AMATEUR TELESCOPE MAKING

BOOK ONE

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AMATEUR TELESCOPE MAKING

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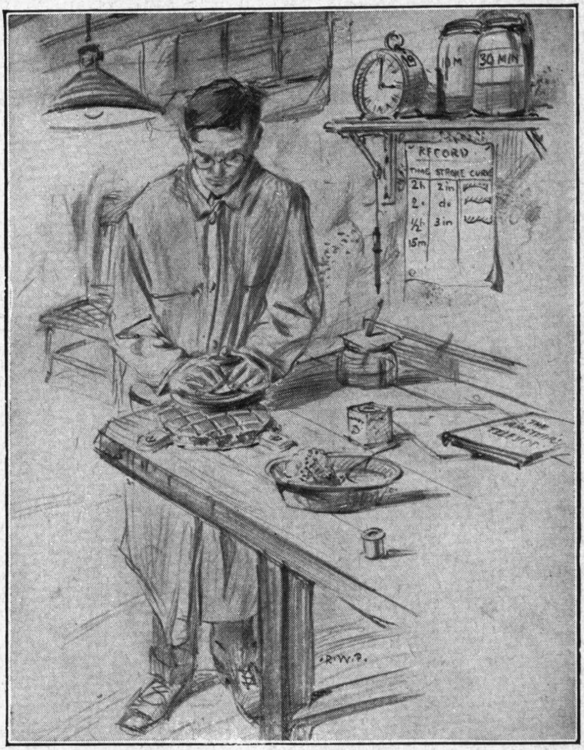
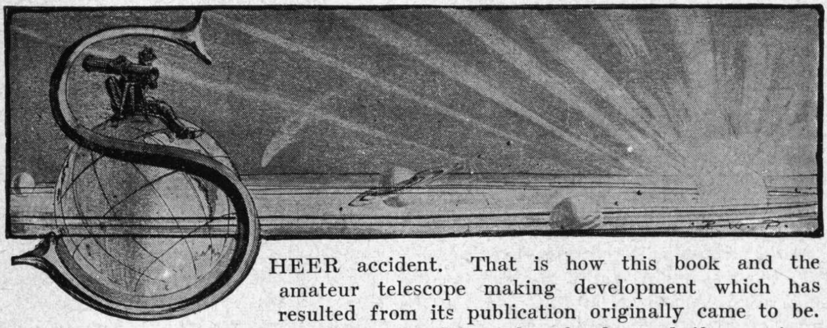


3 A. M. AND STILL AT IT

Here Porter, the artist, depicts the enthusiast as utterly absorbed in the most exacting and interesting part of the work —parabolizing the mirror. The cellar is the best place to work because its temperature is fairly uniform.

HOW IT CAME ABOUT



SHEER accident. That is how this book and the amateur telescope making development which has resulted from its publication originally came to be.

If you are bitten by the bug of the amateur telescope making hobby, you may pretty nearly blame the fortuitous fumbling of one man's thumb. Thus closely are things that are worth while in life linked up with the most trifling circumstances. Some years ago the editor of this volume, while in a public library, was half-consciously thumbing over a bound volume of *Popular Astronomy,* and by merest chance caught sight of the intriguing words "The Poor Man's Telescope." These words, it proved, formed the title of an arresting article (Nov. 1921) by Russell W. Porter, which told how the author made the concave mirror for his own reflecting telescope. A second article (Mar. 1923) related how a group of Vermont villagers under the same writer's instruction made their own telescopes and became amateur astronomers. The "poor man's" telescope, it was set forth, was not the more familiar refracting kind but the reflector. It was called the poor man's telescope because even a poor man, if he did not begrudge hard labor, might possess one by making it himself.

After reading these articles, an attempt was made at once to find detailed treatises on telescope making and, since the book resources of the whole vast New York Public Library were immediately at hand, it was fully anticipated that an armful of works on that art in the English language would be found readily available. Now it is a rare thing in these days of plentiful books concerning everything under the sun, when one cannot easily lay hands on at least a dozen works about even an obscure subject; generally, in fact, one's first task is to eliminate all but the best of the lot. Nevertheless, it turned out that in the whole English-speaking world there was only one book on telescope making for the amateur, and even that was not available in American book stores. This was "The Amateur's Telescope," by the Rev. William F. A. Ellison, Director of Armagh Observatory in Northern Ireland and a veteran maker of telescope mirrors. A copy of that book was obtained from London and it proved to be a gold mine. With its aid work was started on a modest mirror of six-inch diameter.

At this juncture Russell W. Porter, author of the articles on the poor man's telescope, was personally discovered and proved willing to lend ready ear to certain frantic appeals for practical advice, and in course of time the mirror was completed and installed in a most unpretentious mounting of wood.

