

before use in warm water. When it is desired to fasten paper labels on tin vessels, it is advisable to coat the places previously with diluted dammar or copal varnish (1 part of oil of turpentine and 2 parts of varnish).—Deutsche Drogisten Zeitung.

#### CO-OPERATION AMONG AMERICAN GEOGRAPHICAL SOCIETIES.\*

By ISRAEL C. RUSSELL.

In considering the many ways in which the science having as its special province the study of the earth's surface can be enhanced and its service to mankind rendered more efficient through the agency of geographical societies, five subordinate themes present themselves for consideration. These are: The scope and aim of geography; the methods of gathering and distributing geographical knowledge; the functions of geographical societies; the present status of the geographical societies in America; and in what ways can the geographical societies of this country increase their influence and enlarge their usefulness.

Geography has been well defined recently as the science which deals with the distribution of every feature and the environment of every creature on the face of the earth. The geographer, however, must remember that the earth's surface is not fixed and rigid, a dead, motionless thing, but ever changing in response perhaps to the fall of a raindrop or an eruption of Krakatoa, and that it is clothed with beauty both of form and color, and whispers with a thousand tongues to the admirer who inclines a listening ear. What then is geography? The study of the distribution of earth features and of the environment of living things, to be sure, but also the reading of the fascinating story of the development of those features, and a search for the complex antecedent conditions which gave birth to the present marvelously delicate adjustment of life to its environment. Illuminating this temple not made by hands are pictures of the earth beautiful, and the many charms that are imparted to nature-study by all that is lovely in form and color, and fascinating by reason of sound or motion on the still developing earth's surface with which man's life is linked and of which his body is a part.

The popular idea in reference to methods of acquiring geographical knowledge is, no doubt, to traverse unknown lands, make voyages in Arctic and Antarctic seas and scale mountains never before pressed by human foot. Geographical advances, however, are to be made not only by crossing ice fields and climbing mountains, but by excursions into the realm of ideas as well. The science culminates in the study of the relation of life and particularly of man to surrounding physical conditions. While the explorer of new lands gathers facts, the philosophical geographer arranges those facts in orderly sequence, interprets their meaning and deduces from them hypotheses, which have for their purpose the discovery of the laws of Nature. It is the formulating and elucidating of these laws which constitutes the noblest aim of geographical science. This philosophical stage in the growth of geography has but recently been entered upon, and is the one which is to claim the greatest share of attention in the future.

From this point of view it appears that fresh fields for exploration surround the scientific geographer on every hand, and the sea has only just begun to yield up its secrets. Some of the most important advances in geography yet made can be claimed as the fruits of home study rather than resulting from explorations in new lands, although based on and supported by extensive field investigations. The gaining of geographical knowledge at first hand, or geographical research, consists, then, of both journeying and thinking, and the two are inseparable in order to secure the highest results. To the question: What is to be done with the fruits of geographical studies when gathered? the true answer is: Give them away. Sow the seeds of knowledge broadcast in the minds of men, with faith that some of them will germinate there and multiply a thousandfold.

With the change from traversing unknown areas to exploring the domain of ideas, which made geography a science, the sphere of usefulness of the geographical society has been vastly enlarged and new duties placed upon it. Thus far, however, geographical societies do not seem to have awakened to the full realization of the dignity of this new life, and the vast possibilities it opens for their own growth and elevation. It needs no argument to show that it is a duty of a society having the study of the earth's surface for its chosen field, to foster and encourage geographical research in the laboratory and library, in cultivated fields, and amid hills and valleys, just as truly as it is to aid the African explorer or encourage the mountaineer who would scale Mount Everest.

The principal functions of geographical societies may be summarized as being: The encouragement of exploration and research; the holding of meetings for the presentation of information on geographical matters, and eliciting discussion; public lectures; field excursions, etc.; publication of instructive geographical reports, essays, maps, etc.; maintenance of libraries; facilitating personal conferences between men engaged in like explorations or investigations; the stimulating of public interest in matters geographical; and the education of legislators as to the relation of geography to human advancement. Even this suggestive summary does not exhaust the subject in hand; the recog-

nition of work well done, as when a geographical society bestows a medal on an explorer; the assumption of the duties of an executor, as when such a society administers a legacy; the opening of halls for the exhibition of loan collections of various kinds, etc., show that the functions of geographical societies are still wider and more varied. The fact should be emphasized that in the exercise of several, if not all, its functions, the power of a geographical society to do good and enhance the welfare of mankind increases both with the growth of its ideals and its increase in numbers.

