Tillinghast secondary tilts

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Sensoft analysis of TWFS images yields a prescription for adjustments of the secondary as “tilt M2 East by X$''$ and North by Y$''$.” I calculate the numbers of turns of 2 of the 3 bolts that tilt M2 with respect to the optical axis to yield the Sensoft prescription.

Figure 1 is a low-quality reproduction of a photograph of a full-scale drawing of the back of the plate that holds M2. The 3 adjustment bolts are labeled A-C, and N marks the north direction. Figure 2 is a copy of a cut-out diagram (reduced from full-scale) along line AA in Figure 1, showing M2 and bolt A. Figure 3 is a diagram of the plate shown in Figure 1, with labels for the 3 bolts, the cardinal directions, and 2 known angles I use in the calculations. Various axes are also shown.

The Sensoft prescription gives the rotation angles δ_E (tilt M2 East) and δ_N (tilt M2 North). These are small angles in radians, so I treat them as vectors. When a bolt is turned, M2 rotates about the axis formed by the other 2 bolts. I'll leave bolt A fixed, as we have 2 degrees of freedom. I picked A to remain fixed, because access to B and C is easier with the telescope tilted toward the mezzanine. Turning bolt B (C) then rotates M2 about axis AC (AB). These axes are shown in Figure 3 in green and red, respectively. In matching colors, axes parallel to AC and AB (A'C' and A"B', respectively) are shown through the center of M2. These define angles α (NA') and β (NA") which relate small rotations about AB and AC to correspondingly small rotations about NS and EW:

$$\begin{aligned} \delta_E &= \delta_B cos(\alpha) + \delta_C cos(\beta) \\ \delta_N &= \delta_B sin(\alpha) - \delta_C sin(\beta) \end{aligned} \tag{1}$$

Figure 3 shows vectors representing δ_B (green) and δ_C (red). For small motions of the bolts, in the small-angle approximation δ_B and δ_C satisfy:

$$\delta_B = \frac{h_B}{R}, \quad \delta_C = \frac{h_C}{R}$$

where h_B and h_C are bolt displacements (positive away from M2) and R is the distance from each bolt to its corresponding axis of rotation (e.g., B to AC), which in turn is equal to the radius of the bolt circle multiplied by 1.5, from the geometry. The signs of δ_B and δ_C are such that positive h_B and h_C produce CCW rotations about AC and AB, respectively. These displacements satisfy:

$$h_B = \frac{T_B}{P_{mm}}, \quad h_C = \frac{T_C}{P_{mm}}$$

where T_B and T_C are the numbers of CW turns of the bolts and P_{mm} is the pitch of the bolts in turns per mm.

Solving eqn. 1 for δ_B and δ_C yields:

$$T_B = RP_{mm}\frac{\delta_E sin(\beta) + \delta_N cos(\beta)}{sin(\alpha + \beta)}$$
$$T_C = RP_{mm}\frac{\delta_E sin(\alpha) - \delta_N cos(\alpha)}{sin(\alpha + \beta)} \tag{2}$$

The quantities required to calculate T_B and T_C are:

$$\alpha = 7.55^\circ$$
$$\beta = 52.45^\circ$$
$$R = 1.5 \times 187.\ \text{mm}$$
$$P_{mm} = \frac{24\ \text{turns/inch}}{25.4\ \text{mm/inch}}$$

The Sensoft prescription based on the best data from 23 March 2009 is:

$$\delta_N = 80.2''$$
$$\delta_E = 188.2''$$

Using the equations above and scaling the prescription from arcsec to radians, I obtained:

$$T_B = 0.294$$
$$T_C = -0.081$$

These are very small turns, so I conclude that we are reasonably close to a good collimation.

We will test TWFS further by turning bolts one at a time and acquiring images to verify that Sensoft yields the appropriate corrections.

