THE PORTABLE TRANSIT INSTRUMENT IN THE VERTICAL OF THE POLE STAR

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Trieste

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PORTABLE TRANSIT INSTRUMENT

IN THE

VERTICAL OF THE POLE STAR,

TRANSLATED

FROM THE ORIGINAL MEMOIR OF WM. DÖLLEN,

BY

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DIRECTOR OF THE CINCINNATI OBSERVATORY.

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NOTE.

The accompanying translation and Appendix and Tables were prepared for the Bureau of Navigation in May, 1868. The proof-sheets have been kindly read by Professor Asaph Hall, of the Naval Observatory. A second memoir of Mr. Döllen upon this subject may be shortly expected and will be at once translated and published.

CINCINNATI, *January*, 1870.

ON THE DETERMINATION OF THE TIME BY MEANS OF THE PORTABLE TRANSIT INSTRUMENT MOUNTED IN THE VERTICAL OF THE POLE STAR.

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1. The method of determining the time, which is now to be considered, was proposed long since, and earnestly recommended by the most approved judges; it has been, indeed, developed in different works, sometimes with great thoroughness. Nevertheless, the fact remains that it has in nowise found that extensive dissemination and repeated application that it incontestably deserves.

The principal reason for this disregard is certainly to be found in this, that we have always regarded it as a kind of *dernier resort* to which we could at any rate have recourse, when perhaps circumstances would not allow of the generally more appropriate establishment in the meridian; moreover, the observations in and of themselves offered many inconveniences, and demanded a certain experience on the part of the observer in order to overcome difficulties which partly were inherent in the construction of our portable transits, partly, also, on the other hand, arose from the opinion that we must, for the sake of simplicity of computation, set for ourselves certain limitations. And moreover, especially when one desired the attainment of the finest possible results, the computations seemed so much more laborious than for the establishment in the meridian that the advantage of the shorter duration of the observations would be thereby more than counterbalanced.

It is the object of the following lines to oppose the above opinion and to give expression to the conviction, based upon many applications, that the method of observation under consideration has indeed not only even now a much greater importance than in general seems to be attributed to it, but that it may at once be unconditionally pronounced as the most preferable, after that certain changes, to be more exactly described hereafter, have been introduced in the instrument. Only this method develops for us the full value of the instrument; only this affords, under all circumstances and with the least delay, as accurate a result as can anyhow be attained with the means at hand.

It seems precisely now* of earnest importance to gain for the preceding truth the acknowledgment due to it, since an exceedingly important application of the portable transit to the determination of time is in such immediate prospect that a decision upon the method to be followed therein ought not to be longer delayed.

2. For the orientation of a transit instrument on our northern hemisphere α Ursæ Minoris, the Pole Star, offers important advantages over every other star, by reason of its brightness and nearness to the pole, as well as by reason of the accuracy with which its place in the heavens can be given for any moment of time. Therefore, in mounting a portable transit for the purpose of determining the time, even if the mounting

* This memoir was first published in 1863.

in and of itself be sufficiently trustworthy, we shall often do well, for the sake of observing Polaris, to renounce the other advantages that accompany an observation made as near as possible to the meridian.

This will, however, be absolutely necessary, if perhaps, as only too easily happens with the traveler, the mounting is by no means solid enough to sufficiently assure the invariability of the instrument during the entire interval necessary to a complete time determination in the meridian. In fact, under such circumstances no other method remains than to limit the duration of the observations to the shortest possible time, and to effect this, therefore, it is necessary to not wait until the proper stars, especially those situated near the pole and necessary for orientation, have reached the meridian, but to leave the meridian and to seek the most appropriate of them all, Polaris itself, wherever it may be in its diurnal circle. The dexterity of the observer will then show itself in the shortness of the interval which elapses after or even before the transit of Polaris over one of the threads of the reticule and the observation of the transit of the time star proper, (of course on all or at least as many threads as possible;) and we know from much experience that with a little practice this interval need be only a few minutes. The observation in the first position is completed by a careful determination of the inclination of the horizontal axis, or, as is very desirable, by two determinations inclosing the observations of the stars, and whose agreement bears testimony to the actual invariability of the instrument. It is, however, important immediately to execute a similar series of observations in the other position of the instrument, in order to free the result from the influence of the error of collimation and the difference in diameters of the pivots, without being under the necessity of taking these quantities from other sources.

It is easy, and will certainly also be intended in these observations, to observe Polaris both times upon the same thread, by preference the middle thread, and the succeeding computation will, in fact, be thereby somewhat simplified. One easily sees, however, that so far as concerns the true object of the observation, this is quite without serious importance, while in the execution of the observation a great relief may result from not being bound to any such condition. This stands in connection, however, with certain imperfections of the transit instruments in their present construction, to which the attention of the observer deserves to be especially called.

