consequently the position of the contact plates, relative to the north-south axis of the compass card. The follow-up motor, in circuit with the contact plates and the pair of balls between them, now maintains such an angle between the north-south axis of the compass card and the spin-axle of the sensitive element that the latitude and the meridian-steaming errors of the sensitive element do not appear in the compass card indication. The probability of any failure to operate is reduced by the addition of a duplicate corrector system consisting of a second cosine cam Y' together with an additional pair of contact plates and pair of silver balls placed diametrically opposite the ones just described.

152. Avoidance of the Ballistic Deflection Error. — In the Florentia, as well as in all other gyro-compasses, the deflection of the spin-axle of the sensitive element from the meridian, that would be produced when there is a change in either the speed or course of the ship, is avoided by designing the instrument so that the period of the undamped azimuthal vibration back and forth is about 84 minutes when at the equator (Art. 113). At other latitudes the period should be less. The period of the Florentia gyro-compass is fixed by the makers so as to reduce to a negligible value the ballistic deflection error in the region in which most sailings are to be made. There is no device on the gyro-compass of 1924 by which the navigator can alter the period, nor any device for avoiding the ballistic damping error (Art. 114).

153. Avoidance of the Error Due to Rolling and Pitching of the Ship When on Intercardinal Courses. — Deflection of the spin-axle of the sensitive element from the meridian produced by rolling and pitching of the ship is much reduced by keeping the entire suspended system always nearly vertical, however the ship may roll or pitch (Arts. 115 and 117). This result is accomplished by making the phantom into a gyro-pendulum of long period.* The period of the conical oscillation of the phantom element about a vertical axis is increased to about 40 seconds by means of a gyro, *SG*, Fig. 197, having a mass of about 10 kg. and a moment of inertia of about 405,000 gm. cm.^{2} This stabilizing gyro not only increases the period of vibration of the phantom but also greatly reduces the amplitude of vibration. A top view of the entire instrument is given in Fig. 202.

The stabilizing gyro opposes any torque that tends to rotate the phantom about any axis inclined to its spin-axle. Consider

* U. S. Patent. Martienssen, No. 1493214, 1924.

the effect of a torque that tends to rotate the phantom element about an axis perpendicular to the plane of the diagram, Fig. 197. Such a torque causes the spin-axle of the stabilizing gyro to precess slowly about a horizontal axis in the plane of the diagram. The annular mercury trough is thereby slightly tilted but the mercury

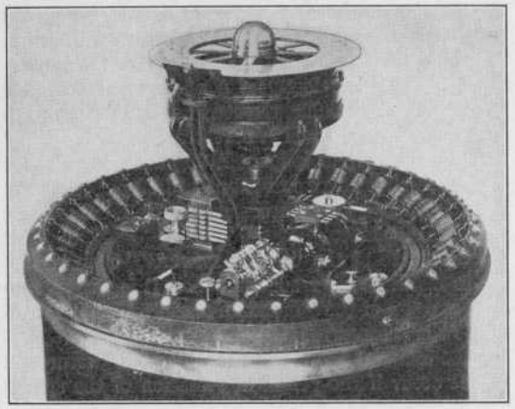

FIG. 202

surface remains practically horizontal. Consequently, the direction of the meridian-seeking gyro axle is unaffected by the precession or by the torque that produced it.

QUESTIONS

1. Would a gyroscope which is entirely free from friction about its separate axes align its spin-axis with the rotational axis of the earth when the gyro-axle is given an initial easterly or westerly displacement? Explain.
2. What are the controlling forces which convert a gyroscope into a meridian-seeking device?
3. Show why the spin-axle of a pendulous gyro-compass tends to set itself in the meridian plane and with the direction of spin in the same direction that the earth rotates, that is, clockwise as seen from the south.
4. Show why the spin-axle of a liquid-controlled non-pendulous gyro-compass tends to set itself in the meridian plane and with the direction of spin in the direction opposite the rotation of the earth, that is, counter-clockwise as seen from the south.
5. Show that each end of the spin-axle of an undamped gyro-compass moves in an elliptical path.
6. Describe three methods employed to damp the vibration of gyro-compasses back and forth across the meridian plane.
7. Show that the damping device used on the Anschütz gyro-compass is