There is abundant evidence that by means of co-operation something is gained which is denied the isolated individual, and so far as experience suggests there is no upper limit to the number that can to advantage unite their efforts. At the present time, there are in North America not less than seventeen societies, associations, and clubs, which have geography in some form as the chief bond which unites their members. The distribution of the societies includes, in an east and west direction, Boston and San Francisco, and its range in latitude is from Washington to Quebec on the east, and from San Francisco to Seattle on the west. Of these there are perhaps ten which, as declared by their constitutions, and made evident by their work, can reasonably claim recognition as geographical societies; the remainder are of the nature of social clubs, with geographical features, rather than societies having for their leading aim an earnest desire to increase and diffuse geographical knowledge. The combined active membership of what may be termed *bona fide* geographical societies is over nine thousand, a number which in itself is significant of a wide popular interest in geographical matters particularly among the people of the United States. Each of our geographical societies has its home in a large city, but it is probable, however, that there are many thousands of people outside the cities in which the societies referred to are located who would join similar organizations if it were practicable for them to attend their meetings.

Exploration has been aided by some of our great societies, but research aside from expedition work has not been directly fostered by them. The greatest efforts our societies have made have been in the direction of disseminating geographical information and attracting popular attention to the results explorers and travelers have brought home. During the year 1903, our geographical societies, clubs, etc., held a total of over 60 home meetings, in part scientific and in part popular; conducted not less than 44 public lectures, and engaged in about 16 field meetings. In addition to these direct methods of spreading information, mostly by addresses and lectures, our societies publish on an average approximating 2,000 octavo pages of printed matter each year. These statistics certainly make a favorable showing, and furnish hopeful signs by which to judge of the possibilities of the future, but the quality of the work our geographical societies are doing is difficult of even approximate determination, since there is no generally accepted standard of measurement available.

The lectures delivered under the auspices of our geographical societies must in general be considered good and their influence wide-reaching. The scientific sessions, too, of the societies must be accredited with having added important truths to the world's store of knowledge and with having exerted a beneficent influence on thought and methods of thinking. But the smallness of the assemblies, when the questions bearing on scientific geography are discussed, is discouraging. The publications of our geographical societies, when judged as attempts to popularize geographical knowledge, may in general be considered with truth to lack literary merit. They are merely descriptive and do not usually lead the reader on to think for himself, although it must be stated that they do contain a few papers that are direct and first-hand additions to science. As specimens of the book maker's art, furthermore, their appearance is in general not attractive, and the illustrations are poorly reproduced. The bulletins are not widely known and, although they are exchanged with scientific societies in this and other lands, they do not find their way into public, collegiate or private libraries to the extent that could be wished. The scattering of the efforts of the societies is too great for strength.

As a summary of the defects of our present system, it may be stated that our geographical societies are not only lacking in unity of purpose, but are antagonistic rather than co-operative. Their influence in each case is local, and their aims narrow and ill defined. In no case has research, the true foundation of geography as a science, been made a prominent feature, and never, apparently, has it received direct financial aid or popular recognition. Owing to the local character of the societies in question and the narrowness of their respective habitats, the facilities they furnish for men to become acquainted with their fellow workers are much less than could be desired. But the most glaring failures are evident in the general weakness of the publications issued, and the inefficiency of the means employed for their distribution.

The best remedy for the trouble seems to lie along one of two lines. One plan, which contemplates the reorganization of our geographical societies, provided it can be satisfactorily adjusted to the interests of all concerned, has for its chief feature the union of all the geographical societies of North America with the oldest in the list, namely, the American Geographical Society. Under this plan each society effecting such a union would become a chapter of the home society

but retain its own organization and its own property, but unite with the parent society in holding annual meetings and in publishing a monthly magazine.

The other proposes that the several geographical societies now in existence, and such other similar societies as may be organized in North America, while retaining their individual names and autonomy, unite in a brotherhood of societies to be designated by some appropriate name, as for example, the "League of American Geographical Societies." Suggestions more in detail which point the way for securing such co-operation were then presented, it being understood that the first step would be the holding of a convention at which representatives of each society which might desire to join the League should be present and assist in framing a constitution and by-laws.

