VIII.—*On the Advantages to be derived from the Use of Metallic Reflectors for Sextants and other Reflecting Instruments ; and on Methods of directly determining the Errors in Mirrors and Sun-Shades used in Reflecting Instruments.* By JOHN ADIE, Esq.

(Read February 17. 1845.)

It has frequently occurred to me that the difficulty experienced by instrument-makers, in obtaining for sextants and other similar instruments, reflecting mirrors perfectly parallel in their polished surfaces, and also the greater difficulty of procuring glass perfectly homogeneous in its structure, might be overcome by the use of metallic reflectors.

It is well known, that, from the want of perfect parallelism in glass mirrors, there arises an error in the reading of such instruments, inasmuch as the emergent ray does not pass out of the glass at the same angle as the incident falls upon it, and that from the want of homogeneousness in the substance, and the unequal refractions caused by the veined structure of the glass.

Whether this structure of the glass arises from the process of its manufacture, or the want of proper admixture of the component parts, before being cast into plates, I am not prepared to say ; but in all the plate-glass I have tried, by polishing it on the edges, this structure was observed ; so much so, that the plates, on being seen through perpendicularly to the plane of their surface, shewed objects perfectly distinct ; while objects, when viewed through the glass at right angles to this plane, were seen with difficulty, distorted and twisted in all directions. Of such glass, the mirrors of sextants, and other reflecting instruments, are made ; and it is easy to conceive how very erroneous the angles may be, particularly when the incident ray falls on the mirror at a low angle, as it does when large angles are observed, as in lunar distances and the like ; while the indistinctness of the image observed under these circumstances, detracts much from the utility of instruments fitted with such mirrors. As a practical illustration of the above, if we take a number of objects, and observe with a sextant the angles between each, then observe the angle between the extremes, suppose this 120° , it will be found, in the great majority of cases, that the sum of the angles observed does not agree with the observed angle of the extremes, which should be the case.

These errors, and sources of error, are obviated when we make use of metallic reflectors, having their surfaces polished perfectly flat ; a matter of no very difficult attainment in practice.

But, besides the avoidance of error, there are direct advantages in the use of such reflectors, which may be stated thus:—In the marine sextant, or reflecting circle, the reflection of faint objects is more easily obtained; in other words, objects are seen reflected by metallic mirrors which cannot be seen by the ordinary silvered ones. Another advantage is, that larger angles can be observed. This applies more particularly to the pocket or box-sextant, used in surveying, both at sea and land. From the small size of the index mirror, we cannot, when glass is used, reflect an angle much above 100° , the thickness of the glass cutting off the incident and emergent rays, when these fall on the silvered surface at low angles; whereas, with the metallic reflector, the reflected angle can be obtained to its utmost limit, or to about 140° , being nearly one-half greater than that which can be obtained by means of a silvered glass reflector.

I am not aware of any account having appeared of the use of metallic mirrors heretofore in the construction of such instruments, although I have little doubt, from the obvious advantages attending them, that the idea must have suggested itself to many others; and that the fact of their not having been brought into use, must be accounted for from the difficulty of obtaining speculum metal possessed of the requisite qualities.

The liability of a highly-polished reflecting surface to be destroyed by tarnish and rust, from exposure to the atmosphere, and more particularly from exposure to the influence of sea air, is an objection that occurs on first view to the use of metal.

All who are acquainted with the reflecting telescope, know how subject the mirrors of such an instrument are to deterioration from tarnish; and that, in many cases, even when due care has been taken of them, they have been altogether destroyed. Yet, it should be stated, that this is not the case with all such instruments. There are many reflecting telescopes, now very old, in which the mirrors are in a state of perfect preservation; those I am best acquainted with, as having stood the test of time (and they are in general very good), having been made by the late James Short of London, who lived about eighty years ago. On the other hand, it is well known, that many speculum metals will not retain their lustre for many weeks under ordinary exposure.

From these facts, we may infer, that it is the composition of the metal which causes the difference in the permanency of the polish.

My attention was therefore directed to procuring pure metals to form the alloy or speculum metal. Tin is not difficult to be had in a state of great purity; but it is otherwise with copper; for, as we advance in commerce, we find, that, day after day, this metal is brought to market more and more impure; so much so, that bar and cake copper of commerce are now so bad that they are nearly unfit for compounding as brass.

The recently discovered process of electrotpe, however, affords us the means

of easily procuring copper in a state of purity; and it is with the metal so procured my experiments have been made.

By compounding copper and tin in their atomic proportions of 16 parts of copper to 14.92 parts tin, a metal of high lustre is obtained; and, so far as my experiments have gone, this metal is not liable to tarnish, if ordinary care be taken to guard against this effect. My course of procedure was as follows:—I first exposed polished pieces of this metal to the free open air, and found, after some months' exposure, that, when the dust and rain stains were rubbed off, the surface was in a very good state of preservation. I next tried exposing the mirrors to the fumes of acids, and watering them with sea water for a considerable length of time. Under the operation of these corrosive agents, they still retained their lustre. But, notwithstanding the encouragement held out from these experiments, feeling yet reluctant to put such instruments into the hands of navigators without first submitting them to the test of actual service; and a favourable opportunity having last spring presented itself, through the kindness of Mr O. MOSSMAN, one of the surveyors on board of H.M. Ketch, Sparrow, then about to engage in a survey of the Pentland Firth, I put into the hands of that gentleman a sextant fitted with these metallic reflectors, of which he politely took charge, promising to give it a fair trial during a season's survey. Mr MOSSMAN amply redeemed his promise; and I shall now take the liberty of quoting the letters which he was good enough to address to me, giving an account of the working of the instrument.

