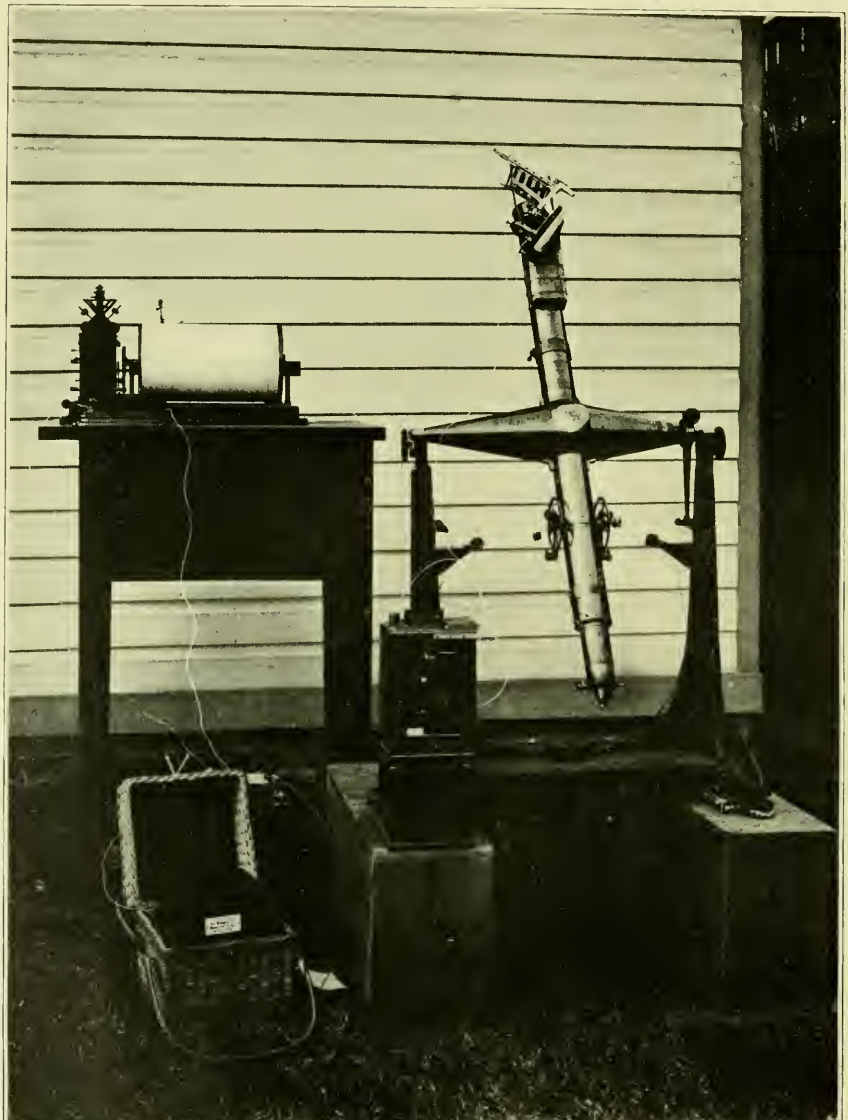

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A METHOD OF AVOIDING PERSONAL EQUATION IN TRANSIT OBSERVATIONS

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Many years ago the writer devised and published[1] preliminary accounts of a method for avoiding the so-called "personal equation" in observations of the time of transit of stars. The following quotation from the article cited will give the fundamental idea described in the former article, to which the present one adds some more recent experiments and slight modifications. The writer, after speaking of the comparative merits of and objections to a photographic method, and one where the star is seen intermittently projected on wires which are illuminated by consecutive flashes, observes:

"There is one particular case, however, where the result is the same for both, that, namely, where when the flash comes, the star is on the wire and bisected by it; in this case we know its position as accurately by the eye, as if we bisected its image on the plate by the wire of our micrometer. If we suppose, then, that by a happy accident, the flash came just as the star was crossing the first wire, this wire would be sharply defined on the disc of the star and bisecting it, and a simultaneous record on the chronograph (made without the intervention of the observer) would evidently give us the same result as though the star had recorded its own passage by an electrical contact. Further, we may particularly notice that it is immaterial whether the star was at rest, when thus seen, or in motion. Now what we have just supposed as a single case of a favorable chance among hundreds, it will be our task to *make* occur, whatever the wire interval, and for any star observed."

