fering with rays converging from the object-glass to any point in the field of view. A new feature in this instrument is the platform at the lower end of the polar axis, where an assistant can view the hour circle by one eye-piece and the declination circle by another (looking up the perforated polar axis), and where he can also set the telescope to any hour angle by one wheel, or to any declination by a second, with the greatest ease. The observer at the eye end can also read off the hour and declination circles and communicate quick or slow motions to the telescope both in right ascension and declina­tion by conveniently placed handles. The eye end presents an appearance too com­plicated to be figured here ; it has a mi­crometer and its illumination for the position circle, a micrometer head, and a bright or dark field,@@1 clamps in right ascension and declination and quick and slow motion in the same, a finder, microscopes for reading the hour and de­clination circles, an illumin­ated dial showing sidereal

time and driven by a galvanic current from the sidereal clock, and counter weights which can be removed when a spectroscope or other heavy appliance is added. All these, although making up an ap­parently complicated apparatus, are conveniently arranged, and are all necessary for the quick and easy working of so large an instrument. We have the authority of Otto Struve for stating that in practice they are all that can be desired. There is in this instrument a remarkably elegant method of relieving the friction of the polar axis. Let AA (fig. 27) be a section of the polar axis; it is then easy to adjust the weight P of the circles, &c., attached to its lower end so that the centre of gravity X of the whole moving parts of the instrument shall be in the vertical (VV) of a line passing through the apex of the hollowed flange *pq* at *q,* which flange forms part of the polar axis. If now a wheel W is forced up against *q* with a pressure equal to the weight of the moving part of the instrument, the whole weight of the moving

part would rest upon W in unstable equilibrium ; or if a pressure R, less than W, is employed, we have the end friction on the lower bearing removed to an extent = R sin *φ,* and the friction on the bearings of the upper pivot removed to the extent of F cos *φ,—* where *φ* is the latitude of the place. The wheel W is therefore mounted on a guided rod, which is forced upwards by suitable levers and weights, and this relief of pressure is precisely propor­tional to the pressure on the respective bearings. The Repsolds find it unnecessary to relieve the friction of the declination axis.

Fig. 28 shows the equatorial mounting which Grubb designed for the great object-glass of 36-inches aperture that Messrs Clark have completed for the Lick trustees, and which may be supposed to express Grubb’s latest ideas as to the mounting for a very large telescope. The Repsolds have a large driving circle at the upper end of the polar axis, thus avoiding torsion of the polar axis at the expense of greatly increased length of the cross-head. Grubb

by employing a driving arc gets the telescope much closer to the polar axis with an increased radius for driving, and he makes the polar axis a very large hollow steel or cast-iron cylinder in which torsion is insensible. Both Grubb and the Repsolds seem to think that for the tube of the telescope all necessary rigidity can be attained with cylindrical tubes of riveted steel, the thickness of the successive sheets of which dimin­ish from the centre-piece out­wards without making the extremities cone- shaped.

In these very large tele­scopes the

arrangements for giving access to the eye end and for following its diurnal motion have hitherto proved a source of difficulty. The travelling stages of the new Pulkowa telescope are the most man­ageable and practical that have yet been contrived, but even they leave much to be desired. For energetic work the standing posi­tion is best, provided that the eye-piece is situated at the precise height above the stage which is most convenient for the observer, and that the altitude of the observed object is not greater than 60o. For altitudes above 60o a small chair with a back, the top of which is stuffed for the head to rest upon, is the best seat, provided that the observer’s eye can be kept at the height of the eye-piece. Accordingly Grubb has suggested the following plan for the observatory at Mount Hamilton, California, which is to cover the Lick telescope. The whole floor, 70 feet in dia­meter, is to be raised or lowered by water-power under control of the observer by means of electric keys, which act on a secondary piece of mechanism, that in turn works the valves and reversing gear of the water-engines. Other water-engines, similarly con­nected with keys at the observer’s hands, rotate the dome and per­form the quick motions in right ascension and declination.@@2 By this arrangement a large instrument can be worked with perfect facility and comfort. There is only one other plan, that of suspend­ing the observer’s chair to the eye end, so that his eye is near the centre of motion of the chair. This is quite practicable for a 36- inch telescope, and one observer, with the necessary guiding keys at hand, could easily work a telescope and dome of the largest dimensions as quickly and with more ease than he could one of 10 or 12 inches aperture. Probably a nervous astronomer would prefer a solid floor to work upon, as in Grubb’s proposal ; in the latter case the quickest working can only be accomplished by two persons, one seated on the platform at the foot of the polar axis and doing the rough setting in right ascension and declination, the other meanwhile adjusting the height of the floor and the azimuth of the dome opening.

In very large equatorials there must be in existing methods con­siderable inconvenience from the extended width of the apparatus at the eye end. Were we called upon to design a great refractor we should abolish all such apparatus and provide the observer with a few conveniently placed small handles or keys for electrical connexions, and we should perform all motions of the telescope whatsoever by electromotors. There is no form of energy so con­venient for the astronomer. It provides by incandescent lamps the most suitable light for his purpose, perfectly constant, giving off little heat, and unaffected by wind ; and such a light can be placed where required without the aid of reflectors or any complicated apparatus, and its intensity can be regulated with ease and precision by changing the resistance of the conductors. Moreover the electromotors can be as powerful or as delicate as we please, and can be placed in the most convenient or suitable posi­tions. The energy of a 5-horse-power steam-engine working for ten hours can be stored in accumulators of no inconvenient dimen­sions ready for use as required during a whole week or even a month, and can be brought into action in force equivalent to several horse­power to raise or lower the floor or turn the dome, or to perform slow motions requiring no greater energy than that exercised by the finger and thumb, or to illuminate a lamp of ½ or ¼ candle­power. There would be no limit to the rigidity which could be given to such a telescope, as great ease of motion would not have

@@@1 There is also an elegant arrangement for printing on a ribbon of paper, by pressure of the linger, the readings of the number of revolutions and fractions of a revolution of the head at each observation, the ribbon being automatically moved forward for another record after each observation.

2 A woodcut showing these arrangements appeared in the *Engineer,* 9th July 1886.