch times recorded in actual meets where the men reputed to be the best stop watch timers are employed. The results of such an investigation

could then be compared with the results of this study.

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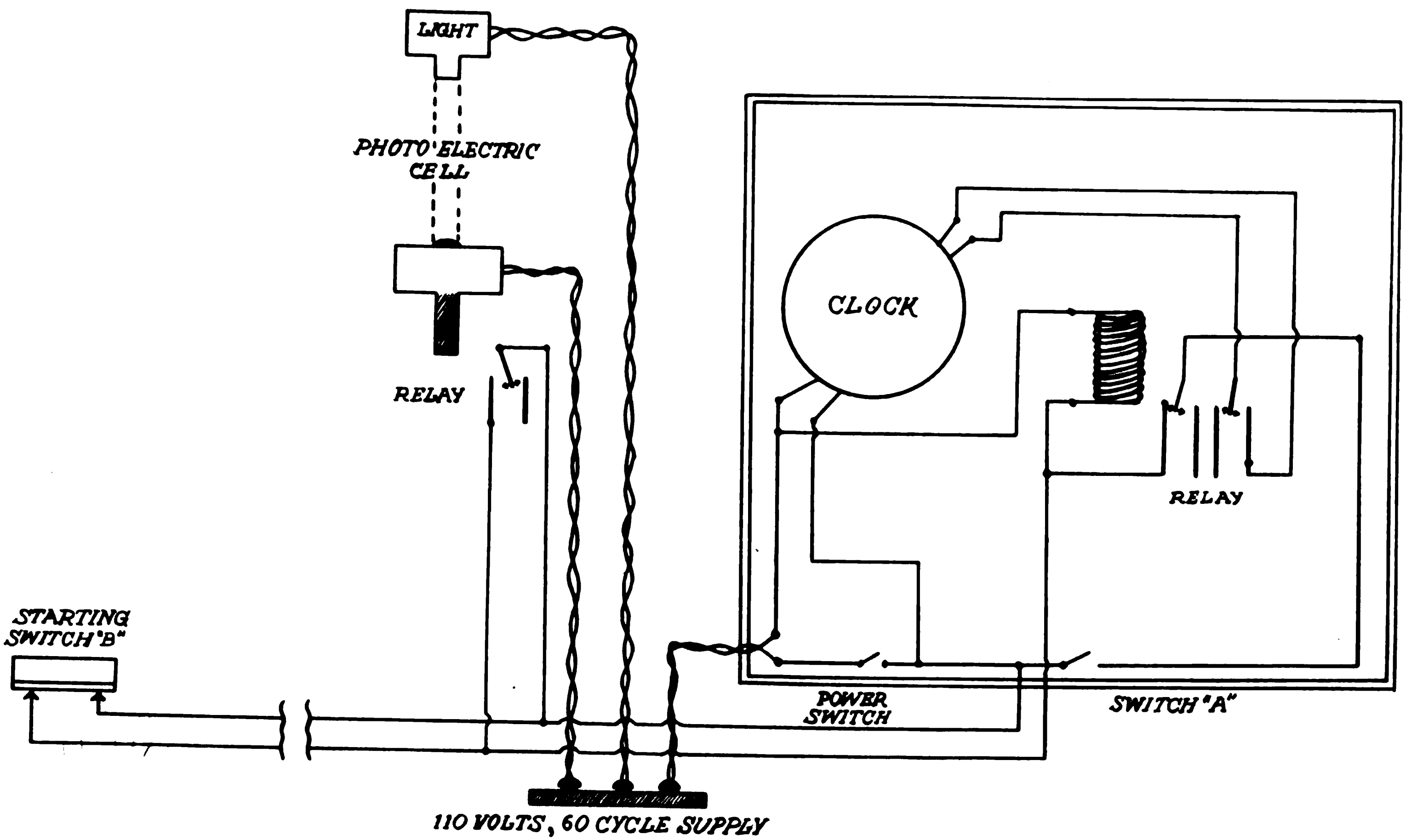
APPENDIX A