3. The instrument to which the following remarks are especially applicable is the Ertel portable transit instrument, although they certainly have also a more general importance. This instrument, in different forms, but all of nearly identical construction, has attained an extensive distribution, and may, indeed, through the descriptions given in words and drawings in different authorities, be considered as generally known. It differs chiefly from the formerly much-used Troughton's transit in the broken telescope and the possibility of the motion about the vertical axis. The former secures a marked facility in the observation, especially in the neighborhood of the zenith, and by reason of the shortening of the supports of the horizontal axis conduces much to give a greater rigidity to the entire instrument. The other change had certainly as immediate object to facilitate the exact adjustment in any azimuth, especially in the prime vertical, but the slow-motion screw serving thereto and the careful divisions of the horizontal circle, for reading which four verniers are provided, as well as the circumstance that by the pressure of a supporting spring the motion of the limb, in respect to the alidade, can be facilitated at will, give reason to suspect that the additional design was

entertained of rendering possible the exact measuring of horizontal angles.

But since any such intention is, through the absence of the assurance (or watch) telescope, only to a limited degree attainable, the greater mobility in azimuth therefore directly and very seriously endangers the excellence of the instrument as a transit. The clamp that ought to hold fast the two circles, with reference to each other, and thereby, therefore, the moveable upper, with reference to the immoveable lower portion, performs this service very imperfectly, not only because it operates only on one point, and that a point on the circumference, but also because of the slow motion that is combined with it. Very soon, therefore, it was that two simple clamping screws, distant 180° from each other, were applied, which are to be tightened as soon as the instrument is brought into the proper azimuth; and these are quite well adapted to greatly increase the security of the mounting.

On the other hand, not only is the exact adjustment in a known azimuth, as given by the readings of the circle, made almost impossible by reason of these clamping screws, since their greater or less tightness is accompanied by sensible flexures and corresponding derangements in the azimuth, but, furthermore, directly through these flexures is the fulfillment of the other condition, that the inclination of the horizontal axis shall be always the least possible, made much more difficult. These clamp screws can, moreover, if they are not applied to the proper points, give rise to a further danger, against which one must be forewarned. Evidently they should only be placed at the points where the supports of the horizontal axis are. In the earlier instruments they are, indeed, always found at these points, and only recently they have been placed 90° distant therefrom, probably for the sake of greater convenience in the manipulation; this is, however, precisely where they least of all realize their object; for if the previously-mentioned supporting spring be even very slightly compressed, then, notwithstanding the tightening of the misplaced clamp screws, the supports of the Y's will remain in a more or less unstable position, and thereby is generated the danger that the inclination of the axis may change when the level is set upon it.

We have persuaded ourselves, by direct trials, that the danger is not a fancied one, but that in the above way very sensible errors can arise. These become very apparent if on such an instrument with the spring compressed a series of levelings in alternate positions is made, as though for the determination of the difference of the pivot diameters. In case the necessary care in the reversions has been taken, we may certainly receive very accordant but entirely deceptive values; for, the influence of the unequal pivot diameters will have entirely disappeared, in comparison with that of the unequal weights of the two sides of the instrument. Therefore it is indispensable that in using such an instrument the spring should be perfectly slack, in order that before the tightening of the clamp screws the upper portion may rest entirely around with its whole weight, even though thereby the slow motion in one direction will, to a great extent, refuse to work. On no account, however, should the circumspect observer neglect to make a special investigation with the object of determining whether the application of the level itself does not still alter the inclination of the axis.

4. What precedes will quite suffice to show that some experience is necessary in order successfully to conduct the series of observations in that rapid succession which constitutes the importance of this method, as also that it affords a very important relief to be allowed to observe the Pole Star on any thread, but especially upon different threads, in the

two positions. This latter finds its full importance if it is thereby made possible to preserve the former azimuth after the reversion. Independent of the convenience which thus results to the observer, since he needs only once to clamp his instrument and adjust it for the inclination of the axis, the accuracy of the observation itself will thereby undoubtedly be increased, since it is well known that for some time after every change in the position of the instrument there remains the danger of a reactionary change; and finally one finds a very acceptable control for the entire operation in that for each position the same azimuth should result, although so far as the determination of time is concerned it is only necessary that the position of the instrument should not have changed during the observation in each position by itself.