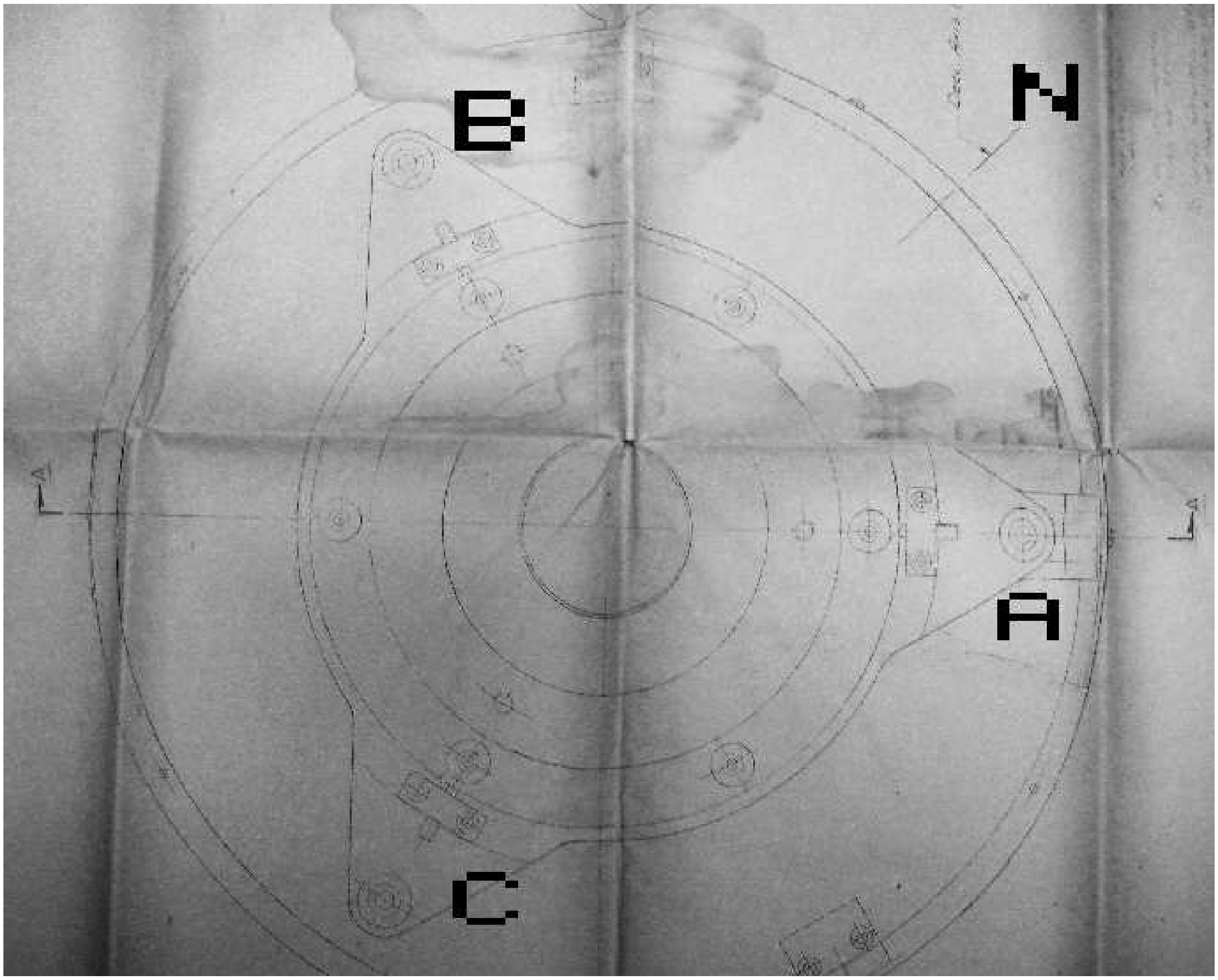

Fig. 1.—

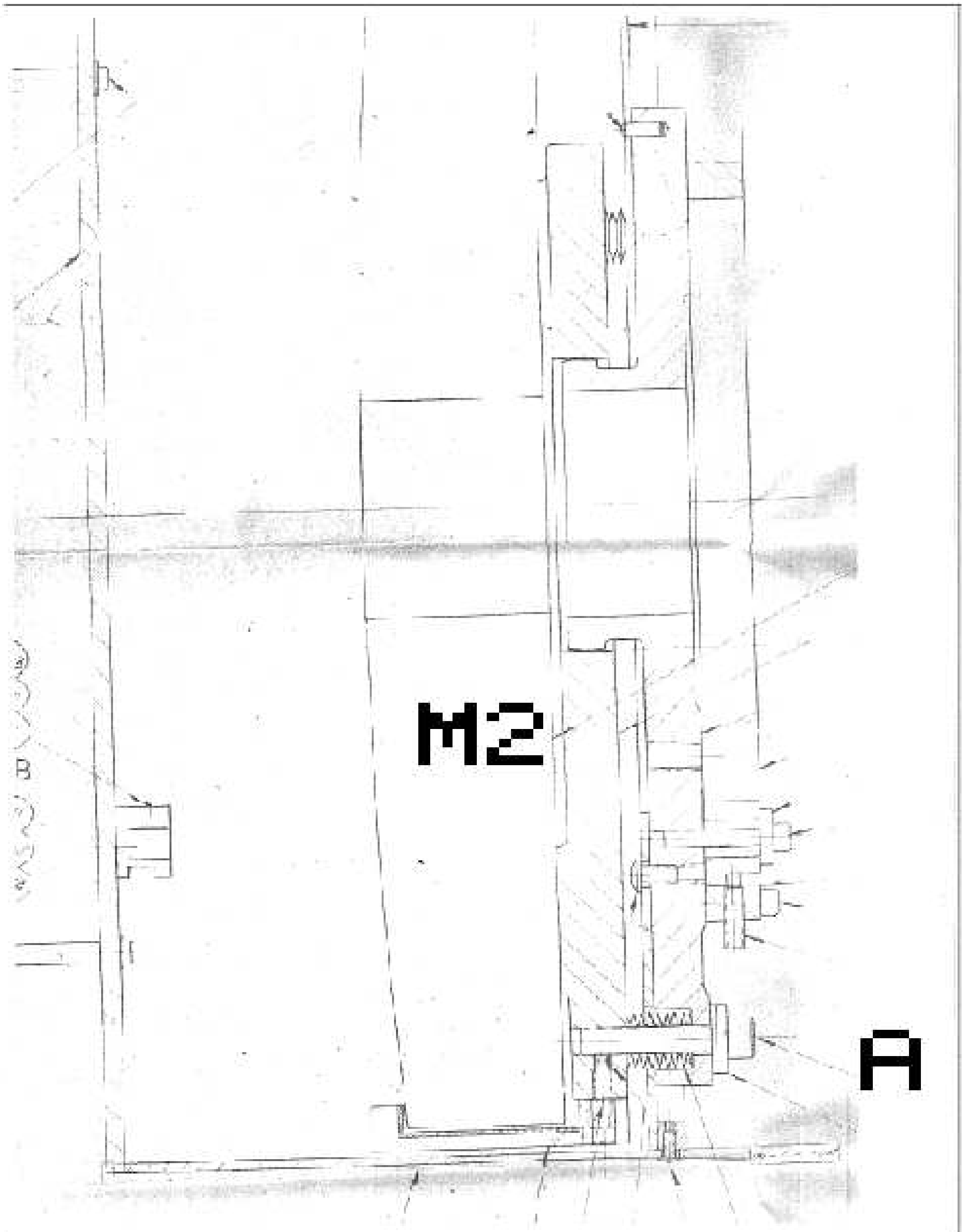