The management of the League would be intrusted to a council consisting of the president, vice-presidents, secretary, and a body of councilors elected by the constituent societies. The presidents of the local societies would be the vice-presidents of the National League. The functions of the League would be the holding of an annual congress at some center of geographical interest, open to all the members of the affiliated societies, for the purpose of reading and discussing papers, etc., and the publishing of a monthly magazine or other journal to take the place of the publications previously issued by the several affiliated societies. The expense of each annual congress to be borne by the members in attendance, and the cost of the magazine to be shared by the affiliated societies in proportion to their active membership.

The advantage of an annual congress as may be predicted would be, large audiences with wide geographical representation, favorable opportunities for personal conferences and the cementation of friendships, and the encouragement that large and representative gatherings would extend to explorers and investigators to present the best fruits of their labors. To these gains should be added the stimulus such a congress would have in the home cities of the affiliated societies, at which sessions would be held, thus tending each year in an important way to extend the influence and enlarge the membership of some one local society. The greater influence on legislation to be expected from the combined voices of many societies over the efforts of any single local society suggests a practically new field of usefulness to the geographers of America.

The gains to be expected from a concentration of publications are, to a marked degree, expressed by the fact that the proposed magazine, in case all of our geographical societies united in its support, would start with a circulation in excess of ten thousand, not including libraries or subscribers not members of the affiliated societies. With such a vigorous start, rapid growth and a constantly widening influence for many years to come may reasonably be predicted. Perhaps the greatest gain to be hoped for is in the direction of a higher tone and better preparation, that a widely recognized, well edited, well printed and well illustrated magazine would have over the most part obscure and indifferently printed proceedings, journals, magazines, bulletins, etc., now issued. Again, it may reasonably be expected that an attractive geographical magazine would replace to a considerable extent the popular literary magazines of to-day, and secure a large number of readers outside of the societies from which it derived its main support. A magazine having for its aim the diffusion of all branches of geographical knowledge, would be welcomed by tens of thousands of our school teachers and other intelligent people in isolated communities who are debarred from oral instruction by leaders in geographical exploration and research.

In addition to the richer harvest to be expected from an annual congress of American geographers and a jointly published magazine as just considered, earnest and active co-operation among our geographical societies, as may reasonably be expected from such concentration of energy, should lead to their taking the initiative in several other directions. Among such hopes of the future is the securing of a map of North America on a scale of 1-1,000,000, as a contribution to the map of the world in the completion of which certain European societies are interested. Another desirable undertaking would be the publication of detailed instructions for the use of travelers and others, as to how and what to observe, in reference especially to the securing of the best possible illustrations of the results of known physiographic processes, and the recording of facts which are likely to lead to the discovery of new laws. Again, time and money might well be expended in preparing and publishing a dictionary of geographical terms; a bibliography of geographical literature; in assembling a library of photographs particularly of regions where geographical changes are most active, and in yet other directions.

In proposing the application of modern business methods in the concentration of geographical factories, as our societies may be termed, attention may be directed to the fact that geography more than any other science is best adapted for the purpose of general or popular education. Added to the fascinations of exploration, we now have the equally absorbing results of scientific physical geography, pertaining to the fields through which we walk, the brook whose murmurs have appealed to us since childhood, the waves that beat on the shore where we perhaps spend our vacations, and many other equally familiar scenes. The ability to read the history of the earth at first hand should be within the reach of every civilized man, woman, and child. It is in order to secure to all the people in North America this means of public educa-

\* Address as retiring vice-president of the American Association for the Advancement of Science, before the section of Geology and Geography at the Philadelphia meeting, December 28, 1904.

tion, coupled with never ending pleasure and a constantly expanding mental horizon, that our geographical societies are asked to unite their efforts.

[Continued from SUPPLEMENT No. 1514, page 24265.]

# ON THE MODERN REFLECTING TELESCOPE, AND THE MAKING AND TESTING OF OPTICAL MIRRORS.\*

By G. W. RITCHEY.

## XIII. TESTING AND FIGURING PARABOLOIDAL MIRRORS.

THE work of changing a spherical mirror to a paraboloidal one is accomplished entirely by the use of polishing tools, by shortening the radii of curvature of the inner zones, instead of by increasing or lengthening those of the outer zones. The methods of effecting this change of curvature will be described after the methods of testing a paraboloid have been discussed.