Then a larger idea took shape. Why not, with the book by the Rev. Ellison and the immediate assistance of Russell W. Porter, and with the Scientific American as a ready medium of access to large numbers of scientifically-minded persons, attempt to popularize amateur telescope making as a widespread hobby? Would it make appeal? Would it? No one knew. To test the potential "reader interest," if any, in the subject, an article was published in that magazine (Nov. 1925), describing a night spent with the group of Vermont amateurs which Mr. Porter had fostered, at their star-gazing mountain-top clubhouse-observatory near the village of Springfield. In response, 368 of the readers of that article wrote to the editor of the Scientific American urging the publication of practical instructions for making telescopes such as the Vermont amateurs had made and used.

This looked like an auspicious beginning for so specialized a hobby, and Mr. Porter was accordingly invited to prepare two such articles. These two articles (Jan. and Feb., 1926), brief and inadequate as any mere article or two on such a subject must necessarily be, aroused so much interest that the publication of a book of instructions, more detailed in nature, was at once decided upon and a request for the right to reprint "The Amateur's Telescope" in America was cabled to the Rev. Ellison in Northern Ireland. This book, or most of it, and the two Scientific American articles by Porter were combined with other matter to make a modest volume of 102 pages, the first thin edition of the present work.

As time went on, the telescope-making hobby enlisted the interest and keen enthusiasm, sometimes almost fanatical, of more and more of the readers of the Scientific American. Descriptions of telescopes actually made were published in every issue of the magazine after 1926, and clubs of enthusiastic amateur telescope makers and astronomers were formed in many of the larger communities. Through correspondence and travel their members became mutually acquainted and, all over the nation and, indeed, all over the world wherever the Scientific American circulated—in the mountains of Java, in South Africa, the Argentine, Australia and New Zealand, India, Japan, Canada and elsewhere—amateurs interested in science and refined mechanics found themselves engaged in rubbing one piece of glass on another to make a telescope mirror and, as soon as this was completed, eagerly starting larger and larger ones. The first edition, some 3400 copies, of the little 102-page book was gone by 1928. A second edition, enlarged to 285 pages by the addition of new matter, was prepared that year, and the 5400 copies of that edition had vanished by 1932. The present edition contains the same matter, with trifling alterations and deletions, and with some 200 pages added.

Still the hobby goes marching on. Thousands of telescopes have been labored over by eager workers young and old, skilled and less skilled, men and women (several of these), "poor" men and rich men too. Telescope making is a scientific hobby and it appeals doubtless because it exacts intelligence; requires patience and sometimes dogged persistence in order to whip the knotty but fascinating problems which arise; demands hard work—is not dead easy; and compels the exercise of a fair amount of handiness—enough to exclude the born bungler but no more than is possessed by the average man who can "tinker" his car or the household plumbing, or dissect and wreck a watch. Some use of the brain is also called for, but one need not be an Einstein. The hobby also appeals because the worker derives something of a thrill while shaping the refined curve of the glass as he realizes that, with scarcely any special tools but chiefly with the aid of an elementary test which greatly magnifies minute irregularities on the curve, he is able to work to within almost a millionth of an inch of absolute perfection. Finally, it may legitimately make appeal because the end-product, the telescope, is not only a tangible evidence, visible to all, of the worker's possession of the several virtues cited above, but is a valuable scientific instrument which places him on the threshold of astronomy and astrophysics, perhaps the most romantic branch of modern science.

The reader doubtless will discover that this book is a mine of practical information but that the same information is not arranged in a single sequence—he must mine it out. This is because the various parts were written by many different authors and at different times. Like Topsy, the book "just grew" or, as is sometimes said of the British Empire, it is "a fortuitous, unsystematized agglomeration of ill-assorted entities acquired at different times by opportunism and otherwise." However, like that very practical commonwealth, it works—thousands who have used it can testify to that. To organize its contents thoroughly, so that the reader might march straight through a logical sequence without jumping about, would require that it be rewritten entirely and by a single writer. But then it would lose most of its claim to authoritativeness, simply because it would thereby lose most of its numerous contributing authorities; one cannot eat one's pie and have it too. So the diligent worker will be forced to make the best of this disability, reading the volume twice or more while he works, and using the index to correlate cognate phases of the work.

It is suggested that the beginner read the first two chapters of Part I as an introduction or preview; then skip to Part II, where he will find the main detailed instructions for making his mirror. He should pause over Part III for a double reading, with strong emphasis on rigidity in design. If he wishes, he may attempt to fish assistance and sundry sidelights from the Miscellany at the back, skipping the harder notes which, with the remaining parts of the book, are for more advanced workers.