“H.M. KETCH, SPARROW,

THURSO, 26th October 1844.

“DEAR SIR,—After you have examined the reflectors you will be able to judge of the durability of them, after being in constant use for most part of the season, during which, they have been exposed to all sorts of weather. As regards the power of their reflection (although dark), they are beyond all the silvered glasses I have ever had in use; also, for measuring large or small angles, they excel the others by far. When we are once properly settled at Portsmouth, I shall be able to make a full descant of the good properties of your metallic reflectors, and shall strongly recommend them to be in all reflecting instruments. I have subjected them to all exposure which I could call fair play, only, at the same time, having been careful not to put the instrument away damp.—Yours truly,

(Signed) “WM. O. MOSSMAN.”

In a second letter, dated Portsmouth, 13th December, Mr MOSSMAN says:—
“I am sorry my spare moments are rather scarce, or I should have said something more concerning the merits of your metallic mirrors. However, I should very strongly recommend them to be used in all instruments that are likely to be exposed to much wet; because, if the instrument fall overboard, for instance, and

does not lie so long in the water as to allow the rust to commence, if it be carefully wiped dry, when taken out, there is no danger of spoiling afterwards. Now, this is a very important matter, and more particularly to surveyors, than any other class of nautical men; for such accidents frequently occur in boat-soundings."

I come now briefly to notice the second subject announced in the title of this paper, viz., direct methods of determining the errors in the mirrors and sun shades used in reflecting instruments. I am not aware of any method adopted by practical men for the discovery of such errors, except that of a careful process of what is termed parallel grinding, and testing the glasses in the instrument when fitted up. This is effected by observing known angles, and noting that a contact of the sun's limb, by reflection, does not vary on changing the sun shades interposed between the direct and reflected images seen in the telescope. This variation is noticed by Mr M'KAY, in his work on Determining Longitude, and he recommends that it should be observed and applied as an index error affecting the several shades. Errors may, however, exist in the reflectors and shades, which, from the particular position they have in their settings, are not discovered by such trials. The methods I have adopted are as follows:—

First, For the mirrors I place a mirror at about an angle of 45° before the object-glass of a telescope, mounted on a divided circle, capable of reading an angle of $10''$; I have, besides, a moveable micrometer wire at the stop holding the cross wires of the telescope, by which an angle of one second may be observed; the mirror placed before the object-glass rests on three smooth studs, to which it is pressed up by a light spring at the back. In this position we turn the telescope and mirror in azimuth till we obtain the reflection of a well-defined distant object, which is brought to the intersection of the cross wires of the telescope. If we now turn round, or reverse the mirror on these studs, and find the same object in the intersection of the cross wires, we know that in that line there is no want of parallelism; and if we have the same result on repeating the trial at right angles to the first direction, the mirror is said to be perfect in respect to the parallelism of its surfaces. If, however, we find on turning the mirror that the reflected object is not intersected by the cross wires, then, the glass is not parallel; and half the amount of error read by the circle or micrometer head, is the error which would arise if such a mirror were applied to a sextant.

Second, For the sun shades I have a telescope whose object-glass is divided, and the one-half moved over the other by means of micrometer screws, having a divided head. The value of the divisions of the micrometer head is obtained by measuring the sun's diameter. In that which I use, two divisions on the head are equal to one second.

Before one-half of the object-glass is placed a fixed sun shade; and before

the other, an arrangement is made for placing the shades to be tested in such a way that they can be turned round. Having placed in this frame a shade for trial, I bring the two images of the sun seen in the telescope into contact, by means of the micrometer screws; and if, on turning the shade before the object-glass, the contact remains perfect, then we know that its surfaces are parallel; if, on the other hand, the contact is broken, we can, by turning the shade, find the point of nearest contact; and by turning the shade through 180° , we measure the amount of opening of the images, by means of the divided micrometer head. This gives double the error which would be caused by the shade when used in making a direct observation. But as all angles observed by reflecting instruments are double, or, in other words, the divisions on the limbs of reflecting instruments are equal only to half those of an instrument used for direct observation, the double error given by this method goes all to deteriorate the observation, as an unparallel shade affects the angle when reflected by twice the amount of direct observation. Another important object is gained by this method of testing the shades. It being a very difficult matter to obtain these altogether perfect, I reject all where the error would amount to $10''$, which is the usual reading of a sextant; and when an error of a smaller amount does exist, I find, by turning the shade, the line in which the want of parallelism exists; and by placing this line at right angles to the plane of observation in a reflecting instrument, the angles observed by such an instrument are not affected even by the small error of the shade.