rays become visible on the moon; and this is the point which I wished to bring forward this evening. I have 3 records of the rays having been seen even at the dark part of the moon, and that goes to show that these rays do not change physically, but that the variation is merely a question of waxing or waning light. The rays have also been seen by me in the Earth-light as well as on occasions of a total eclipse of the moon.

Mr. Simmons.—Do you think this explanation applies to the white spots also ?

The President.—There is a probability that it does. The only thing about a white spot is, as a rule, that it is an elevation, but taking this into account the same thing ought to apply to a mountain range or a slope.

The President.—Before we close our meeting this evening I would mention that we have a rule about the election of the Council, and names proposed by members will have to be sent in by the next meeting, which will end the present session. A list of members will be sent to members with the next number of the JOURNAL.

The President then adjourned the Meeting to Tuesday the 27th June 1911 at 5 p.m.

On the Construction of Glass Specula for Reflecting Telescopes.

BY N. N. DHAR.

Reflecting telescopes have been popular with amateurs and are likely to be so, I may say, always. The reason is that they are easier to make; I mean the principal part of them, namely, the object mirror or speculum. Besides, as the object mirror forms the image by reflection, there is no colour trouble due to what is called "chromatic aberration," which is a source of annoyance with refracting instruments.* Another great advantage with reflectors is (in the case of their most popular form, the Newtonian) that the observer is always comfortable in his position, as he has never to look up but always looks down or straight forwards. In these few introductory remarks, I do not

* Reflectors are not, however, altogether free from chromatism, which is introduced more or less by the lenses in the eye-piece.

propose to institute any comparison between the two forms of instruments, the reflector and the refractor, but I only state the reasons why reflectors are popular with amateurs, who can, if so inclined, make their own instruments. The cost of making them is also much less than that of making refractors.

I have said before that an object mirror is easier to make. This is because in a mirror only one surface has to be dealt with, while in the case of an object glass for a refractor (which is generally a combination of two glasses of different kinds) four surfaces have to be operated upon.

It is not to be supposed, however, that a good telescopic mirror is so easy to make. I merely mean that the difficulties are less. Months, nay, years of patient work are necessary before one can achieve a fair amount of success in finishing object mirrors. A good many years ago Sir Howard Grubb in a lecture on "Telescopic Objectives" said that "no one could learn the process under nine years' hard work." A finished object glass (or object mirror) is, according to the same authority, "more a work of art" than a product of mere mechanical operation. I am quite sure that workers in this field will agree with me when I say that none but enthusiasts can overcome the difficulties in this "fascinating and exasperating pursuit," as Mr. Buchanan observes in his interesting paper on the subject in the March number of the JOURNAL.

I will now proceed to give some practical hints on the construction of glass specula. As is well-known, formerly metallic specula were much in use; they have in modern times been replaced by the silver-on-glass mirrors. In this paper I intend to deal only with the latter. After the glass disc is selected and rounded, the process of making it into a speculum or mirror consists of four stages; they are, according to their sequence, (1) rough grinding, (2) fine grinding, (3) polishing, and (4) figuring. It is the last process which is the most important and exacting.

First of all the glass must be selected. It must be sufficiently thick so that there may be no flexure when it is tested during the figuring process by standing it on end. The usual rule is that the thickness of the glass should be one-sixth of its diameter. Even a thickness of one-eighth may do.* I have never met with any trouble with my

* Mr. Buchanan's 16" mirror is 2·5 inches thick: one-sixth thickness would be 2·7 inches; so that the thickness is very nearly one-sixth the diameter. The fear I had occasion to express in regard to this mirror at the February Meeting was not therefore well founded. I earnestly hope that the mirror when finally tested will be found to be perfect.

eight-inch mirrors of one-inch thickness. For mirrors up to eight-inch thickness the quality of glass is not of much moment; good plate glass of the required thickness should be used and such glass is always available in Calcutta.

Then the glass must be roughly cut into a circular shape. This can be conveniently done at the glass seller's when purchasing the glass. The glass must now be attached to an ordinary lathe so that it turns on a horizontal axis. The edges are then smoothed by being ground with ordinary coarse sand and water supplied on an iron band just pressing against the edge of the glass. When the edge is sufficiently smooth, it is better to grind it with finer and finer sand of grades up to thirty minutes as described below. These are prepared from the mud that collects when grinding with ordinary coarse sand. This mud being vigorously stirred in a deep vessel nearly full of water, is allowed to settle for 5 seconds. The water is then gently poured off into another vessel leaving the sediment at the bottom. This sediment is preserved and called "5 second sand." From the muddy water that remains we get by a similar process grades of sand of ½ min., 1 min., 5 min., 15 min, 30 min. and 60 min. All these grades of sand are carefully bottled and kept apart.