Such testing can be done at the center of curvature, by determining there the foci or the radii of curvature of successive zones of the mirror; it may be done at the focus of the paraboloid, by the aid of a finished plane mirror which should be at least as large as the paraboloidal one; and it may be done directly on a star. The first two methods named have the very great advantage that they may be conducted without interruption, under the practically perfect atmospheric and temperature conditions of the optical laboratory.

**Testing a Paraboloid at the Center of Curvature.**—A knowledge of the properties of the parabola enables the optician to compute the positions of the centers of curvature of successive, definite, narrow zones of the mirror, and the surface must be so figured that the radius of curvature of each zone agrees with the computed value. In testing, each zone in succession is exposed by means of a suitable diaphragm, all of the rest of the surface being covered. In practice, two entirely different formulæ may be used, depending upon the position of the illuminated pinhole.

Let  $F$  be the focal length of a finished paraboloidal mirror, and  $R$  the semi-diameter of any extremely nar-

and of ordinary ratios of aperture to focal length that it can be neglected; even in testing the outermost zones of the 5-foot mirror of 25 feet focal length, this quantity is less than 0.002 inch, while the quantity  $R^2$

— amounts to  $1\frac{1}{2}$  inches.

$2F$

Now let us consider what is the best method of determining the planes of the reflected foci. Draper, Common, and other workers used an eyepiece for this purpose; this serves well for mirrors of moderate angular aperture, but for mirrors in which the ratio of aperture to focal length is as great as 1 to 5 or 1 to 6 this method presents serious difficulties; if narrow zones are used the image in the eyepiece is blurred and indistinct on account of the diffraction effect produced by the edges of the zonal openings in the diaphragm, while if wide zones are used the difference of

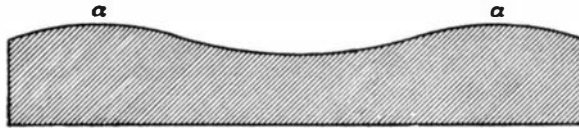


FIG. 8.

focus of the inner and outer parts of a zone is so great that the image shows evidence of marked aberration; with neither narrow nor wide zones can the position of the focus be determined with very great accuracy.

In "Publications of the A. S. P." vol. xiv, No. 87, Hussey gives a formula for the position of the "circle of least confusion" when a zone of given width is used; if Hussey's formula were employed and the pinhole were made very small and round, with smooth edges, it is probable that much greater accuracy could be attained than by the use of an eyepiece in the ordinary way.

The method of locating the reflected foci which is used by the writer is as follows: it is capable of surprising accuracy when the optician has become experienced in its use. The reflected focus of a zone is found with the knife-edge, precisely as the focus of a spherical mirror is found. The knife-edge is moved across the reflected cone from the left; if the left side of the zone is seen to darken first, the knife-edge is inside of the focus; if the right side darkens first, the knife-edge is outside of the focus; when the right and left sides of the zone darken simultaneously, the knife-edge is at the focus of the zone. One advantage of this method is that it is independent of changes of focus of the eye itself; but the great advantage is that very narrow zones or arcs can be used. Diaphragms with zonal openings  $\frac{1}{4}$  of an inch wide serve admirably for mirrors of 10 or 15 feet focal length; indeed the width of the zones which are actually used is considerably less than this; for, on account of diffraction, the edges of the openings in the diaphragms always appear as brilliant lines, even while the illumination near the center of the openings is being cut off by the knife-edge; it is therefore only the illumination near the center that is used in making the comparison.

The diaphragms which I use in this method of testing do not expose entire zones, but only pairs of arcs on the right and left sides of the mirror. Fig. 7 shows the diaphragm which was used in testing in this way the mirror of the two-foot reflector of the Yerkes Observatory. The arcs are cut in a long and narrow strip of thin metal; this is attached to the inner edges of two wooden strips,  $a$ ; these edges are curved so that all parts of the thin metal diaphragm are nearly in contact with the curved surface of the mirror. The edges of the openings are beveled so as to be extremely thin, and are finished dead-black. Twelve pairs of arcs were used, with mean radii of 1, 2, 3, . . . 10, 11, and  $11\frac{1}{2}$  inches. The openings of these arcs are  $\frac{1}{4}$  inch in width. The foci of the successive zones (except those near the center) can be readily determined by this means to within 1-500 inch along the axis, for a mirror of two feet aperture and of ten or fifteen feet focal length.

