ART. XXXIX.—*On a Hitherto Untried Form of Mounting, either Equatorial or Altazimuth, for a Telescope of exceptional size, either refractor or reflector, in which Telescope, observing-floor and dome are combined in one*; by DAVID P. TODD, Director Amherst College Observatory.

NEARLY all the great telescopes of the world have in turn signalized their extraordinary power by an important astronomical discovery. Sir William Herschel's reflector first brought to light the planet Uranus; Lord Rosse's Leviathan, the spiral nebulae; the 15-inch Cambridge telescope, Saturn's dusky ring; the 18-inch Chicago refractor, the companion of Sirius; the Washington 26-inch, the satellites of Mars; the 30-inch Pulkowa objective, the nebulosities of the Pleiades; and the 36-inch Lick telescope revealed a new satellite of Jupiter.

With such a record is it not safe to predict farther advance with larger telescopes still? There is as yet no indication that a refracting telescope of five or even six feet aperture would fall short of a gratifying success to its projector. Two American opticians, of wide experience and high competency, can be relied upon to grind and figure such an object glass. To be most effective, it must be as thin as possible—which means that its focal length must be very great. Therefore the question of a suitable mounting becomes all important.

The difficulties inherent to the conventional type of mounting practically prohibit any great increase of size, because the tube is hung at or near the middle. This is in many respects the least advantageous point. The tube should be rigidly supported at or near both ends, as well as in the middle. If, then, we invoke the fertile resources of the modern bridge engineer, and his relatively light but rigid constructions of steel, the fixedness of axis in all positions of the great telescope becomes a requisite easily met.

The object of this paper is to outline one method of applying modern engineering resources to the mounting of a telescope of exceptional proportions.

A sphere 100 feet in diameter can readily be designed and built, with an interior, meridional rib-structure so rigid that flexure deformation will not exceed a small fraction of an inch. We coat this sphere, first with steel plates, then with oak planks about three inches thick. These not only allow the exact spherical figure to be trued up, but also, like the wooden sheathing sometimes employed on men-of-war, permit attachment of an outer coating of copper,—or better still, of Tobin bronze.

We float this sphere, in such manner as to admit the utmost ease of motion in any required direction. Masonry of brick or stone is built, about 25 feet in depth, and perhaps 100 to 120 feet square. This is constructed in the shape of a zonal basin with Portland cement, and its interior is smoothed up to exact figure, by erecting a platform above the center of the basin, and swinging from it a convex trowel attached to a radial arm.

The sphere is of course assembled and erected piecemeal *in situ*. A small amount of wood-preserving liquid is added to the basin, as the sphere is built up; and this suffices to keep it always just floated, thus making it very easy to turn into any desired position for attaching one part after another. When the steel coating of the sphere is finished, the wooden jacket is next put on, the structure all the while floating in preservative, till this exterior of oak is complete and trued up to figure. Then the bright metal sheathing begins. When finished, the preservative is withdrawn, and water substituted therefor. Only a few barrels of water poured into the basin will be required to float the sphere and all its subsequent appurtenances. The water is made part of a circulatory system, and warmed in winter to prevent freezing.

If we are content with a telescope a little short of 100 feet in focal length, the object glass may be set in the surface of the sphere. On its opposite side, the eyepieces, spectroscopes, photographic cameras, and other accessories are capable of permanent and rigid attachment to its internal rib-work.

The observer is there, too; but free to move about on a swinging platform, a good model of which is furnished by the glass crystal of an ordinary ship's chronometer. The platform maintains itself always horizontal, no matter in what direction the axis of the telescope is pointed.

But a sphere of 100 feet diameter very readily admits the possibility of a telescope approaching 200 feet in length, if we attach a tube 100 feet long to the exterior of the sphere. This method of mounting the objective is illustrated schematically in the engraving (fig. 1).

At intervals of perhaps 30 feet, girdling rings are attached to this exterior tube, and to these are fastened guy-rods which anchor in the outside of the sphere, thereby holding the outer end of the tube rigidly in position, even if the weight of the objective in its cell should be as much as a ton.*

*The author is not unaware of certain objections to the design proposed, and others may be suggested. The effect of temperature inequality is one. An obvious objection arises from the vibration which it is natural to suppose a variable wind pressure would induce. But the open-air telescopes of Sir William Herschel, Lord Rosse, and Lassell were subject to this difficulty also. Experiment with a model of perhaps one-quarter or one-third the full size seems to the author the best method of testing the validity of these objections.

Tube, objective, and guy-rods are all counterpoised by means of permanent weights on the interior of the sphere, adjacent to the self-adjusting observer's platform (not shown). An objective weighing a ton is counterpoised by a mass of three tons. The mirror for a great reflecting telescope might form the counterpoise.