In illustration let it be imagined that the observer is watching the passage of the star through the field of his telescope, but that

[1] *American Journal of Science and Arts*, July, 1877, pages 55–60.

he has no illumination of that field sufficient to discern the wires of the tally. Suddenly a flash illuminates the field, and we may suppose that by accident this occurs just at the instant when the star image is bisected by the central wire. If now the flash had recorded itself automatically on the chronograph, an observation independent of the ordinary personal equation would have been obtained, since we know where the star was at that recorded time of observation.

The device I have already described consisted in making this unlikely accident occur for any star, and for numerous wires of the tally.

At the time when it was first devised, such a method consisting not in correcting time observations for personal error committed, but in preventing the committal of such errors, was unique, and it had for the writer the good fortune of attracting the interest and commendation of Professor Clerk Maxwell. But the writer was prevented by distinct duties from developing it, and more recently Repsold and others have attacked the same problem in another way, with much success. Still it is possible that this older method may prove of value, and I have thought best to give this brief account of some recent trials of it.

The instrument whose purpose is to illuminate the field at the required instants, was constructed from my design by A. Hilger, as follows: A conical pendulum consisting of a graduated rod with a heavy ball which may be set at any height on the rod, is suspended by two pairs of thin flat springs acting as a universal joint. At the lower end of the rod is a needle which, as the pendulum revolves, governs the rotation of a grooved arm carried by a clock-work which also drives a drum carrying fine platinum brushes which make instantaneous electrical contacts at each revolution. (Plate LVII.) Thus the intervals between these contacts are governed by the rate of the conical pendulum, which itself goes fast or slow according as the ball is raised or lowered on the rod, this rod being graduated so as to correspond with the declination of any star between 0° and 60°. Knowing the declination of the star, it can be arranged beforehand, therefore, that the interval between contacts is equal to the average interval between transits of the observed star across the successive wires of the tally. By appropriate electrical connections this system of contacts is caused to produce a system of instantaneous discharges in a vacuum tube, which is used in place of a lamp to illuminate the cross wires of the telescope, and if the star be first seen, for instance, half way between the first and second wires of the tally, it will be seen at the second illumination half way between the second and third wires, and so on.

We have thus arranged that flashes shall occur at recorded instants, without limit as to number, and at intervals such that if one, by chance, occurs when the star is bisected by a wire, it will be seen bisected by all the wires in succession. It now remains to arrange that this bisection shall actually occur. This is accomplished by providing an independent control of the position of the contact points under the clockwork, so that with a cord in the hand of the observer he can cause the series of contacts to occur sooner or later, without altering the interval regulated by the pendulum. Thus if the flash comes a little too early for bisection of the star image by the first wire of the tally, a slight adjustment is made, delaying the succeeding flashes, and with a little practice one or two adjustments suffice to secure bisection. To add the weight of independent observations, several displacements and readjustments may be made during the passage of the star over the tally.

As the times of all the flashes are recorded automatically upon the chronograph, an independent signal is made by the observer to mark each flash which has revealed a satisfactory bisection.

I have thus far given the device substantially as described in the early paper. To test the value of the method under circumstances admitting of distinguishing error, an artificial star was arranged to move by an accurate clockwork at about the apparent rate of an actual equatorial star. The shaft which carried the screw by means of which the artificial star was moved, had upon it an arm provided with an adjustable point which instantaneously broke an electrical circuit at each revolution. By careful adjustment, *with the artificial star stationary*, it was arranged that exact bisection took place at the middle wire of the tally, and with the point in position to break contact. Thus the artificial star was caused to record its own time of transit upon the chronograph wholly without personal equation of time.

A transit instrument of 2¾ inches aperture and 48 inches focal length was kindly loaned me by the Superintendent of the United States Coast and Geodetic Survey, for the purpose of making an experimental test of the personal equation machine.

In reconsidering the theory of the method a possible cause of failure appeared. The observer sees the star continually moving across the limited field of view, and thus his mind may unconsciously be influenced by the perception of motion, just as it undoubtedly is in observations by the usual method. In order to

TEST OF PERSONAL EQUATION MACHINE USED BY IMPROVED METHOD.

