Cost: $100+ Difficulty: ■■□□□ **Danger 1: (No Hazards)** Utility:
About These Ratings

Amateur Telescope, Observatories, the Hartmann Method of Testing. From Amateur to Pro

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by Albert G. Ingalls
September, 1940

THING OF FIRST importance in a telescope is functional excellence, of course, but it is, however, nearly always possible, without compromising this quality, to combine attractiveness. By attractiveness some may have its place provided it does not run to over-decorativeness and to "gingerbread." Perhaps, however, the best source of that something which gives beholders an instinctive feeling of satisfaction in any machine or structure is good proportion of parts and of the whole.


Fig. 1: Hopkins' pleasing design

It is a long time since this department has received photographs of so well proportioned a telescope, whether made by amateur or professional, as the one shown in Figure 1. This 6" reflector was made by Edward Hopkins, 431 Fulton St., Elizabeth, N. J., who, according to our advices, is in charge of a machining department in one of the big airplane manufactories.

"The knowledge required to build this telescope," Hopkins writes, "came entirely from the Scientific American books 'Amateur Telescope Making' and 'Amateur Telescope Making -Advanced.' Its base was made from an old traffic sign, to which three leveling screws were added. The pedestal was converted from a truck torque tube. This was cut in two, and two flanges were welded on and machined, to permit the top section to be rotated slightly in order to line up the telescope.

"Atop the pedestal, the axle housing, from a Nash car, is slantingly welded on. The R. A. shaft turns on tapered roller bearings and is drilled through, so that Polaris can be sighted through a ring welded on the declination shaft. The declination shaft also turns on roller bearings mounted in a Model A Ford axle housing.

"The R. A. setting circle is graduated to units of lo' and has a vernier to read to 1'; the declination circle to 1 degree, with vernier to 5'.

"The Bakelite tube can be turned in a split sleeve and is guided by two brass rings that were not yet on when the photograph was made. The mirror is Pyrex, of 48" *f.l.,* and is supported in the cell by a split brass ring with a cork insert. It is held by six screws around the edge, and behind by a triangular plate with three cork pads. The prism holder is universally adjustable.

"Accuracy in the working parts was held to a very high degree, the limits held as close as possible with precision measuring instruments.

"The whole thing handles easily and can be carried by a delicate woman, with the help of a strong man."

Not every amateur has access to fine machine tools or has had a chance to learn their use. Yet good proportion does not require these things; in fact, some who have them do not attain to it. Take, for example, the counterweights of this telescope, even though this is not a very vital part. If we were to make these only a few percent fatter and stubbier, or else skinnier and longer, the telescope would seem to one judge, at least, to have lost its fine figure, just as your scribe has. Maybe Hopkins just happened to have metal of these proportions but our guess is that he planned it so, as he did with other details.

Fig. 2: Bohm's observatory

STONE is the chief material from which Anton Bohm, a monument maker, Apex Monument Works, 6815 W. 29th Avenue, Edgewater, Colorado, built his observatory (Figure 2). Its granite, brick, and stucco-lined wall is 12" thick and 8' feet high (including the 2' part that is hidden). The outside diameter is 12-l/2'. Inside are three stone steps rising 24" to the concrete floor, with a trap door to cover the stair well, thus forestalling broken necks. In front is a low surrounding wall to contain earth for Mrs. Bohm's flowers and vines. Bohm says Mrs. Bohm helped him with the observatory by mixing concrete. The telescope pier goes 8' below the surface. Absolutely no vibration is noticeable.

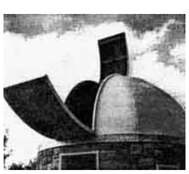

Fig. 3: Petal type shutters

The dome is framed with 25/32" lumber and covered with 3/16" building board oiled three times inside and outside with linseed oil. To this, heavy canvas strips were added over the joints and the entire surface was given three coats of white outside paint. The shutters (Figure 3) are self-explanatory, also satisfactory. The acoustics inside the dome is fine; especially for people with squeeky voices, Bohm states.

A lead cable from the residence conducts current for light and drive. A temporary telescope is in use while Bohm patiently proceeds with a 12" reflector whose tube is shown in Figure 4. Each of the eight main struts of aluminum was cast in one piece from patterns previously made and used by Carroll C. Spencer, of the Spencer Laboratories, Denver. "Don't think the foundryman didn't cuss when casting the pattern eight times," Bohm writes. "He had to lie awake nights to figure out a way to prepare the mold so that the castings, with about 3/4" shrinkage, would not break as they cooled." To clean up these castings, Bohm filed 15 hours on each strut! The rings are 14" brake drums from old Essex cars. The profile of the tube gives a feeling of nice proportion-or have we gone entirely mad on proportion?

