Paper on the Testing of Parabolic Mirrors.

BY DR. E. P. HARRISON.

Messrs. S. K. Dhar & Bros., of Hughli, who manufacture mirrors for reflecting telescopes, have lent me the mirror which is exhibited this evening. It was tested by Babu Nagendra Nath Chatterji and myself in the Physical Laboratory at Presidency College, and the tests indicate that the figure of the mirror is excellent. The work of grinding and polishing seems to be very creditable to a local manufacturer.

It occurred to me that a short account of a method of testing telescope mirrors might be of interest to members who possess reflecting instruments, or who contemplate grinding their own mirrors. There are methods of testing which involve the calculation of what is called the aberration of the mirror, but for reasons of simplicity it is proposed to describe a more empirical process known as the "Shadow method."

The primary object and the chief difficulty in grinding and finishing a mirror for a reflecting telescope is to get a *spherical* figure. The sphere can afterwards be converted into the required paraboloid with comparative ease, but a sphere is the most satisfactory figure to start with.

The elementary theory of the shadow method of testing is, somewhat roughly, as follows :—

Several kinds of conicoid surfaces may result from the grinding of a glass or metal mirror :

(*i*) Prolate spheroids, which will be ellipsoidal surfaces of revolution, the major axis forming the principal axis of the mirror.

(*ii*) Spherical surfaces.

(*iii*) Oblate spheroids, which will be ellipsoidal surfaces, in which the minor axis of the ellipse becomes the principal axis of the mirror.

(*iv*) Paraboloids.

(*v*) Hyperboloids.

The diagram, Fig. 1, shows sections of a series of such surfaces, approximately drawn to indicate the general relation of one with another.

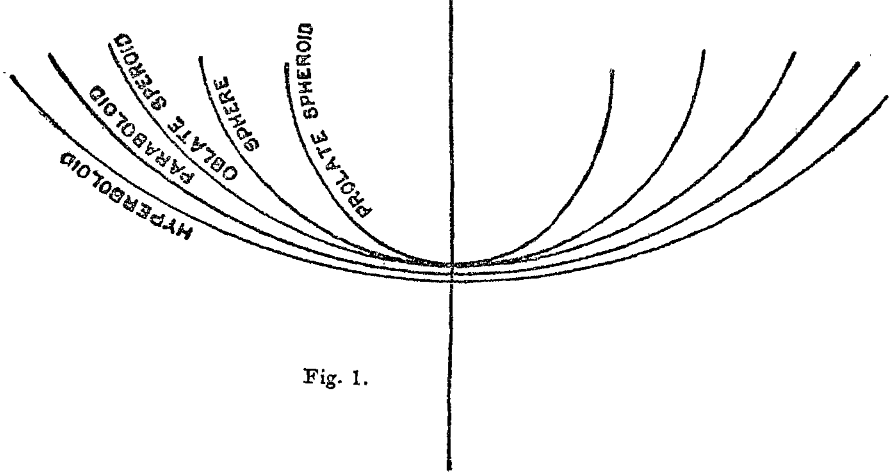

Fig. 1.

Suppose a mirror of true spherical form is placed so as to reflect light from a *small* aperture situated at its centre of curvature, the reflected beam will, as the properties of a spherical mirror indicate, "come to a focus" *at* that centre of curvature. Source and image will coincide.

Consider this focus. (Fig. 2.)

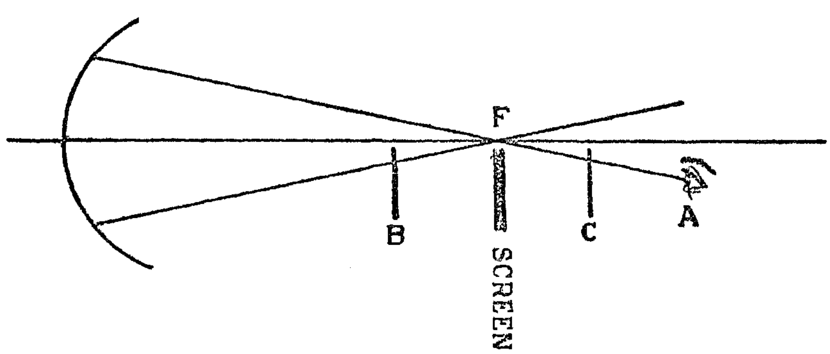

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Fig. 2.