	Observer, C. G. A.				Observer, F. E. F.				Observer, N. E. G.			
Method	Usual Method Without Personal Equation Machine		With Personal Equation Machine Intermittently Obscuring Star		Usual Method Without Personal Equation Machine		With Personal Equation Machine Intermittently Obscuring Star		Usual Method Without Personal Equation Machine		With Personal Equation Machine Intermittently Obscuring Star	
	Error of Observed Time of Transit	Deviation From Mean Error	Error of Observed Time of Transit	Deviation From Mean Error	Error of Observed Time of Transit	Deviation From Mean Error	Error of Observed Time of Transit	Deviation From Mean Error	Error of Observed Time of Transit	Deviation From Mean Error	Error of Observed Time of Transit	Deviation From Mean Error
Date	July 25, 1902		July 25, 1902		July 25, 1902		July 25, 1902		July 25, 1902		July 25, 1902	
1	$-0^{s}.14$	$0^{s}.034$	$-0^{s}.02$	$0^{s}.004$	$-0^{s}.02$	$0^{s}.002$	$+0^{s}.03$	$0^{s}.08$	$+0^{s}.02$	$0^{s}.086$	$-0^{s}.004$	$0^{s}.033$
2	— .20	.094	+ .05	.066	— .09	.068	— .02	.03	.06	.046	+ .040	.011
3	— .14	.034	.01	.026	— .10	.078	— .07	.02	.04	.066	— .056	.085
4	— .06	.046	.07	.086	+ .01	.032	+ .06	.11	.20	.094	+ .008	.021
5	— .05	.056	.00	.016	— .08	.058	± .00	.05	.00	.106	+ .007	.022
6	— .12	.014	— .06	.044	— .03	.008	— .03	.08	.18	.074	+ .002	.027
7	— .18	.074	+ .05	.034	— .05	.038	— .10	.05	.03	.076	— .012	.041
8	— .09	.016	— .03	.014	+ .06	.082	— .08	.03	.05	.056	+ .054	.025
9	— .20	.094	+ .06	.076	— .02	.002	— .08	.03	.16	.054	— .007	.036
10	— .13	.024	— .10	.084	— .14	.118	— .09	.04	.25	.144	+ .120	.091
11	+ .01	.116	— .12	.104	— .03	.052	— .08	.03	.26	.154	+ .058	.029
12	— .01	.096	— .08	.064	+ .06	.082	— .12	.07	.10	.006	+ .085	.056
13	— .06	.046			+ .09	.112	— .13	.08	.03	.076	+ .049	.020
14	— .04	.066			— .03	.008	— .07	.02			+ .030	.001
15	— .12	.014					— .02	.03			+ .063	.034
16	— .17	.064									+ .027	.002
Mean.	—0.106	0.055	—0.016	0.052	—0.022	0.053	—0.050	0.050	+0.106	0.080	+0.029	0.033

overcome this objection a rearrangement of the apparatus was made so that instead of intermittently obscuring the wires of the tally, the wires were now continuously illuminated as in the usual method, but the star itself was obscured by a shutter, except at the instants when the wires had formerly been illuminated by the glow tube. As thus modified the observer by this second method sees the star only during well-separated intervals of a hundredth of a second or less, so that all appearance of motion is avoided. This device, suggested by Mr. Abbot, appears to be an improvement on the former method, and has been used in the observations presented in the accompanying table. These observations were made by three observers, C. G. A., F. E. F., and N. E. G., of whom F. E. F. was most experienced in observing transits without the personal equation machine, and accustomed to its use by the former method, but less practiced than the others with the machine as now employed.

The general result appears to be in favor of the personal equation machine. In the case of the observer C. G. A., whose usual equation was about —0.10 seconds when observing without the machine, the error became only —0.016 seconds with the machine; and the average deviation was reduced slightly. Similarly with the observer N. E. G., whose direct observations were usually rather variable, but which now yielded an average personal equation of +0.106 seconds, the employment of the machine was of marked advantage, reducing his personal equation from 0.106 to 0.029 seconds and the average deviation of it from 0.080 to 0.033 seconds. With the observer F. E. F., the usual personal equation was small and the average deviation of it was slightly reduced.

So far as it has been tried, then, the advantage of observing by the aid of this device seems to be marked.