defects in annealing are very easily detected by means of the polari­scope. The polished disk is placed in light reflected from a polar­izing surface, such as a sheet of glass blackened at the back, and examined with a Nicol’s prism as an analyser. If the bright rings and black cross (see Light, vol. xiv. p. 613) are visible the disk is unfit for use ; but, since few disks are so perfectly annealed as not to show a trace of the black cross, such as show it in no marked degree may be safely employed. Perfect annealing has now become the most "difficult portion of the art of making optical glass, and large disks (more particularly of crown glass) are rejected by the optician more frequently for defects in annealing than for any other cause.

The disks having been selected, their refractive and dispersive powers determined, and the radii of curvature computed, it remains to convert the disks into lenses with surfaces of the required curva­ture, and to complete the object-glass. The work consists of five distinct operations—(1) rough grinding by a revolving tool supplied with sand and water ; (2) fine grinding with emery ; (3) polishing with oxide of iron, rouge, or putty powder, the grinder being faced with fine cloth, satin, paper, or—best of all—pitch ; (4) centring ; (5) figuring and testing. These processes are essentially of a tech­nical character, and can only be familiar to those who practise the art. The details would be out of place here, but are well described in a lecture delivered by Sir Howard Grubb at the Royal Institu­tion, 6th April 1886, and printed in *Nature,* 27th May 1886.

*Construction of Specula.*

The composition of metallic specula in the present day differs very little from that used by Sir Isaac Newton. Many different alloys have been suggested, some including silver, nickel, zinc, or arsenic ; but that which has practically been found best is an alloy of four equivalents of copper to one of tin, or the following pro­portions by weight :—copper 252, tin 117∙8. Such speculum metal is exceedingly hard and brittle, takes a fine white polish, and when protected from damp has little liability to tarnish. The process of casting aud annealing, in the case of the specula of the great Melbourne telescope, was admirably described by Dr Robin­son in *Phil. Trans.,* 1869, vol. clix. p. 135. Shaping, polishing, and figuring of specula are accomplished by methods and tools pre­cisely similar to those employed in the construction of lenses. The reflecting surface is first ground to a spherical form, the parabolic figure being given in the final process by regulating the size of the pitch squares and the stroke of the polishing machine. The pro­cess of testing is identical with that of an object-glass.

“ Soon after Liebig’s discovery of a process for depositing a film of pure metallic silver upon glass from a salt of silver in solution, Steinheil (*Gaz. Univ. d'Augsburg,* 24th March 1856), and later, in­dependently, Foucault (*Comptes Rendus,* vol. xliv., February 1857), proposed to employ glass for the specula of telescopes, the reflect­ing surface of the glass speculum to be covered with silver by Liebig’s process. These silver-on-glass specula are now the rivals of the achromatic telescope, and it is not probable that many tele­scopes with metal specula will be made in the future. The best speculum metal and the greatest care are no guarantee of freedom from tarnish, and, if such a mirror is much exposed, as it must be in the hands of an active observer, frequent repolishing will be necessary. This involves refiguring, which is the most delicate and costly process of all. Every time, therefore, that a speculum is repolished, the future quality of the instrument is at stake ; its focal length will probably be altered, and thus the value of the constants of the micrometer also have to be redetermined. Partly for these reasons the reflecting telescope with metallic mirror has never been a favourite with the professional astronomer, and has found little employment out of England. In England, in the hands of the Herschels, Rosse, Lassell, and De la Rue it has done splendid service, but in all these cases the astronomer aud the instrument-maker were one. The silver-on-glass mirror has the enormous advantage that it can be resilvered with little trouble, at small expense, and without danger of changing the figure. Its chief work has been done in the hands of Draper and Common, who were the engineers, if not the actual constructors, of their own instruments. Glass is lighter, stiffer, less costly, and easier to work than speculum metal. The silvered mirrors have also some ad­vantage in light grasp over those of speculum metal, though, aper­ture for aperture, the former are inferior to the modem object-glass. Comparisons of light grasp derived from small, fresh, carefully silvered surfaces are sometimes given which lead to illusory results, and from such experiments Foucault claimed superiority for the silvered speculum over the object-glass. But the present writer has found from experience and careful comparison that a silvered mirror of 12-inches aperture mounted as a Newtonian telescope (with a silvered plane for the small mirror), when the surfaces are in fair average condition, is equal in light grasp to a first-rate refractor of 10-inches aperture, or area for area as 2 : 3. This ratio will become more equal for larger sizes on account of the additional thickness of larger object-glasses and the consequent additional ab­sorption of light in transmission.

