angle. An hour circle attached to EP and a declination circle attached to the box containing the mirror N, both of which can be read or set from E, complete the essentials of the instrument. Its mechanical details present no great difficulty, and are most conveniently arranged. But we entertain grave doubts as to the practical value of the instrument, not on mechanical, but on optical grounds. There must be a certain loss of light from two additional reflexions ; but that could be tolerated for the sake of other advantages, provided that the mirrors could be made suffi­ciently perfect optical planes.

A few years ago it was very difficult to obtain an op­tically perfect plane 6 inches in diameter, and having obtained it there remained the further difficulty of mounting it so that in all positions it should be free from flexure. By making the mirrors of silvered glass, one-fourth of their diameter in thickness, MM. Henry have not only succeeded in mounting them with all necessary rigidity free from flexure but have given them optically true plane sur­faces, notwithstanding their large diameters, viz., 11 and 157 inches. The present writer tested the equatorial coudé on double stars at the Paris observatory in 1884, and his last doubts as to the practical value of the instrument were dispelled. He has never seen more perfect optical definition in any of the many telescopes he has employed, and certainly never measured a celestial object in such favourable conditions of physical comfort. The easy position of the observer, the convenient position of the handles for quick and slow motion, and the absolute rigidity of the mounting leave little to be desired. In future instruments the object-glass will be placed outside the mirror N, so that both the silvered mirrors will be protected from exposure to the outer air, and probably will retain the brilliancy of their surfaces for a long period.

*Adjustment of the Equatorial.*

Let us take the usual case, that of an equatorial of type C. (1) By means of an azimuth compass, or, better, by the shadow of a plumb line at apparent noon, lay down a meridian line on the upper surface of the stone pier, or other foundation, previously built for the instrument. (2) Employ this meridian line to set up the instrument and with it the polar axis approximately in the azimuth of the meridian, which can be tested by stretching a wire through the centres of the bearings of the polar axis, and dropping a plumb line from the extremities of the wire upon the meridian line. If this is carefully done when the azimuth adjustment is near the middle of its range all desirable accuracy in this preliminary de­sideratum will be secured. (3) Place the polar axis approximately at the altitude of the pole. This is very easily done for an instru­ment in which the polar axis is cylindrical or is encased in a box with an upper side parallel to that axis (as in Grubb’s or Cooke’s equatorials). Prepare a right-angled triangle of wood of which the acute angles represent the latitude and co-latitude of the place. Lay the hypothenuse of this triangle upon the line of the instru­ment parallel to the polar axis (or the wire of operation 2) with the angle equal to the co-latitude next to the elevated pole, and change the inclination of the polar axis till a mason’s level placed on the side of the triangle opposite to the angle of the latitude shows the side in question to be horizontal. (4) Adjust the movable micro­meter web to coincidence with the axis of the position circle by bi­secting the image of a distant object and reading the number of revolutions or fractions of a revolution at two different readings of the position circle 180° apart. The mean of these two readings is the reading for coincidence with the axis of the position circle. Set the micrometer to this mean. (5) Adjust the polar axis more exactly to the required altitude as follows. Point the telescope to a well-known star not far from the equator and near the meridian, and turn the position circle so that the image of the star by the diurnal motion runs along the web. Read the declination circle. Now reverse the telescope to the other side of the polar axis and bisect the same star again, and again read the declination circle. The mean of the two readings is the star’s instrumental apparent declination ; the difference of the two readings is twice the index error. To eliminate this latter it is only necessary to shift the vernier of the declination circle by the screws provided for the purpose, without unclamping in declination, till the circle reads the star’s instrumental apparent declination. This being done, select another star near the meridian and compute its apparent declination (allowing for refraction). Set the telescope to this com­puted reading and clamp in declination ; then cause an assistant to change the altitude of the polar axis (by the screw for the purpose) till the star is bisected by the micrometer wire. (6) Select any convenient known star about six hours from the meridian ; compute its apparent declination (allowing for refraction) ; and set the tele­scope to this reading in declination. Cause the assistant to turn the slow motion in azimuth till the image of the star is bisected by the micrometer web. (7) Repeat operation 5 and make final corrections if necessary. (8) Repeat operation 6 with stars both east and west of the meridian, and readjust azimuth if necessary. (9) Turn the position circle of the micrometer 90° ; place the declination axis nearly horizontal ; clamp the telescope in right ascension ; and ob­serve the time of transit of a known star across the web of the micrometer. Compute the true hour angle of the star from the known error of the micrometer and the star’s right ascension, and set the vernier so that the hour circle shall read the computer hour angle. By these means, with a previously prepared pro­gramme, the writer has frequently completely adjusted an equa­torial in less than an hour, so far as operations 4 to 9 were concerned.

There still remain two instrumental errors of the stand. (1) The line joining the optical centre of the lens with the axis of rotation of the position circle may not be at right angles to the declination axis. (2) The declination axis may not be at right angles to the polar axis. In modern equatorials it is usual to leave these adjustments to the maker, as to leave them to the astronomer would be incompatible with the greatest stability of the instrument. In a good instrument these errors will certainly be extremely small and have no influence on its efficiency for practical purposes. The methods for determining their amount are given in most works on practical astronomy.@@1

There remain two important optical adjustments which must be very carefully attended to, viz., the centring of the lenses of the object-glass relative to each other and the centring of the axis of the object-glass relative to that of the eye-piece. The former consists in placing the lenses of the object-glass so that the centres of curva­ture of their surfaces shall lie in one straight line, whieh line is the axis of the object-glass. This operation is so delicate and requires such special experience and skill that it should be left to the maker of the object-glass. An elegant method of testing this adjustment was given by Wollaston in *Phil. Trans.,* 1822, p. 32. If the object­glass itself is perfectly centred, the test of the centring of its axis with that of the eye-piece is very easy : are the diffraction rings which surround the image of a bright star shown as in fig. 33, or is there flare, that is, are the rings extended on one side as in fig. 34 ? If the latter is the case, that side of the object-glass towards which the flare is directed is too far from the eye-piece, and should be brought towards it by the appropriate screws or other means provided by the maker. In a good object­glass perfectly centred, on a night of steady de­finition, a bright star in focus should appear as in fig. 33.

A useful apparatus for the adjustment of cen­tring is a small telescope (fig. 35) whose axis is in the centre of and at right angles to a flat piece of brass in the shape of an equilateral triangle fitted with screws at the three angles. To use this in­strument, place the points of the screws on the object-glass as in fig. 36, so that two angles of the triangle are in contact with the inner edge of the cell of the object-glass, and adjust the screw *a* so that the cross-wires in the common focus of the object­glass and eye-piece of the small telescope coincide with the image of the cross-wires of the micro­meter of the telescope which mark the axis of rotation of the position circle. Now, keeping the same angles of the brass triangle in con­tact with the cell, move the small centring telescope round the cir­cumference of the object-glass and note where there is the greatest de­parture from coincidence. Correct this departure half by the screw *a* of the small centring telescope and half by the centring screws of the object-glass. The adjustment is perfect when the centring telescope can be moved round the whole periphery of the object-glass in the above manner whilst its cross-wires continue to bisect the cross-wires of the micrometer of

@@@1 Chauvenet, *Practical and Spherical Astronomy,* vol. ii. pp. 379-390 ; Brunnow, *Spherical Astronomy,* p. 445 ; and Loomis, *Practical Astronomy,* pp. 28-32.