Care must be taken when testing in this way that the entire mirror surface is uniformly illuminated by

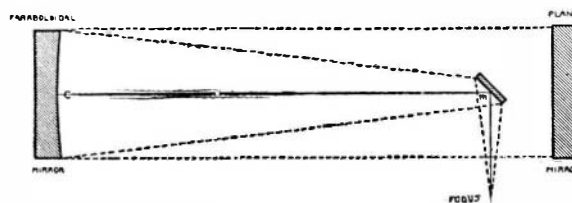


FIG. 9.—TESTING A PARABOLOIDAL MIRROR AT ITS FOCUS.

the cone of light proceeding from the illuminated pinhole; this condition, once secured, is easily maintained, since the illuminated pinhole remains immovable.

I have described at considerable length the methods of testing paraboloids at the center of curvature, because of the importance of the subject, and because this will probably continue to be a favorite method, especially among amateurs. But when testing is done at the center of curvature, even with the extremely accurate method just described, the making of a large paraboloidal mirror of great angular aperture and really fine figure is an exceedingly difficult task. This is due in part to the necessity of very frequent tests, in each of which the foci of a large number of zones must be

determined; it is due far more to the uncertainty in determining the exact nature of errors of surface (considering the surface as a whole) corresponding to focal readings which do not agree with the computed values. In the case of mirrors of small or moderate angular aperture, much important information can be gained by viewing the surface as a whole, from the (mean) center of curvature, by means of the knife-edge test; a finished paraboloid, when thus seen, appears to stand out in relief, in strong light and shade, as a surface of revolution whose section is that shown in Fig. 8; knife-edge and pinhole are both at the center of curvature of the zone  $a$ ; the apparent curve of the surface should be a smooth one. But in the case of a mirror of large angular aperture the change of curvature is so rapid that only a narrow zone can be seen well at one time, i. e., with a given focal setting of the knife-edge.

**Testing a Paraboloid at its Focus.**—This method was briefly described by the writer in the Astrophysical Journal, November, 1901. It is incomparably more simple, direct, and rigorous than the test at the center of curvature. A well-figured plane mirror, which should not be smaller than the paraboloidal one, is necessary in order that the testing may be done in the optical laboratory. In practice a small diagonal plane mirror is also used, to avoid the necessity of a central hole through the large plane mirror. Both of the plane mirrors are silvered. The arrangement of mirrors is shown in Fig. 9. The diagonal prism is placed at  $f$ , with the illuminated pinhole very near the axis; pinhole and knife-edge are in the same plane, at a distance from the vertex equal to  $cm + mf$ , which is equal to the focal length of the mirror. The paraboloid is now tested as a whole, without the use of zones, precisely as a spherical mirror is tested at its center of curvature.

If  $F$  be the desired focal length of the paraboloidal mirror whose semi-diameter is  $R$ , then the spherical surface which is fine-ground and fully polished prepar-

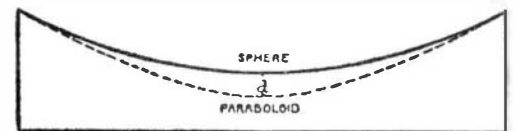


FIG. 10.

atory to parabolizing should have a radius of curvature  $2F + \frac{R^2}{4F}$ . This is because parabolizing is done

by shortening the radii of curvature of all the inner zones of a mirror, leaving the outermost zone unchanged, as shown in Fig. 10; this is a far easier and better method in practice than to leave the central parts of the mirror unchanged, and to lengthen the radii of curvature of all of the outer zones, as shown in Fig. 11.