This, however, it must be confessed, at least for our present instruments, assumes that the Pole Star has a definite motion in azimuth. Therefore, in the immediate neighborhood of its elongation this advantage must be renounced, and we are reduced to the necessity of adjusting anew the instrument in each position upon the almost motionless star. For, that Polaris becomes in general in this portion of its daily orbit less proper for our object, and therefore may, or even must, be replaced by another star in the neighborhood of the pole, perhaps by δ Ursæ Minoris, is, as it seems, a wide-spread yet manifest error. This has probably arisen, first, from the fact that the determination of the moment when the star bisects the thread will truly be then very inaccurate, and that, secondly, the reduction of such a transit from the thread to the great circle will always be large, and, under some circumstances, infinite.

Now, as concerns the first point, we shall, on consideration, recognize that therein not only no disadvantage exists, but there even results an advantage to the actual object of the observation, since precisely then the orientation of the instrument is achieved as accurately as the optical force of the telescope will at all allow; and in reference to the second point it is to be remarked, that this is a difficulty existing only in a certain method of computation, and therein is a proof that this method is not the proper one. No, if we are to leave the meridian at all it must be only for the sake of the advantage which the Pole Star offers; there is really no sufficient reason for choosing any other star for the orientation than Polaris.

At the same time, however, it is not to be denied that the observation in the neighborhood of the elongation has its special difficulties. We must, that is to say, not wait until the star, by its motion, is brought upon the thread, but must adjust the instrument directly upon the star, while, as above remarked, the azimuth will again be changed by the fastening of the clamping screw. With some practice, however, this difficulty is overcome, in that the clamp screw itself can, up to a certain point, replace the slow motion; but it is thereby always necessary carefully to watch that the simultaneously changing inclination of the horizontal axis remains small enough to allow of its accurate measurement. Furthermore, the correction of the inclination by means of the foot screws offers a means of changing a little the position of the star with reference to the threads, which can be occasionally very serviceable to the expert observer for the attainment of his object, especially if the construction of the instruments allows the level to remain upon the axis during the observation. Still another means of facilitating the observation at the elongation consists in the use of a somewhat inclined thread; we have, however, on this point no experience as to how advantageous this would prove itself in practice.

5. I allow myself, finally, two further remarks concerning the arrange-

ment of the observations, regard to which can be of practical importance under certain conditions. If we relinquish the maintenance of the same azimuth in both positions of the instrument, it is then occasionally possible to secure the other, in some circumstances not unimportant, advantage of being able to observe the same time star in both positions. This is especially important if no other time star of sufficient brilliancy is at hand; so that one must, without this resort, content one's self with observations in one position. The application of such a method fails on the approach of the time star to the zenith, on account of its increased azimuthal change. Neglecting the error of collimation and the advance of the Pole Star in azimuth, both which can affect the circumstances as well favorably as unfavorably, then in the latitude of 60° a change in azimuth of nearly 1° corresponds to a thread interval of 15′; that is to say, after the reversion the instrument must be changed in azimuth by this quantity in order still to be able to observe the Pole Star on the same thread; and it is easy to decide what change in the hour angle of the time stars corresponds to this change in azimuth. For α Bootis, for instance, it amounts to nearly three minutes of time, and it depends only upon the expertness of the observer and the arrangement of the instrument whether this interval suffices for the reversion and adjustment in azimuth.

The other remark refers to the difficulty known to all observers of observing the transit of Polaris if the star is very faint. Often one catches the star very fairly at some distance from the thread, while on approaching it it completely disappears. The observation is then usually made by noting the disappearance of the star on one side of the thread and its reappearance on the other, and the mean of both moments is considered as the time of transit. Of course, however, such an observation is far less accurate than if the star remains visible upon the thread itself, and it will therefore be the less available the longer the interval between the disappearance and reappearance. Now, we have in such cases, with the best results, replaced the observations upon the thread by the observation in the middle between two threads, and find that with an appropriate third interval there results thereby scarcely an appreciably diminished accuracy of observation.

6. If we review the previous remarks it results that for the determination of time by means of a portable transit instrument, the method of observation here considered is only in very special cases inferior to the observation in the meridian; on the other hand, in other circumstances which far more frequently present themselves, it will, by this method only, be possible to realize any determination at all; and therefore the advice seems to be authorized, that we do not shun the labor of putting ourselves by means of the necessary practice, to a certain extent at least, in possession of all the means which the instrument can offer to the observer to whom it is intrusted.

The judgment must, however, be quite different if it should be possible to give to the instrument an arrangement by which the various difficulties, above mentioned, are still further removed from the observation. And this is now in reality very completely attainable, and that through changes which have already proved themselves as individually quite applicable, although their aggregate combination has still first to stand the proof of actual experience. Now, for our purpose, the most important addition to our present transit instruments seems to me to be the introduction of a movable thread, whose position, with respect to the fixed threads, will be any time recognized by means of the micrometer screw that carries it. This change, since it only affects the ocular, is also com-