# Further note on the printing chronograph

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# Further note on the printing chronograph, by *W. de Sitter*.

In *B. A. N.* 84 a description was given of the printing chronograph of this observatory. Since then we have continued experimenting, especially with the disc *s*, which by its inertia breaks a contact when the synchonising magnet arrests the clockwork. It will be remembered that in the first design of the Société Genevoise this contact was broken by two springs *q*, *q'* sliding off the brass projections *t*, *t'* onto the ebonite ring *v* (*l. c.* fig. 12). This arrangement gave rise to trouble by particles of brass being carried by the springs *q*, *q'* from the projections *t*, *t'* onto the ebonite, and it was then replaced by a new arrangement designed by the Société Genevoise, where the contact is broken at *h'* (fig. 12*a*, *l. c.*) when the permanent magnet *m* is separated from the pieces of soft iron *h*, *h'*. In *B. A. N.* 84 it was stated that "the new arrangement has now been in use for some time, and it has never failed to work satisfactorily". I regret to have to report that it has since then failed once or twice, the motor losing one or two seconds during the course of the night. The most probable explanation for these failures is, that by the many electric currents which at various moments pass in the neighbourhood of the permanent magnet *m* and through the electromagnets *S*, *H* and *P*, the magnetism of *m* is affected, and at times weakened so much that *m* is separated from *h* and *h'* by the spring *l*, and thus the contact at *h'* is broken, although the tooth *n* is not arrested, and it should remain closed, the motor consequently being slowed down when it should be accelerated.

As soon as the old arrangement was dismounted and replaced by the new one, we tried to alter the old one so as to avoid the carrying over of small particles of brass onto the ebonite. Mr. ZUNDERMAN succeeded in attaining this aim by soldering on the brass at *t*, *t'* small strips of silver, which project about half a millimetre above the inner face of the ring *v*. When the disc *s* is carried on by its inertia, the springs *q*, *q'* drop from these silver strips on the ebonite and, as their tension is only just sufficient to make a good contact on the silver, they move over the ebonite with very little friction, in fact hardly touching it. When the pin 8 strikes the spring 9 they are brought back to their original position over the silver strips. The edge of these strips is rounded and made into a small inclined plane, so that the shock, which the wheel 1 would receive if this edge were sharp, is practically abolished. Still it is important to ascertain whether any effect of this shock on the running of the motor can be traced.

For this reason we caused the mean time clock to register its seconds on the chronograph while the latter was being synchronised by the sidereal clock. Any irregularities in the running of the motor must produce a deviation of the plot of these printings from a straight line. Several of such series of printings were taken. Those of one of them, taken on Oct. 25, 1925, are represented in the annexed diagram, the abscissae being the whole seconds and the ordinates the hundredths read off from the strips. The even (upper line) and odd (lower line) seconds were plotted separately, the ordinates being shifted $0^s 40$, since there may be a systematic difference in the contacts made at the two ends of the swing of the pendulum of the mean time clock. The straight lines were drawn through the centre of gravity of the middle minute ($1^m 0^s$ to $1^m 59^s$) with the computed slope, taking account of the known daily rates of the two clocks, and disregarding the systematic difference between the odd and the even seconds. In judging these plots it should be kept in mind that the strips are read to the nearest hundredth of a second, no attempt being made to estimate thousandths. Some of the small fluctuations would undoubtedly have disappeared if thousandths of seconds had been read off, but it was thought better to use the readings as they are made in actual work on stars. The deviations from a straight line are due to three causes. Firstly to irregularities in the contacts of the mean time clock and in the time of reaction of the several relays and of the electromagnet *H*, secondly to irregularities in the contacts of the sidereal clock and the time of reaction of the relays of the synchronising circuit and the electromagnet *S*, and thirdly to irregularities in the synchronising and in the running of the motor and the clockwork. It will be seen that the sum of these three errors never amounts to more than $\pm 0^s\!\cdot\!03$, and is generally smaller than $\pm 0^s\!\cdot\!01$. Especially at the point (about ${}^s\!\cdot\!85$) where the disc *s* is brought back to its original position by the spring 9 acting on the pin 8, which is marked by an arrow in the diagram, there is not the slightest discontinuity in the curves.

If we take means of a number of successive residuals, the effect of the accidental errors, and of the estimation of whole hundredths, is eliminated. From the remaining residuals we can determine **1**: a constant correction to the zero point of each series, **2**: a systematic difference between the even and odd seconds, which is assumed to be the same for all series taken on the same date, and **3**: a correction to the adopted relative rate of the two clocks, also constant for all series taken within a short time of each other. For the series represented in the diagram this correction was $+ 3^{s}.24$ in the relative daily rate, a large quantity, but not at all impossible, since especially the mean time clock is not an instrument of precision, and its rate may very well vary considerably during the day. *) All the series were treated in this way. The residuals remaining after this treatment still contain a considerable percentage of accidental error, different for the different series. If, however, we take the mean of several series, we may hope to eliminate the accidental error, and these means may thus be considered to represent the effect of periodic errors in the clockwork and in the motor, and systematic errors of the synchronisation.

The following table gives in the first column the time $t$ elapsed since the last synchonisation. The next two columns give, for the series represented in the diagram, the residuals of the means of from 15 to 20 consecutive printings remaining after the treatment explained above. It will be seen that these are very small indeed. The fourth column contains the mean deviations derived from four different series. including the one taken as an example. The formula

$$- {}^{s}.002 \sin \pi t - {}^{s}.002 \sin 2\pi (t + .07)$$

leaves the residuals given in the last column. It is very doubtful whether the periodicity represented by this formula is real, but even if it were real, it would be entirely negligible. It is thus proved that after the synchronisation the clockwork does take up the full speed at once, and between two synchronsisations the motion is to all practical purposes absolutely uniform.

*) It is known that this clock has a very large barometric correction, and the date of this series was one of rather wide variation of atmospheric pressure.

| $t$ time since last synchronisation | Mean deviation | | Mean of four series | Res. |
|---|---|---|---|---|
| | odd seconds | even seconds | | |
| s | s | s | s | s |
| 0·05 | | — ·014 | — ·003 | ·000 |
| 0·15 | + ·002 | — ·009 | — ·005 | — 1 |
| 0·25 | — ·003 | — ·008 | — ·005 | — 2 |
| 0·35 | — ·000 | | — ·001 | + 1 |
| 0·45 | + ·006 | | + ·001 | + 2 |
| 0·55 | + ·010 | | — ·001 | — 1 |
| 0·65 | + ·004 | | + ·001 | + 1 |
| 0·75 | — ·001 | | — ·000 | 0 |
| 0·85 | + ·002 | | — ·000 | + 1 |
| 0·95 | — ·006 | | — ·003 | — 1 |
| 1·05 | — ·009 | | — ·004 | — 2 |
| 1·15 | — ·004 | + ·002 | — ·001 | + 1 |
| 1·25 | — ·001 | + ·002 | + ·001 | + 1 |
| 1·35 | | + ·007 | + ·002 | 0 |
| 1·45 | | + ·011 | + ·004 | + 1 |
| 1·55 | | + ·004 | + ·003 | — 2 |
| 1·65 | | + ·001 | + ·003 | — 1 |
| 1·75 | | — ·000 | + ·003 | 0 |
| 1·85 | | + ·003 | + ·003 | + 2 |
| 1·95 | | + ·000 | + ·000 | + 1 |