When the glass is nicely edged, it is now ready for the next stage, namely, the hollowing out of the surface to the required curve, a convex iron or brass gauge for which is prepared beforehand. The focal length of the mirror should be about nine times its diameter, so that the gauge is of a radius of curvature eighteen times the diameter. Besides this *convex* gauge, another gauge of the same radius of curvature but *concave* should also be made, as it will be required for future use.

The hollowing-out may be done by placing the intended mirror face-up and grinding it with a circular piece of glass plate of half its diameter. The abrading material used is coarse sand mixed with water placed between the glass surfaces. Carborundum may be used at this stage with advantage. During this process the glass for the intended mirror should be placed on a wooden bed having a small hole at the centre. This hole loosely fits round a pivot fixed on the surface of a table, so that the bed along with the glass may be turned round in its place on the table from time to time. The smaller tool should be firmly held by means of a wooden knob attached to its back with melted pitch or resin and moved forwards and backwards (in *straight* strokes), as well as round and round (in *circular*

strokes), over the glass, care being taken that the tool does not go beyond the edge of the mirror-glass. While giving these strokes the tool should also be constantly rotated with the hand as also the mirror itself, but less frequently.

When the grinding is carried on for some time in this way the surface of the intended mirror will be hollowed out into a concavity. From time to time this concavity must be measured by placing the convex gauge edgewise across the middle of the glass. When it is found that the gauge fits the concavity, further grinding with coarse sand must be stopped. This finishes rough grinding.

The mirror should now be removed from its wooden bed and kept apart, as all future operations will have to be made with the mirror face *down* and not *up*.

The fine grinding has to be done now. For this purpose a new tool should be made. A circular slab of marble half an inch larger in diameter than the intended mirror and about an eighth of its diameter in thickness should be procured. One surface of this should be turned on an ordinary lathe to a *convexity* of the same radius of curvature as the *concavity* of the intended mirror. The convexity of this surface should be tested by the *concave* gauge prepared before.* A quantity of pitch or resin being melted in a vessel should now be poured on the convex face of the marble (which face should be slightly warmed previously over a fire) and spread uniformly *all over* this face about a quarter of an inch thick. The hollowed face of the mirror shall now be smeared all over thoroughly with water and placed over the pitch or resin surface and pressed down more or less so that the said surface fits the concavity of the mirror. The mirror should then be removed. Next, a number of bits of glass one inch square and about a quarter of an inch thick should be procured and slightly heated and placed in rows over the pitch surface of the marble slab about $\frac{1}{8}$ inch apart from each other. Instead of squares of glass similar pieces of iron may be used. The bits must be cut from one and the same piece of glass plate or iron bar. I prefer iron as the bits may be cut more easily from a bar one inch broad and $\frac{1}{4}$ inch thick. The bits being thus arranged in rows on the entire surface leaving a margin of about a quarter of an inch in width all round, and the surface warmed over a fire, the hollowed face of the mirror shall again be smeared with water as before and placed over the prepared surface of the marble tool and gently pressed till the several bits of glass or iron all come in contact with the concavity of the mirror.

* Instead of the marble slab, two well-seasoned circular teakwood boards, each $\frac{1}{4}$ inch thick and screwed to each other with their grain at right angles, may be used.

It will be seen that the whole surface of the tool will be a trifle larger in diameter than the surface of the mirror. The mirror should then be removed and the marble surface allowed to cool. When the marble tool has completely cooled down fine grinding should be begun.

The marble tool should now be placed with its prepared face up on the wooden bed on which the glass for the mirror was placed during the hollowing-out process. The mirror being now placed with its face *down* over the marble slab, the grinding process should be carried on with the finer grades of sand one after the other, beginning with the 5 second grade. After grinding with each grade the mirror surface should be cleaned with water from time to time, dried and examined. When it is found that the entire surface has assumed a uniform texture, the next grade should be begun. The face of the tool should be cleaned from time to time and before a new grade of sand is begun the tool should be scrupulously cleaned with a brush and plenty of water, so that not a single particle of sand of the previous grade may linger on the tool surface or side. In the last stages of fine grinding (with the 30 min. and 60 min. sand) great care should be taken to see that the abrading powder remains quite wet and does not dry up, as in that case there is danger of the fine surface of the mirror being scratched. Care must also be taken that during grinding with these two grades, the abrading powder is not mixed with too much water; in that case also there is danger of scratches by reason of the mirror surface coming in too close a contact with the tool. The abrading material should be kept sufficiently wet with a good supply of the powder; that is to say, the mixture of the powder with water should not be too thin.