If the eye is placed at A, and a screen put in *at the focus F*, the light will very suddenly be cut off and the mirror suddenly appear dark or uniformly illuminated.

Should the screen be introduced at B, the appearance of the mirror would be as in Fig. 3 (*a*), the shadow moving bodily over the mirror.

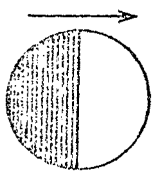


Fig. 3. (*b*).

Only when the screen is put in at the precise focus will there be *sudden* appearance or disappearance of illumination over the whole surface. By such means the focus can be located.

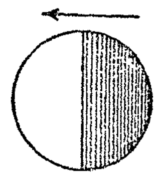


Fig. 3 (*a*).

Now consider a mirror whose figure is that of an oblate spheroid or flattened sphere. (Fig. 4.)

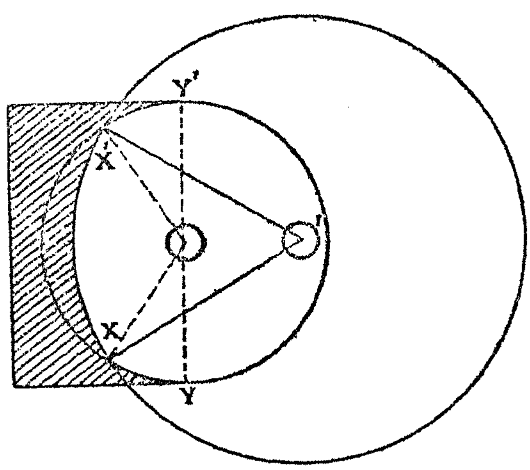


Fig. 4.

Its circumference may be considered as (*i*) part of a sphere of radius OX and centre O, and (*ii*) part of a sphere of radius O′X and centre O′.

This last forms the central portion of the mirror, while the sides X′ Y′ and XY are formed by the smaller sphere. The rays from the central portion of the mirror will come to a focus further from the mirror than those from the outside zones. Thus there will be no true centre of curvature as in the case of a sphere, but only a *mean centre* which will be between O and O′.

The appearance of the mirror, when illuminated by an artificial star placed at the mean centre of curvature, and looked at through an eye-piece placed also in that position, but somewhat eccentrically (and with part of the reflected rays cut off by a screen), would be no longer uniform. It would consist of a gradation of shadows and high lights at different parts of its surface; these shadows would, however, *suddenly* appear as the screen was introduced at the mean centre of curvature, and as suddenly disappear on removal of the screen.

There would be hills at the sides, hollows at X and X′ and a hill at the centre. The eccentric method of illumination would show up the high lights on the tops of the hills and emphasise the shadows in the hollows, so that we should expect the mirror to have the appearance of Fig. 5 when looked at in the way described.

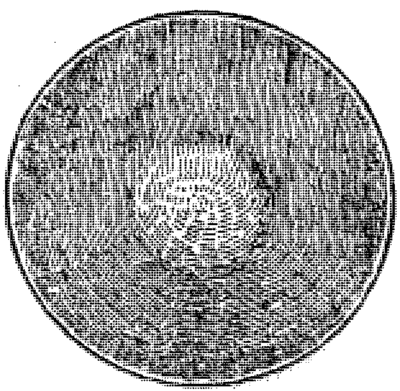


Fig. 5.

A section of the mirror-form could obviously be obtained from this shadow-diagram, and would be somewhat as shown in Fig. 6.

Fig. 6.

Accordingly, to make such a mirror spherical, we should have to grind away the hill in the centre and also the hills at the periphery. The resulting shadow-diagram would then be quite uniform, provided the true spherical figure had been obtained.

Next consider a mirror of hyperbolic type. This will differ from the oblate spheroid just discussed, in having a *depressed* central portion. The side portions (Fig. 7) have their focus further away from the mirror than the central portions.