When not in use the sphere is revolved until the exterior tube comes down to a nearly horizontal position, and the objective is weather-proofed underneath a removable roof (not shown), something like that of a transit-room. The objective is then accessible in all weathers, for adjustment or other requisite service. With the tube in this position, the observer and his assistant enter the sphere through a door in the tube close to its juncture with the sphere itself. They walk along an internal *trottoir*, till they reach the adjustable platform. This is maintained always charged with its maximum load; if additional observers go in, their equivalent weight is removed from the platform, and deposited outside the sphere before observations begin. In this way, the sphere

is kept submerged to a constant depth—a requisite, the design of which will be apparent farther on. From this platform and out through the opening extends an electrical cable, with perhaps twenty independent circuits, each of which controls an exterior automatic apparatus, whose action very readily gives to the sphere any rapid motion that may be desired, as follows:

- (1) In altitude.
- (2) In azimuth.
- (3) In declination.
- (4) In right ascension.

These motions suffice for any necessary pointing of the telescope. I need not here go into the details of these automatic mechanisms further than to say, that the specified motions may be obtained by means of rubber-faced wheels, strongly mounted in swinging forks or levers (fig. 2), and

engaging the outer surface of the sphere. Three wheels for each coördinate, mounted in proper planes, all press against the outside of the sphere simultaneously, and electric motors then turn them at the speed required. The sphere can, of course, be revolved in but one coördinate at a time; and the cable connection enables the observer inside the platform to throw into gear any treble set of wheels he may desire.

Above the platform, or alongside it, are the automatic setting devices, one for the horizon system, and another for the equinoctial system of coördinates. At the zenith of each of these is an index, which shows, as a vernier on graduated circles, the pointing of the tube. These setting-systems are gimbal-mounted and pendulum-controlled, the antique armillary sphere furnishing the basis of their design.

A peculiar sort of finder is essential—with a duplex coudé tube, so that its eyepiece can be brought close to the eyepiece of the great tube.

Slight differences of poise in the sphere and its appurtenances are compensated through the instrumentality of radial rods, upon which travel masses of a few hundred weight, by means of rack-and-pinion motors. Thus the sphere's center of gravity is easily adjusted to exact coincidence with its center of figure.

Probably the moving sphere and all its accessories will weigh not far from 2000 tons, and it must be as susceptible of delicate adjustment and subsequent following-motion as is a telescope of the usual German or English type of mounting. Quite obviously such a great telescope will require clockwork of exceptional power.

Two or three methods of clock-motion are feasible: I will outline but one. A huge polar axis (fig. 3) is built into the exterior masonry due south of the sphere, and its upper end terminates in four arms, each of which carries a large shallow cup, of the exact spherical concave. These cups are faced on the inside with rubber belting; and when the chuck is in action—(telescope clamped in right ascension)—they push with a few hundred pounds stress against the sphere. Two rubber-faced wheels, on the northwest and northeast sides of the sphere, oppose the poleward thrust of the chuck. They are of course mounted parallel to the equatorial plane. We depend upon the polar axis and opposing wheels to preserve the axis of rotation of the sphere invariable. This axis passes in a constant direction through the center of figure of the sphere. We apply the clock power, not to the polar axis itself, but to an opposing pair of rubber-faced wheels, whose planes are coincident with the sphere's equator. There is thus the distinct advantage of a driving wheel 100 feet in diameter.

An electric motor, or gas engine electrically controlled, will be found well adapted to this delicate service; but in order that the movement may be perfectly steady, care must be taken to provide a considerable excess of the power actually necessary to set the sphere in motion.

I have given much attention to the question of slow motions. Several different schemes are possible, and all admit of automatic control and action through the multiplex cable. Should it be desired to maintain the utmost delicacy of adjustment in the field, for spectroscopic or micrometric work or long-exposure photography, it may be found best to provide a sliding collimator-plate, to which the tail-piece is rigidly attached. Corresponding and appropriate collimation of the objective would not offer any serious mechanical difficulties.

No one familiar with observatory construction will fail to notice that this projected type of instrument combines telescope, observing-chair and dome all in one. I have made an attempt to estimate the cost of such an astronomical establishment, but the largest present element of uncertainty pertains to the sphere itself.

As the sphere will not need the ordinary running-gear, we cannot be far wrong in estimating double the cost of a hemispherical dome. This will make,

Approximately	\$175,000
Allow for a 5-foot objective	75,000
For the masonry and cement basin	5,000
For the clock-work and motions	10,000
For the tube and eyepiece accessories	10,000
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	\$275,000

I need hardly add that some of the unique advantages of M. Loewy's equatorial coudé are available with this type of mounting; for by sealing the internal tube, the sphere or a part of it can be kept at a comfortable temperature by electric heaters. And if such a telescope were installed on a high mountain, the barometric pressure of sea-level might be mechanically maintained within a compartment of the sphere, housing over the adjustable platform. By connecting with exterior rooms through closed passage-ways, this might readily be so contrived as to safeguard the observer against those serious effects of *mal des montagnes*, which hitherto have precluded the permanent astronomical occupation of mountain elevations much in excess of 8,000 feet.

Amherst, Mass.