During the entire fine grinding process there should be very little circular stroke used; the stroke should be straight and of one-third amplitude, that is, the mirror being held with the hand should be moved backwards and forwards, the edge of the mirror not passing more than one-third its diameter beyond the edge of the tool; while giving this straight stroke, the mirror should also be rotated with the hand very frequently and moved at the same time a very little to the right and also to the left, while the tool is turned with the left hand round and round from time to time always in one and the same direction, along with its wooden bed.

Throughout the grinding process, the operator may remain stationary and need not walk round and round as he would have to do if the tool or the mirror, whichever

is lower, were fixed on the table. Before the grinding of the surface with 5-second sand is begun, the circular margin of the surface should be bevelled with the same grade of sand about $\frac{1}{8}$ inch in width by grinding the margin with the mirror face down over an iron concave tool; and this bevelling should be done with the next grade of sand before surface grinding is commenced with the same grade. This may be continued up to the 30-min. sand and no further. An ordinary concave country frying-pan sold in the bazars may serve as the bevelling tool.

Instead of the tools suggested above, a circular piece of glass plate of the same size and thickness as the intended mirror may be used as the grinding tool. The glass for the intended mirror should be ground over the glass for the tool throughout all the stages of the grinding process from the very beginning. The result of such grinding will be that of the two flat surfaces in contact, the upper one will become concave and the lower one convex. This concavity and convexity will increase with the duration of the grinding. This method of grinding may be adopted if preferred.*

This finishes my notes regarding grinding of specula. These notes are intended for mirrors from three inches to eight inches in diameter. I have said before that the focal length should be about nine times the diameter of the mirror. This would be the proper length for the bigger sized mirrors, say six to eight inches in diameter. For the smaller ones, I prefer making the focal length about fifty inches, for in that case greater magnification is obtained with the eye-pieces used.

The cementing material I use is resin powdered and melted with a quantity of mustard oil so as to give it the requisite consistency. In this way the resin may be made soft or hard as required. This material serves all purposes, including cementing as well as making the surface of the polisher. I prefer using resin specially to avoid the bad odour of pitch when melted.

I do not propose to say much about polishing and figuring. The object of the polishing process is to impart to the fine ground surface the lustre of glass. The abrading material used is ronge (an oxide of iron) mixed with water over a bed of pitch or resin. It is really a far more delicate stage of grinding, by which *perfect* evenness is imparted to the surface, which is thus made reflective.

The object of the figuring process is to impart to the polished concave surface the exact parabolic form which

*In this connection may I enquire of Mr. Buchanan if his zinc tool was grooved ?

alone would give a distinct image of a celestial object by bringing all its rays to a focus. For this purpose testing is best done from time to time with the well known shadow (or knife edge) test devised by the eminent French Physicist Lêon Foucault.

I should note here, that I always prefer polishing and figuring with the mirror face *down*, the polisher being placed below the mirror with its face up. In this case there is not much fear of scratching the mirror face; as any particle of grit which may insinuate itself between the mirror and the polisher is likely to settle down in the grooves of the polisher, while if the mirror is polished face up, the same particle may work havoc on the mirror face, and then the entire process of fine grinding may again have to be gone through from the beginning.

The last thing to be done is to deposit a very, very thin film of metallic silver on the finished mirror surface by a beautiful chemical process due to the great German Chemist Liebig.

The processes mentioned above are followed by Messrs. S. K. Dhar & Bros. of Hooghly, in the manufacture of their instruments, and the notes are mainly collected from what they have been led to adopt in their works.

All these processes are described in various articles published from time to time in *The English Mechanic*, *Amateur Work*, *Work*, &c. A little book entitled *Glass Working*, published by Cassell & Co., devotes a short but useful chapter to the subject. The whole subject is elaborately dealt with in Draper's paper on the construction of a 15½ inch mirror and Ritchey's paper on the modern reflecting telescope, which have both been recently published as separate volumes by the Smithsonian Institution of Washington, U. S. A.

Members interested in the subject will oblige the writer as well as other Members by giving additional information in the pages of the JOURNAL.

The View of the Mountains surrounding the Mare Imbrium.

BY N. L. BANERJEE,

This evening we shall see what view our imaginary observer on the moon will obtain of the Apennine, Caucasus and Alpine mountains around the Man Imbrium.

The Apennine Mountains extend from the west of the fine ring plane Eratosthenes, on the south of the Man