DIAGRAM OF ELECTRIC TIMING DEVICE



MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN

GRADUATE STUDIES AND RESEARCH

TOPIC Stop Watch Timing

APPENDIX B

TABULATION SHEET

DATA SHEET OF TRUE AND STOP WATCH TIMES

DATE OF TABULATION

TABULATED BY B. Beck

	TRUE	"A"	"B"	"C"	"D"	"E"	TRUE	"A"	"B"	"C"	"D"	"E"	TRUE	"A"	"B"	"C"	"D"	"E"	
1	7.25	7.3	7.2	7.3	7.1	7.3	8.14	8.0	8.1	8.0	8.1	8.1	7.68	7.55	7.6	7.4	7.6	7.6	1
2	8.18	8.0	8.0	8.2	8.1	8.1	8.52	8.5	8.5	8.5	8.5	8.5	8.82	8.15	8.6	8.6	8.65	8.85	2
3	8.92	8.8	8.8	8.9	8.9	8.8	7.40	7.3	7.3	7.35	7.45	7.45	6.92	6.9	6.8	6.8	6.8	6.8	3
4	7.10	7.0	7.1	7.0	7.0	7.1	9.08	9.0	9.1	8.8	9.0	9.1	7.14	7.0	7.0	7.1	7.1	7.15	4
5	8.34	8.2	8.2	8.2	8.3	8.2	7.86	7.9	7.7	7.8	7.9	7.85	7.54	7.4	7.3	7.5	7.5	7.55	5
6	7.18	7.1	7.2	7.1	7.1	7.1	8.13	8.15	8.0	8.1	8.1	8.15	7.13	6.9	7.0	6.9	7.1	7.15	6
7	8.45	8.3	8.2	8.2	8.5	8.5	9.05	9.0	8.9	8.9	9.0	8.9	8.44	8.3	8.2	8.4	8.4	8.4	7
8	7.30	7.4	7.3	7.3	7.2	7.3	8.35	8.2	8.1	8.2	8.2	8.25	7.05	7.1	6.8	7.05	7.0	7.25	8
9	8.03	7.8	7.9	8.0	7.9	8.0	7.66	7.55	7.5	7.6	7.5	7.7	7.24	7.15	7.1	7.0	7.2	7.1	9
10	7.23	7.1	7.2	7.15	7.3	7.15	8.30	8.15	8.0	8.0	8.1	8.15	7.28	7.15	7.15	7.1	7.25	7.2	10
11	8.37	8.3	8.25	8.4	8.35	8.4	7.95	7.8	7.75	7.7	7.8	7.8	8.55	8.3	8.35	8.3	8.45	8.4	11
12	7.61	7.6	7.55	7.6	7.6	7.6	8.64	8.6	8.5	8.5	8.6	8.5	7.31	7.25	7.1	7.1	7.25	7.25	12
13	8.50	8.3	8.4	8.4	8.5	8.4	8.29	8.2	8.0	8.2	8.2	8.2	7.40	7.15	7.3	7.3	7.3	7.25	13
14	8.55	8.5	8.6	8.5	8.5	8.4	7.31	7.1	7.1	7.0	7.15	7.15	8.62	8.5	8.5	8.6	8.6	8.5	14
15	8.70	8.6	8.6	8.5	8.6	8.6	7.17	7.1	7.0	7.15	7.15	7.0	8.84	8.7	8.7	8.6	8.8	8.85	15
16	8.33	8.3	8.25	8.3	8.35	8.4	7.54	7.5	7.45	7.5	7.5	7.5	8.04	7.95	7.9	7.7	7.8	7.95	16
17	8.22	8.2	8.0	8.0	8.2	8.05	8.89	8.65	8.75	8.8	8.8	8.9	8.97	8.8	8.7	8.5	8.95	8.8	17
18	8.33	8.3	8.0	8.1	8.35	8.4	8.33	8.4	8.1	8.15	8.1	8.2	8.25	8.1	8.2	8.2	8.25	8.2	18
19	8.90	8.9	8.8	8.7	8.9	8.95	7.32	7.2	7.1	7.15	7.2	7.2	8.13	8.0	7.9	8.0	8.0	8.15	19
20	7.27	7.25	7.1	7.1	7.15	7.25	7.05	6.75	7.0	6.8	7.0	6.9	9.05	8.95	8.8	8.9	8.95	8.85	20
21	9.22	9.25	9.2	9.15	9.25	9.2	7.28	7.15	7.15	7.1	7.2	7.0	8.45	8.3	8.3	8.4	8.4	8.4	21
22	7.36	7.15	7.3	7.2	7.4	7.6	7.48	7.35	7.35	7.2	7.4	7.4	8.75	8.55	8.6	8.4	8.5	8.7	22
23	8.73	8.6	8.5	8.6	8.65	8.55	8.58	8.5	8.3	8.5	8.4	8.4	7.93	7.65	7.7	7.75	7.8	7.95	23
24	7.25	7.1	7.0	7.05	7.2	7.0	7.74	7.5	7.5	7.5	7.5	7.55	8.41	8.2	8.25	8.4	8.5	8.4	24
25	8.47	8.4	8.3	8.35	8.5	8.3	8.65	8.7	8.6	8.5	8.65	8.7	8.23	8.0	8.2	8.1	8.1	8.2	25
26	8.38	8.4	8.3	8.3	8.1	8.2	7.13	6.95	7.0	7.1	7.0	6.95	9.23	9.1	9.1	9.0	9.2	9.2	26
27	8.93	8.9	8.9	8.9	8.95	8.9	7.34	7.2	7.3	7.1	7.35	7.35	9.32	9.25	9.15	9.15	9.3	9.25	27
28	8.27	8.2	8.2	8.1	8.2	8.15	6.96	6.8	6.9	6.8	6.8	7.0	8.15	8.15	8.1	8.0	8.1	8.35	28
29	7.33	7.2	7.2	7.05	7.35	7.4	7.54	7.5	7.5	7.5	7.5	7.55	9.21	9.15	9.15	9.0	9.1	9.25	29
30	8.42	8.3	8.3	8.15	8.25	8.2	8.84	8.5	8.8	8.6	8.7	8.7	8.93	8.8	8.7	8.5	8.7	9.1	30
31	8.83	8.5	8.6	8.55	8.85	8.8	7.25	7.15	7.1	7.15	7.1	7.35	7.91	7.7	7.85	7.7	7.75	7.8	31
32	7.22	7.1	7.05	7.05	6.9	7.3	7.13	7.05	7.1	7.1	7.0	7.25							32
33	7.37	7.2	7.2	7.1	7.2	7.3	7.36	7.3	7.3	7.2	7.35	7.55							33
34	8.24	8.15	8.1	8.1	8.1	8.2	8.58	8.5	8.45	8.5	8.5	8.45							34
35	6.80	6.75	6.6	6.85	6.6	6.8	7.27	7.05	7.0	6.9	7.2	7.3							35

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