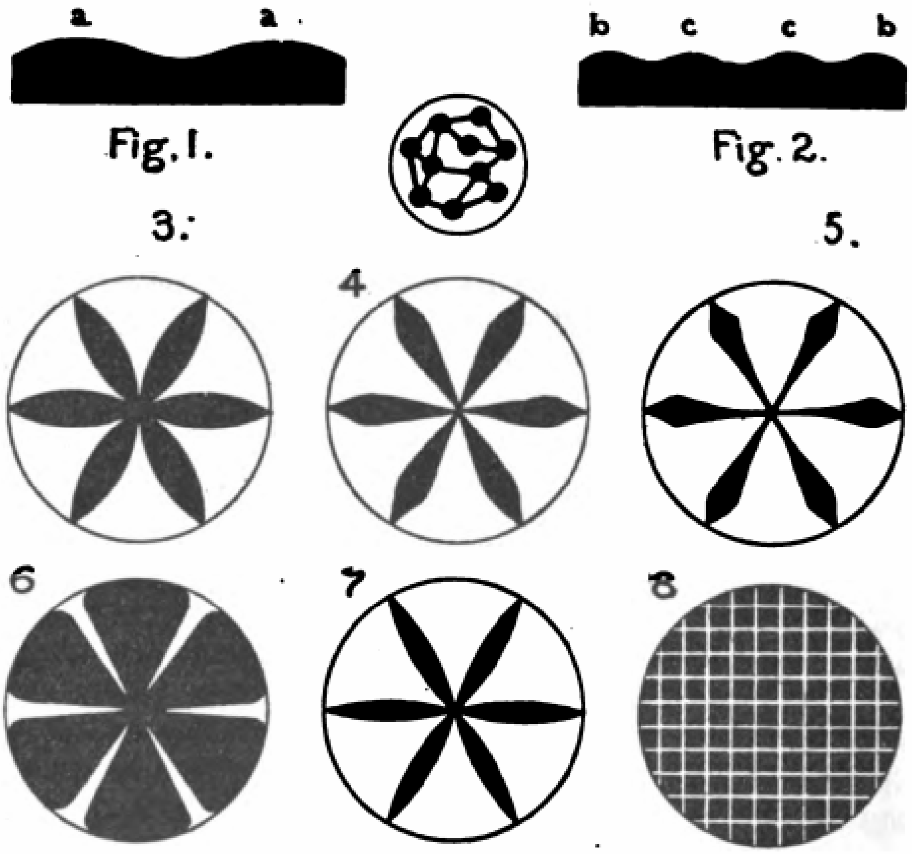
PAPERS READ.

THE PRODUCTION OF OPTICAL SURFACES. By JOHN A. BRASHEAR, Pittsburg, Pa.

It is the purpose of this paper to describe briefly a new method of producing accurate optical surfaces, both plane and curved. The hand and machine methods of past and present workers in this line of research should not be forgotten, especially Foucault's method of local correction and Dr. Draper's excellent modification thereof.

In order that the new method may be the more clearly understood, attention is called to the serious difficulties met with in producing regular surfaces with the ordinary forms and methods of using local polishers. It is quite well known that the tendency of all local retouching is to leave on the surface of the abraded material what may be aptly called residual errors. This may be readily understood by the following illustration.

Suppose in the sectional view, Fig. 1, we wish to work down the high zone, *a*, in an over corrected surface. A local polisher is worked over the high zone, either by hand or machine, of a size corresponding with the breadth of the zone and usually circular in outline. The result of this local abrasion is seen in Fig. 2 in which the zone, *a*, Fig. 1, is seen to be broken down, but generally the residual zones, *b* and *c*, are left incompletely abraded by the edge of the local polisher, which must afterwards be abraded by a larger polisher, which may or may not introduce new periodic or systematic errors. Dr. Draper seems to have overcome this tendency in a great measure by the use of the machine described in his monograph. After many experiments and much careful study of these zonal errors, I endeavored to eliminate them with a machine constructed so as to give an intricate motion to the polisher, a motion that would scarcely return into itself in many thousands of strokes. Notwithstanding the fact that this machine produced a number of excellent curves, it could not be depended upon, for in spite of the intricate interlacing of the polisher, zonal errors would creep in. After six years of labor I reluctantly gave up the pursuit in this direction. From the fact that occasionally good results were produced by the machine, I was led to a careful study of the forms of polishers, and after three years of experimental work, I have been led to this conclusion: that, given a properly shaped polisher, surfaces of the highest excellence may be produced; either by hand or machine work, and that the simple ro-



tary and reciprocal motions are all that are necessary to be given to the polishing tool.