Let us now suppose that the concave mirror shown

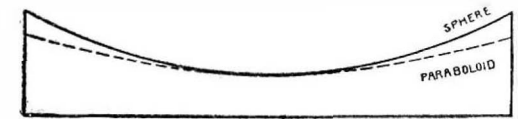


FIG. 11.

in Fig. 9 is a spherical one with radius of curvature  $R^2$

$2F + \frac{R^2}{4F}$ , where  $R$  is the semi-diameter, and  $F$  is

the distance  $cm + mf$ , from the center of the mirror surface to the plane of the pinhole and knife-edge. If the spherical surface be now viewed from the point  $f$  with the knife-edge test, it will appear to stand out in relief, in strong light and shade, as a surface of revolution whose section is that shown in Fig. 12, the height of the protuberant center depending upon the angular aperture of the mirror. The reason for this appearance is readily seen by reference to Fig. 10. To change the spherical surface to a paraboloid, the protuberant center must be removed by the use of suitable polishing tools, until the surface, as seen with the knife-edge test from the point  $f$ , appears perfectly flat, i. e., the illuminated surface darkens with perfect uniformity all over. As the paraboloidal surface nears completion, an elevated or depressed center, a "turned up" or "turned down" edge, or protuberant or depressed zones, can be seen and their character and exact position determined, with precisely the same ease and certainty with which similar irregularities are seen when a spherical mirror is examined at its center of curvature with the knife-edge test.

It should be noticed that even when the pinhole and reflected image are very near each other, as they should be, yet both may be far out of the axis of the paraboloid, if the mirrors are not properly adjusted or collimated; when this is the case the mirror surface, when seen with the knife-edge test, does not appear as a surface of revolution, and cannot be properly tested. The mirrors may be collimated by the following method, thus insuring that the pinhole and reflected image are both extremely near the optical axis.

The mirrors are set up approximately right by measurement. A ring about an inch in diameter, with two fine threads stretched diametrically across it, one vertical, one horizontal, is set up near the plane of the illuminated pinhole, the intersection of the threads marking the desired position of the optical

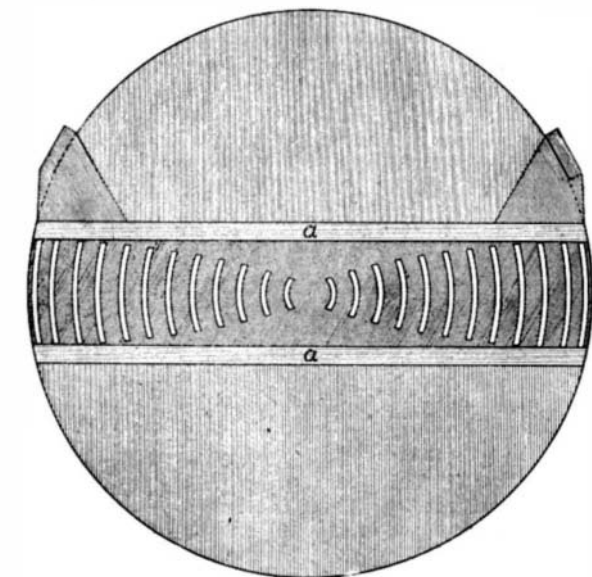


FIG. 7.—DIAGRAM USED IN TESTING A PARABOLOIDAL MIRROR AT ITS CENTER OF CURVATURE.

row zone or ring of its surface, concentric with the vertex or center of the mirror; the normals to this zone cross the axis at a point whose distance from

the vertex is  $2F + \frac{R^2}{4F}$ ; hence, if the illuminated

pinhole be placed very close to the axis, and at a distance of  $2F + \frac{R^2}{4F}$  from the vertex, the rays of light

reflected from the narrow zone will form a focus or image in the same plane (at right angles to the axis) in which the pinhole itself lies. This is the simplest formula which can be used, but it is not the most useful in practice.

In testing paraboloids at the center of curvature the writer has always used the following method and formula: The illuminated pinhole remains fixed at the center of curvature of the central parts of the mirror, i. e., at a distance  $2F$  from the vertex, where  $F$  is the focal length. The intervals, measured along the axis, between the reflected foci of the various zones, are now twice as great as those given by the method described in the preceding paragraph; consequently these foci can now be determined with twice the accuracy which can be attained by that method. Only the rays reflected from the parts of the paraboloid very near to the vertex are now brought to a focus in the plane of the pinhole. If the paraboloidal figure is perfect, the rays reflected from any very narrow zone whose semi-diameter is  $R$  are now brought to a focus

at a distance  $\frac{R^2}{2F} + \frac{R^4}{16F^3}$  back of the plane of pin-

hole, i. e., at a distance of  $2F + \frac{R^2}{2F} + \frac{R^4}{16F^3}$  from

the vertex of the paraboloid. The quantity  $\frac{R^4}{16F^3}$

is so small in the case of mirrors of moderate size

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