Unless you are sure you are a genius, do not succumb to the natural temptation to make a large telescope at the very start; there is plenty of grief to be had at first in a small six-inch glass, and the experience gained on this size will be invaluable on a larger one. If, however, you should essay a 12-inch glass at the outset, as a few have done, you no doubt will succeed in the end. It will, however, prove actually possible in the average case to make a series of, say, three mirrors—a 6-inch, an 8-inch *and* a

12-inch—in less time and with less trouble than is required to make a single 12-inch mirror without the valuable experience gained on smaller and less difficult sizes. It will also prove to be more fun. The usual experience is this: At the start the beginner thinks mainly of acquiring the end-product, the telescope, and regards its construction merely as a task. Later he often discovers that more fun is to be had in making than in actually using it. Don't deprive yourself of this fun by making your last telescope first.

No detailed dimensioned drawings and specifications are given in this book, but the basic principles common to all telescope mountings are explained in Part I, Chapter II, also in Part III, which especially stresses rigidity. Instead of slavishly following someone else's specifications, the resourceful worker will wish to concoct his own mounting, and then it will be uniquely his, expressing his own individuality. This adventure affords half of the fun and satisfaction of the game. It is not, however, unsportsmanlike to study closely the details of telescopes already made by others and to "lift" this or that feature from them, provided one improves upon these features. To that end many photographs of telescopes made by readers of the earlier editions of this book and published, meanwhile, in the Scientific American, have been inserted here and there in this edition.

Some of the workers—a very few—have strongly urged that the amateur's telescopes be standardized on a few definite type specifications, arguing that this would save labor. Others believe that standardized hobbies connote standardized people with standardized ideas, and that the introduction of mass production and labor-saving ideas of efficiency in connection with a hobby is comparable to hiring a workman to play one's games for him. A hobby should be a way to waste time, not to count it.

In his introductory chapter (Part II) Ellison says that in telescope making "the amateur has shown the way to the professional, and forced the pace for him, ever since Herschel's time." Since 1926 when the telescope making hobby was imported from Great Britain, where its antecedents were already ancient, there have been fresh signs which seem to point in the same direction. For example, formerly inexperienced amateurs whose interest in telescope making was first enlisted by earlier editions of the present book now contribute to its pages (Parts IV and X). The former student has become the teacher. This trend will no doubt go on, and we shall be surprised if the next few years do not bring to light at least one Ritchey who perhaps began by making a modest little six-inch telescope with the aid of "Amateur Telescope Making." Many amateurs are already doing work equal to professional grade.

ALBERT G. INGALLS,

New York, November, 1932. Associate Editor, *Scientific American*.

In minor exception to a statement made above, detailed, dimensioned drawings (page 480) for a simple first telescope were appended to the book in 1955, as a part of an optional approach to telescope making. See Editor's Note on page 464.

FOREWORD

By HARLOW SHAPLEY, Ph.D., Director, Harvard College Observatory

"I set myself to work", wrote the great Christian Huygens, one of the earliest of amateur telescope makers, who, inspired by Galileo's telescopic revelations, proceeded to reveal celestial marvels on his own account, and in 1659 unravelled the secret of Saturn's rings—"I set myself to work with all the earnestness and seriousness I could command to learn the art by which glasses are fashioned for these uses, and I did not regret having put my own hand to the task".

"And now that I, too, have fashioned some glasses," the amateur instrument maker may inquire, "what next?"

Three things are next; the first is inevitable, the first two are natural, and all three are possible. The first is to feel satisfaction that you have created something with your own hands. The second is to indulge your curiosity, and incite that of your friends, by using your equipment on the objects for which it is designed; but, in so doing, keep in mind that pride of manufacture is justifiable, but that humility and wonder are the appropriate attitudes in contemplating the stars.

The third privilege of the amateur, who has followed the book and his own intuition in constructing astronomical tools, is to use his product advantageously for science. To do so effectively, he must be sincere and have both freedom and spirit. Assuming that you who read this are so gifted, I shall make some suggestions.

First, if you have "fashioned some glasses" into a telescope of three inches aperture or larger, you can do valuable work on variable stars. The American Association of Variable Star Observers would welcome you to its international membership, give you instructions, charts and encouragement. And if you are of the right stuff, within a few months you should become, in your extra evening hours, one of the contributors toward the solution of some major astronomical problems, such as the nature of stellar variability and the evolution of stars.

If the Earth and the Moon attract you more than the remote telescopic stars, and if you have access to accurate time by observatory clock or radio, you are invited to learn the simple technique of occultations—that is, the accurate timing of the eclipsing of stars by the Moon. It is only of late that we have come to realize the important work that the serious amateur astronomer can do in helping to determine the Moon's position by observing the predicted occultations. Your observations will be directed and studied by professionals; and you will be aiding in a fundamental research—the measurement of irregularities in the rotation of the Earth and the lengthening of the terrestrial day.