*Mounting of Telescopes.*

The proper mounting of a telescope is hardly of less importance than its optical perfection. Freedom from tremor, ease and deli­cacy of movement, facility of directing the instrument to any desired point in the heavens, are the primary qualifications. Our limits forbid an historical account of the earlier endeavours to fulfil these ends by means of motions in altitude and azimuth, nor can we do more than refer to mountings such as those employed by the Herschels, or those designed by Lord Rosse to overcome the en­gineering difficulties of mounting his huge telescope of 6 feet aper­ture. Both are abundantly illustrated in most popular works on astronomy, and it seems sufficient to refer the reader to the original descriptions.@@1

We pass, therefore, directly to the equatorial telescope, the instru­ment *par excellence of* the modern extra-meridian astronomer, and relegate to the article Transit Circle (*q.v.*)a description of those mountings in which the telescope is simply a refined substitute for the sights or pinules of the old astronomers. The equatorial in its simplest form consists of an axis parallel to the earth’s axis, called the “polar axis”; a second axis, at right angles to this, called the “declination axis” ; and a telescope fixed at right angles to the latter. In fig. 15 AA is the polar axis ; the telescope is attached to the end of the declination axis ; the latter rotates in bearings attached to the polar axis, and con­cealed by the telescope itself. The telescope is counter­poised by a weight attached to the op­posite end of the declination axis. The lower pivot of the polar axis rests on a cup bearing at C, the upper pivot upon a strong metal casting MM, attached to a stone pier S. A vertical plane passing through AA is therefore in the meridian, and, when the declination axis is horizontal, the telescope moves in the plane of the meridian by rotation on the declination axis only. Thus, if a graduated circle BB is attached to the declination axis, together with the necessary microscopes or verniers V,V for reading it (see Transit Circle), so arranged that when the telescope is turned on the declination axis till it is parallel to AA the vernier reads 0o or 90o, and when at right angles to AA 90o or 0°, then we can employ the readings of this circle to measure the polar distance or declination of any star seen in the telescope, and these readings will also be true (apart from the effects of atmospheric refraction) if we rotate the instrument through any angle on the axis AA. Thus one important attribute of an equatorially mounted telescope is that, if it is directed to any fixed star, it will follow the diurnal motion of that star from rising to setting by rotation of the polar axis only. If we further attach to the polar axis a graduated circle DD, called the “hour circle,” of which the microscope or vernier R reads 0h when the declination axis is horizontal, we can obviously read off the hour angle from the meridian of any star to which the telescope may be directed at the instant of observation. If the local sidereal time of the observation is known, the right ascension of the star becomes known by adding the observed hour angle to the sidereal time if the star is west of the meridian, or subtracting it if east of the meridian. Since the equatorial is un­suitable for such observations when great accuracy is required (see Transit Circle), the declination and hour circles of an equatorial are employed not for determination of the right ascensions and declinations of celestial objects, but for directing the telescope with ease and certainty to any object situated in a known position, and which may or may not be visible to the unaided eye, or to define approximately the position of an unknown object. Further, by causing the hour circle, and with it the polar axis, to rotate by clockwork or some other mechanical contrivance at the same angu­lar velocity as the earth on its axis, but in the opposite direction, the telescope will automatically follow a star from rising to setting.

Equatorial mountings may be divided into five types. (A) The pivots or bearings of the polar axis are placed at its extremities. The declination axis rests on bearings attached to opposite sides of the polar axis. The telescope is attached to one end of the declina­tion axis, and counterpoised by a weight at the other end, as in fig. 15. (B) The polar axis is supported as in type A ; the telescope is placed between the bearings of the declination axis and is mounted symmetrically with respect to the polar axis ; no counter­poise is therefore requisite. (C) The declination axis is mounted on the prolongation of the upper pivot of the polar axis ; the tele­scope is placed at one end of the declination axis and counter­poised by a weight at the other end. (D) The declination axis

@@@1 Herschel, *Phil. Trans.,* 1795, vol. lxxxv. p. 347 ; Rosse, *Phil. Trans.,* 1840, p. 503, and 1801, p. 681.