I will now give as briefly as possible the leading features of the method which I have found so sure and certain in its results, by which not only zonal errors are overcome, but by which any desired curve may be given to the optical surface under treatment. As it is necessary in all optical work to get the highest attainable polish, the first polishers are made in the ordinary form, *i. e.*, with square or circular facets equally distributed over the surface of the tool, as shown in Fig. 8. This is done to expedite the polishing. When the polish is brought up to the best (the best polish is no doubt the *finest scratching* we are able to do) the glass is allowed to come to a normal temperature, and is then studied by the admirable methods devised by M. Foucault for curved, and by Steinheil and Dr. C. S. Hastings for flat surfaces. Very seldom are the surfaces found free from defect. In order to clearly understand the method which I use for the correction of errors in producing a *regular* curve, let us take the former case of Fig. 1, where the Foucault test shows a decided over correction or hyperboloid of revolution on the concave surface. The zone *a* is to be depressed and at the same time new errors, especially zonal errors, are to be avoided. The iron tool, which is of the same diameter as the surface to be worked, is laid off into six points diametrically opposite with the dividers set to the radius of the tool; as in Fig. 3. The tool is now warmed and the pitch is spread over the leaf-like spaces, which are given the proper curve by being pressed down on the (previously wetted) concave surface. The pitch and tool are now cooled quickly by an abundant flow of water. In the shaping of this leaflet lies the whole secret of success. The zone, *a*, Fig. 1, needing the greatest amount of abrasion, the leaflet is made widest at that point, but in order that no zonal errors may be introduced, as in Fig. 2, it is gently tapered in each direction, the amount of taper being somewhat governed by the amount of lateral stroke given to the polisher, as well as the amount of departure of the zone from the normal curve. After the proper shape is given to the correcting or figuring tool, the pitch is again slightly warmed, pressed on the wetted surface, laid aside for an hour or so, and the work of correcting or figuring is then begun. When the polisher has worked long enough to transfer its own peculiarities to the surface under treatment, the glass is allowed to come to a normal temperature and again tested. If any change in the shape of the leaflets is needed, an inspection of the surface will indicate the character of the change required.

Cooper Key many years ago graduated the square facets of his polisher. Elliptical, ring and other forms of polishers have been tried from time to time with varying success, and I have myself tried many forms, but with none have I had such uniform success as with the form which I have just described. It has all the advantages of a local polisher without its defects, and as these leaflets can be so readily shaped, and so easily manipulated, we have a ready means of giving any desired form to the optical surface we are manipulating. Figs. 4, 5 and 6 show the various forms of these polishers which are designed to correct different forms of errors. Fig. 7 shows a polishing or figuring tool which will give fine results, when time is not an element in the work. Such a polisher would break down almost any form of irregular surface, and give a *regular* curve, the kind of curve — oblate spheroid, spherical, elliptical, paraboloid or hyperboloid, depending on the length of lateral motion given to the polisher; indeed almost any idiosyncrasy which a curve may present can be successfully treated with a slight modification of this form of polisher.

Flat surfaces may also be treated by modifications of the same general form of tool, and overworking the edge zone, so difficult to avoid in hand polishing, can be readily and easily overcome.

It is beyond the limits of this paper to discuss the various difficulties which the practical optician has to deal with besides those noted; but I would mention one thing that seems to be an insurmountable barrier to the production of an ideal optical surface, in the lack of homogeneousness in material. It is a fact well known to every one who has to deal with minute measurements that no two pieces of glass, speculum metal or other optical material made by artificial means are ever absolutely homogeneous when they come into the hands of the optician; hence every piece of material must have its special study, and in many cases idiosyncrasies present themselves which say "Thus far shalt thou come, but no farther." If, in this brief paper, I have said anything that will add to the interest of this study, intimately associated with the names of Newton, Herschel, Ross, Lassell, Foucault, Nasmyth, Dr. Draper and many eminent opticians of to-day, I shall feel more than repaid for my work.

The Giant's Causeway and Portrush Electric Tramway (Ireland). By William A. Traill, C. E., Portrush, Co. Antrim, Ireland.

[Abstract.[1]]

This road has a finished length of seven miles and a gauge of three feet. It follows the turnpike which skirts the cliffs over-

[1] Abstract made from the full paper by J. Burkitt Webb, Secretary of the Section.