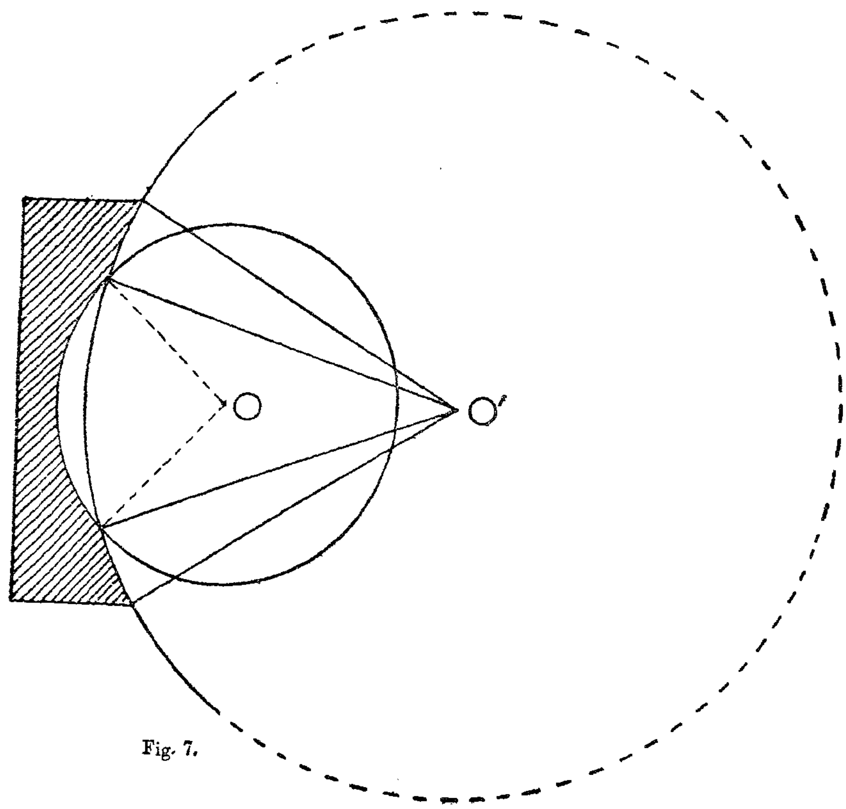
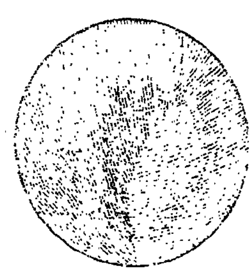


Fig. 7.

Fig. 8.



The figure, though much exaggerated, shows the hills in a zone near the circumference and a hollow near the centre. The shadow-diagram or appearance of the mirror, when illuminated by an artificial star and viewed from the centre of curvature, would then be as shown in Fig. 8, and the corresponding section of the mirror could be prepared and would be somewhat as shown in Fig. 9.

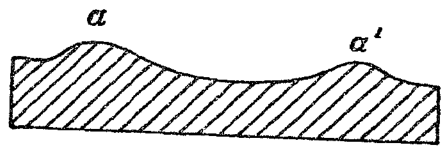


Fig. 9.

To make a hyperbolic mirror spherical, therefore, we should have to grind away the hills a a' (Fig. 9).

We are now in a position to perform an actual test on a mirror of unknown figure.

A bright source of light, such as a pin-hole in a metal lamp chimney, to serve as an artificial star, is placed at the mean centre of curvature of the mirror and rather eccentrically (*i.e.*, "off" the principal axis of the mirror). An eye-piece is placed with its focal plane at the same distance from the mirror as the artificial star. An opaque screen, gradually passed across the field of the eye-piece from left to right serves to locate the mean centre of curvature in the way described above.

If after these adjustments have been made the appearance of the mirror is like Fig. 5, an oblate spheroid is indicated, whose figure is flatter than the sphere and less flat than the paraboloid. If the appearance is like Fig. 9, an over-corrected or hyperboloid figure is indicated.

The actual section of the mirror can be deduced from the shadow-diagram in either case, and the mirror treated accordingly. The parabolic figure will be somewhere between the spheroid and hyperbola. It will show all the characteristics of a hyperbolic figure *but very faintly*, and has very suitably been described as a "study in greys."

A Query.

BY R. MADHAVA RAU.

On the 25th of March (night), when I was standing in the verandah of my house talking to my brother, I noticed a very