better two close parallel threads of spider's web, with which the distance of a division line from the centre of the field can be measured, the drum of the screw being divided to single seconds of arc (0". 1 being estimated) while the number of revolutions are counted by a kind of comb in the field of view. The periodic errors of the screw must be investigated and taken into account, and care must be taken that the microscopes are placed and kept at such a distance from the circle that one revolution will corre­spond to 1', the excess or defect (error of run) being determined from time to time by measuring standard intervals of 2' or 5' on the circle.

The telescope consists of two slightly conical tubes screwed to the central cube of the axis. It is of great importance that this connexion should be as firm and the tube as stiff as possible,@@1 as the flexure of the tube will affect the declinations deduced from the observations. The flexure in the horizontal position of the tube may be deter­mined by means of two collimators or telescopes placed horizontally in the meridian, north and south of the transit circle, with their object glasses towards it. If these are pointed on one another (through holes in the central cube of the telescope), so that the wire-crosses in their foci coincide, then the telescope, if pointed first to one and then to the other, will have described exactly 180o, and by reading off the circle each time the amount of flexure will be found. Μ. Loewy has constructed a very ingenious apparatus@@2 for determining the flexure in any zenith distance, but generally the observer of standard stars endeavours to eliminate the effect of flexure in one of the following ways :—either the tube is so arranged that eye-piece and object-glass can be interchanged, whereby the mean of two observations of the same star in the two positions of the object-glass will be free from the effect of flexure, or a star is not only observed directly (in zenith distance Z), but also by reflexion from a mercury trough (in zenith distance 180o - *Z*), as the mean result of the Z.D. of the direct and reflexion observa­tions, before and after reversing the instrument east and west, will only contain the terms of the flexure depending on sin2*Z*, sin4*Z*, &c. In order to raise the instrument a reversing carriage is provided which runs on rails between the piers, and on which the axis with circles and telescope can be raised by a kind of screw-jack, wheeled out from between the piers, turned exactly 180°, wheeled back, and gently lowered on its bearings.

The eye end of the telescope has in a plane through the focus a number of vertical and one or two horizontal wires (spider lines). The former are used for observing the transits of the stars, each wire furnishing a separate result for the time of transit over the middle wire by adding or subtracting the known interval between the latter and the wire in question. The intervals are determined by observing the time taken by a star of known declination to pass from one wire to the other, the pole star being best on account of its slow motion.@@3 The instillment is provided with a clamping apparatus, by which the observer, after having beforehand set to the approximate declination of a star, can clamp the axis so that the telescope cannot be moved except very slowly by a handle pushing the end of a fine screw against the clamp arm, which at the other side is pressed by a strong spring. By this slow motion the star is made to run along one of the horizontal wires (or if there are two close ones, in the middle between them), after which the microscopes are read off. The field or the wires can be illuminated at the observer’s pleasure ; the lamps are placed at some distance from the piers in order not to heat the instrument, and the light passes through holes in the piers and through the hollow axis to the cube, whence it is directed to the eye-end by a system of prisms.@@4

The time of the star’s transit over the middle wire is never exactly equal to the actual time of its meridian passage, as the plane in which the telescope turns never absolutely coincides with the meridian. Let the production of the west end of the axis meet the celestial sphere in a point of which the altitude above the horizon is *b* (the error of inclination), and of which the azimuth is 90°- *a* (the azimuth being counted from south through west), while the optical axis of the telescope makes the angle 90o + *c* with the west end of the axis of the instrument, then the correction to the observed time of transit will be (*a) [(*sin*ϕ*-δ)/(cosδ)] + (b)[(cos*ϕ*-δ)/(cosδ)]*+ c* secδ ,

where *φ* is the latitude of the station and δ the declination of the star (see Geodesy, vol. x. p. 166). This is called Tobias Mayer’s formula, and is very convenient if only a few observations have to be reduced. Putting *b* sin *φ - a* cos *φ = n,* we get Hansen’s for­

mula, which gives the correction = *b* sec *φ + n* (tan δ - tan *φ)+c* sec δ, which is more convenient for a greater number of observations. The daily aberration is always deducted from *c*, as it is also multiplied by sec δ (being 0".31cos*φ*secδ). The above correc­tions are for upper culmination ; below the pole 180° - δ has to be substituted for δ. The constant *c* is determined by pointing the instrument on one of the collimators, measuring the distance of its wire-cross from the centre wire of the transit circle by a vertical wire movable by a micrometer screw, reversing the instrument and repeating the operation, or (without reversing) by pointing the two collimators on one another and measuring the distance of first one and then the other wire-cross from the centre wire. The inclin­ation *b* is measured directly by a level which can be suspended on the pivots. Having thus found *b* and c, the observation of two stars of known right ascension will furnish two equations from which the clock error and the azimuth can be found. For finding the azimuth it is most advantageous to use two stars differing as nearly 90° in declination as possible, such as a star near the pole and one near the equator, or better still (if the weather permits it) two successive meridian transits of a close circumpolar star (one above and one below the pole), as in this case errors in the assumed right ascension will not influence the result.