Fig. 2.—

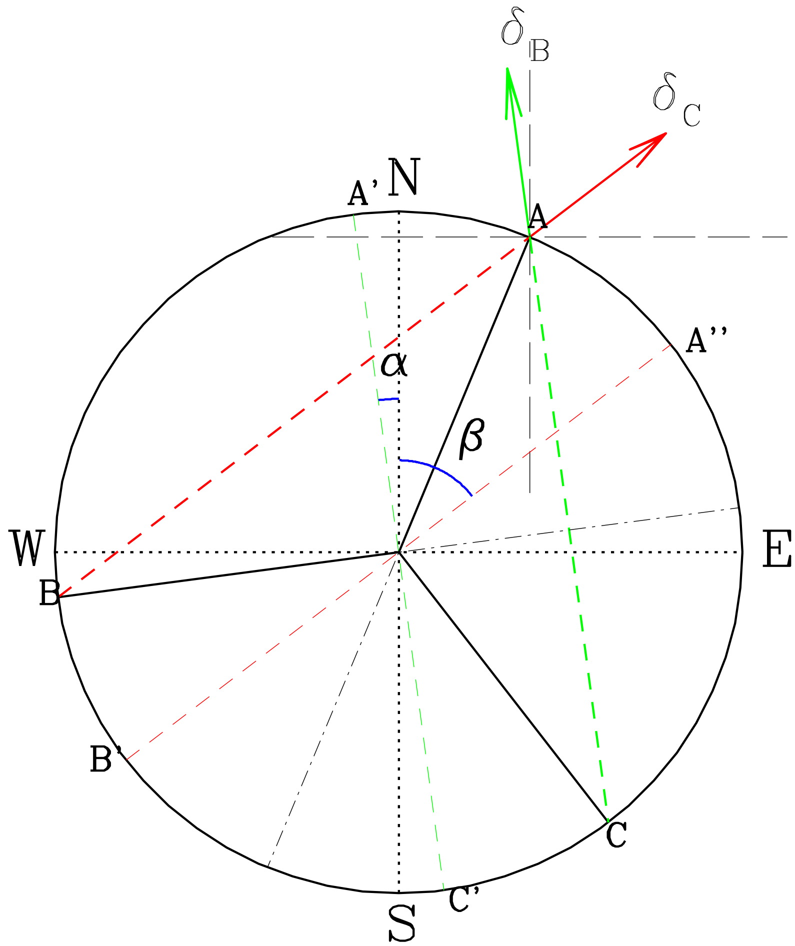

Fig. 3.—