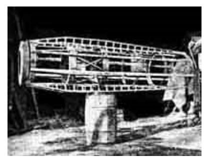
Fig. 4: The leg-shaped tube

IN describing the Goethe Link Observatory, at Brooklyn, Ind., in the June number, Victor E. Maier, Director of the Observatory, mentioned that the Hartmann test of the 36" mirror was reduced by Dr. James Cuffy of Indiana University. Dr. Cuffy writes that, after becoming thoroughly conversant with everything in "ATM" and "ATMA," he was surprised to find that amateurs had almost no appreciation of the value of the Hartmann method of testing. He thinks this may have resulted from the brevity of the chapter on this test in "ATMA," so he wrote up the method as he used it, including shortcuts which he says simplify it enormously. His account, which ought to be in "ATMA," follows:

"The Hartmann method of testing optical surfaces has, apparently, been avoided almost entirely by the amateur astronomer. The avoidance may be due largely to the photographic technique involved, but also, I believe, to the implication ('ATMA,' page 109) that the Hartmann test is one applied to finished mirrors alone. Possibly the following paragraphs will serve to point out its value in testing a mirror at any stage of the figuring process.

"The advantages of the Hartmann method are: 1. Its complete objectivity; there is no judging of equal brightnesses for patches of light separated by considerable distances. The measurement of a radius of curvature is reduced to the measurement of a distance on a photographic plate. 2. The greater number of zones that may be tested at one time. To test numerous zones visually requires time, and fatigues the eye, whereas the Hartmann test gives the radii of as many zones as desired with a minimum of effort. 3. The more detailed knowledge of the deviations of the surface from parabolic, or other required surface, that results from testing many zones of the mirror.

"The disadvantages, as seen by the uninitiated, are the need for large numbers of photographic plates, especially since, in its conventional form, each test requires two plates, and the need for a comparator in measuring the plates. These objections, however, may easily be met. I am confident that, once the amateur has tried the Hartman test, he will be convinced of its superiority over visual zonal testing.

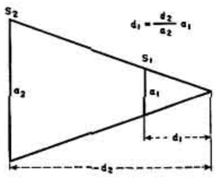

Fig. 5: Geometry, Hartmann

"In Hartmann testing, we place a perforated diaphragm before the mirror. The perforations are customarily placed along eight different axes of the mirror. The diameters of the holes are usually 1/400 of the distance from diaphragm to plate, and the centers of the holes are separated by approximately 2-1/2 times the diameter of each hole. Naturally, it is only when testing for astigmatism that one measures all the axes of the mirror The geometry of the test is shown in Figure 5. We are interested in obtaining the distances, d from the plane of the photographic plate of the points where the rays from a given zone cross the optical axis.

"The first simplification we may make (see Danjon et Couder, 'Lunettes et Télescopes,' p. 507) is to dispense with one of the plates, and to substitute for it the diaphragm itself (at s_2). Since we have constructed the diaphragm with reasonable accuracy, we know immediately the values of a_2, or the separations of the two holes corresponding to the given zone. d_2 is then the distance of the diaphragm from the pinhole, or, with sufficient accuracy, the radius of curvature of the mirror. Thus, it is sufficient to take only one plate, inside focus, and to compute once and for all the factors d_2/a_2, by which the separations on the photographic plate, a_1, must be multiplied to give the distance from the plate to the intersections of the rays with the optical axis.

"The second simplification lies in the method of measuring the plates. Since the Hartmann pattern is usually only 1/2" in diameter, we may use an ordinary photographic enlarger to enlarge the particular row of spots in the pattern to be measured up to about 10" long (strips of bromide paper 1" wide are sufficient). We then measure the positions of the spots with a good ruler. The scale of the enlargement must be known, and a simple method of determining the enlargement factor is to place a small piece of scotch tape of known width on the emulsion of the plate near the row of spots to be measured. We may then divide the separations measured with the ruler by the enlargement factor, in order to obtain the desired values of the a's on the plate.

"One could, of course, avoid photographic work entirely in making a Hartmann test by providing himself with an eyepiece micrometer having illuminated cross-wires; thus making settings of the cross-wires on the image of the Hartmann pattern directly without bothering to photograph it.