The interval of time between the culminations or meridian transits of two stars is their difference of right ascension, 24 hours corresponding to 360° or 1 hour to 15°. If once the *absolute right ascensions* of a number of *standard stars* are known, it is very simple by means of these to determine the R.A. of any number of stars. The absolute R.A. of a star is found by observing the interval of time between its culmination and that of the sun. If the inclination of the ecliptic (ε) is known, and the declination of the sun (δ) is observed at the time of transit, we have sin *a* tan ε = tanδ, which gives the R. A. of the sun, from which together with the observed interval of time corrected for the rate of the clock, we get the R.A. of the star. Differentiation of the formula shows that observations near the equinoxes are most advantageous, and that errors in the assumed ε and the observed δ will have no influence if the ∆α is observed at two epochs when the sun’s R.A. is A and 180-A or as near thereto as possible. A great number of observations of this kind will furnish materials for a standard catalogue ; but the right ascensions of many important catalogues have been found by making use of the R.A.’s of a previous cata­logue to determine the clock error and thus to improve the indi­vidual adopted R.A.’s of the former catalogue.

In order to determine absolute declinations or polar distances, it is first necessary to determine the co-latitude (or distance of the pole from the zenith) by observing the upper and lower culmination of a number of circumpolar stars. The difference between the circle reading after observing a star and the reading corresponding to the zenith is the zenith distance of the star, and this plus the co-latitude is the north polar distance or 90° - δ. In order to determine the zenith point of the circle, the telescope is directed vertically downwards and a basin of mercury is placed under it, forming an absolutely horizontal mirror. Looking through the telescope the observer sees the horizontal wire and a reflected image of the same, and if the telescope is moved so as to make these coincide, its optical axis will be perpendicular to the plane of the horizon, and the circle reading will be 180° + zenith point. In observations of stars refraction has to be taken into account as well as the errors of graduation and flexure, and, if the bisection of the star on the horizontal wire was not made in the centre of the field, allowance must be made for curvature (or the deviation of the star’s path from a great circle) and for the inclination of the hori­zontal wire to the horizon. The amount of this inclination is found by taking repeated observations of the zenith distance of a star during the one transit, the pole star being most suitable owing to its slow motion.

*Literature.—*The methods of investigating the errors of a transit circle and correcting the results of observations for them are given in Brünnow’s and Chauvenet’s manuals (see Time). For detailed descriptions of modem transit circles, see particularly *Annalen der Sternwarte in Leyden* (vol. i.), the *Washington obsecrations* for 1865, and the *Publications* of the Washbum observatory (vol. ii.). The Greenwich circle is described in an appendix to the *Greenwich Observations* for 1852. (J. L. E. D.)

TRANSMIGRATION. See Metempsychosis. TRANSPORTATION. See Prison Discipline. TRANSUBSTANTIATION. See Eucharist.

TRANSVAAL, or South African Republic, a country in South Africa, northernmost of the European states, lying between 22° 15' and 28° S. lat., and 25° and 32° 10' E. long., is bounded N. and N.W. by the Limpopo, separat­ing it from the Makalaka and Bamangwato countries ; W. partly by the Marico and the Hart, partly by an irregular line between these streams, separating it from the new British protectorate of Bechuanaland ; S. by the Vaal and the Buffalo, separating it from the Orange Free State and

@@@1 Reichenbach supplied his tubes with counterpoising levers like those on the Dorpat refractor (see Telescope, fig. 20).

@@@2 *Comptes Rendus,* vol. lxxxvii. p. 24.

@@@3 The transits are either observed by “eye and ear,” counting the second beats of the clock and comparing the distance of the star from the wire at the last beat before the transit over the wire with the distance at the first beat after the transit, in this way estimating the time of transit to 0s∙1; or the observer employs a “ chronograph,” and by pressing an electric key causes a mark to be made on a paper stretched over a uniformly revolving drum, on which the clock beats are at the same time also marked electrically.

@@@4 The idea of illuminating through the axis is due to Ussher, professor of astronomy in Dublin (d. 1790).