"It is important that the Hartmann diaphragm be held in a plane as close to the mirror as possible, and that the plate be perpendicular to the optical axis. If the mirror is of high aperture ratio (*f*/4 or less), the value of *r* for the zone being tested will differ slightly from the value of *r* measured on the screen, because of the inclination of the rays and the fact that the diaphragm is not in contact with the concave surface. Ordinarily, however, we may use *r* as measured on the diaphragm for computing the parabolic radii, r^2/F.

"The writer has used the Hartmann test as described above in testing the 36", *f*/5 mirror for Dr. Goethe Link's observatory (Brooklyn, Indiana), and has found the method convenient and accurate. He had, however, access to a good measuring machine.

"Having obtained the values of the radii for a number of zones of a mirror, we may compare them with the computed values for a perfect mirror and predict the performance of the mirror in actual use. Thus, we may compute the value of the Hartmann criterion, *t*, which is the weighted mean radius of the confusion disk, each zone of the mirror being weighted according to its light gathering power, or its circumference, since the area of any zone is proportional to its circumference. The value of t is given by

$$t = \frac{200{,}000}{F^2} \frac{\Sigma r^2 \Delta F}{\Sigma r}$$

where 200,000 is very nearly the number of seconds of arc in a radian, F is the mean focal length, *r* is the distance of the zone from the optical axis, and ΔF is the axial error from true focus. All the ΔF's are taken as positive numbers, that is, we use their absolute rather than their algebraic values. If a mirror is to perform well, its Hartmann criterion must be less than its theoretical resolving power, or 4.5 seconds/aperture (inches).

"Most of the large mirrors at presenting use have values of *t* between 0.1 and 0.2. A mirror larger than 24" in aperture, and having a value of *t* less than 0.5, is just satisfactory for photographic work, but unsatisfactory for visual work. In fact, seeing conditions combine with photographic graininess and the diffusion of light in the emulsion itself to make star images less than 0.035 mm. in diameter rare, while under ordinary conditions the images obtained with a large instrument are usually between 0.05 and 0.10 mm. in diameter. It is thus evident that the demands for high optical quality are about five times as stringent in the case of a telescope to be used for visual work as for one intended primarily for photography. And therein lies the reason why the average astronomer is able to obtain plates of value on nearly every clear night. The situation is perhaps best described by saying that seeing conditions are seldom too bad for photographic work, while they are seldom good enough for visual work, at least with high powered eyepieces."

WE keep hearing of more and more men who once were ordinary amateur telescope makers and who sweated over their first 6" mirrors "even as you and I," now finding their permanent life work in optics as the ultimate outcome. Ralph Dietz is with the Mt. Wilson shops, two amateurs now are pros with Bausch and Lomb, while around New York are several who are regularly employed in professional shops. What is called the "Optical Division" of the American Astronomical Association is that fraction of The New York City amateur astronomers who enjoy getting their rougey hands on hunks of glass and converting them into telescopes and other things optical. Its organizer was Lew Lojas, and he, for the past three years or so, has earned his living as an employed professional. He is with the Kollmorgen Optical Co., 767 Wyeth Ave., Brooklyn, N.Y., where he polishes and corrects lenses. Edward Hanna, another Optical Division amateur, now is also with Kollmorgen, edging and inspecting lenses, while Walter Howland, from the same amateur group is a Kollmorgen computer.

Working in the Jersey City shops of the Perkin-Elmer Corporation, of 90 Broad St., New York, N. Y., is Daniel E. McGuire, a typical amateur from a typical Ohio small town who went to the great city and who is running the polishers and correcting objectives; also Stanley Brower, who does blocking and works on magnifiers, eye lenses and microscope objectives. We hear there is an opening for one more good man in these shops.

In Keuffel and Esser's shops, at 300 Adams St., Hoboken, N. J., is another7 optical Division man, Carl Grosswendt, doing optical inspection.

Some of these men and others who may choose similar work stand a good, chance of becoming leaders in the optical industry in later years.

We have received a letter from Frank A. Eaton, of the Bausch and Lomb Optical Co., Rochester, N. Y. who mentions the comments about war emergency optical jobs for amateur telescope makers, made here last month, and says: "We are interested in knowing sources from which applicants may be obtained in the future. While it is not our intention to encourage more people to come to the plant for interview at this time, since the numbers now applying far exceed any future employment we shall have for them, if the amateur telescope makers will merely write to us, so that we have their names and addresses on record, with an explanation of what they have done with optical grinding and polishing, that will be sufficient material for us to use in seeking later interviews."

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5600 Post Road, #114-341
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