Second, if you have fashioned (or bought) and mounted a very rapid photographic lens, in which the ratio of focal length to aperture is 3.0, or 2.0, or even less, you are invited to join the select ranks of astronomical sportsmen and go gunning for photographs of shooting stars. Photographing the shooting stars costs no more than trout fishing in the Adirondacks, or hunting mountain sheep in the Rockies, or angling off Catalina Island; but it should have much the same appeal and difficulty, and a greater thrill when success arrives. It is not hard to see shooting stars and make unreliable visual observations of them; but it is an art, mastered by few amateurs or professionals, to photograph the elusive intruders in our upper atmosphere and thereby make permanent and accurate records. We must have more meteor photographs. One hundred thousand plates in the Harvard collection have been examined, and have revealed only a few hundred meteor trails. They form the most important collection of such data in the world, and the importance lies largely in the fact that astronomers now see the great significance of meteors in the problems of interstellar space, of comets, and asteroids, of the nature of nebulae, and of the origin and maintenance of starlight. Meteors are fundamental and little known; they are the game of the astronomical sportsman, and if he can work with others of his kind, so much the more important his contribution.

Third, if you have fashioned some contrivance for the better recording of meteor paths observed visually among the stars, then you should get acquainted with the American Meteor Society, and the work it tries to do. You will find that there is good systematic work to be done in that field without camera and without telescope.

In summary, if you have the time and spirit for it, you can crown the zeal you have displayed in making an astronomical instrument by using it intelligently and constructively on important projects. If you communicate your earnest astronomical aspirations to any of the observatories, you will be freely counselled. The professional astronomer has gained too much from the amateur in the past to disregard him at this time, when many useful contributions can be made by the man whose hobby is astronomy. But remember that constructive work is only one of three privileges of the amateur telescope maker. The second may be the most important—to look into the heavens with uncovered head and humble heart.

CONTENTS

AMATEUR TELESCOPE MAKING

Part I.

CHAPTER I.

Mirror Making for Reflecting Telescopes

BY RUSSELL W. PORTER, M.S.
Formerly Optical Associate, Jones and Lamson Machine Co., Springfield, Vermont
Associate in Optics, The California Institute of Technology

In the reflecting telescope, *the mirror's the thing.* It is the heart of the instrument, and is usually completed before the other parts of the telescope are begun. The tube and mounting are then built to match its focal length, which cannot be precisely predetermined.

We are concerned in this chapter with the shaping of the telescope mirror.

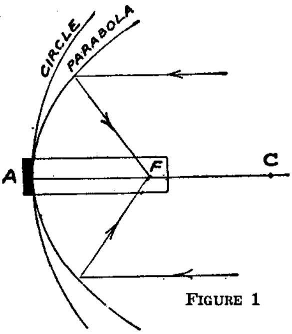


FIGURE 1

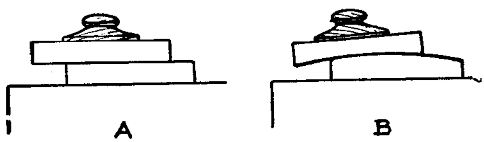


FIGURE 2

FIGURE 1. THEORY OF THE MIRROR. *Many find it difficult to understand why the focal length is only one-half of the radius or distance to the center of curvature, while in the shadow test the light is focused at the center of curvature. In the first case the rays are coming from a star, at almost infinite distance, and are therefore virtually parallel, while the rays that reach the mirror from the pinhole are divergent (radii). In this diagram, let us imagine we could grasp the two parallel rays indicated and actually pull their right-hand ends together until they touched the point C. As we drew them in, the angle at which they would now meet the mirror's surface would change, and since light is reflected away at the same angle at which it strikes a mirror, the reflected rays would shift at the same time from F to C, at double the distance of F.*

FIGURE 2. WHY THE CURVES DEVELOP. *The upper disk tends to hollow out because at the extremities of the strokes the abrasive effect on both disks is increased. This is due to the overhang and to the consequently increased pressure on the central portion of the upper disk, as well as the marginal part of the lower.*

This consists solely in giving one side of it a concave, polished surface. This surface is to be so very nearly spherical that we shall first attempt to make it precisely so; and at the very last we shall alter it to the kind of surface known among the highbrows as a paraboloid of revolution.

Such an automobile headlight has the property of throwing out from a concentrated source of light placed at a focal point near it, a beam of parallel rays. (See Figure 1.) We shall, however, use this reflector the other way around, that is, by receiving parallel rays of light from a distant object (star); and by reflecting them from a properly curved mirror we shall bring them to a point or focus (F, Figure 1).

Our curve, however, is so small a portion of this widely sweeping parabola (the black area represents the mirror) that it is extremely shallow, and so it nearly coincides with the superimposed spherical curve. At first, therefore, we shall seek to hollow out a spherical curve, later deepening it very slightly into the paraboloid.

Since the angle of reflection of a beam of light is equal to the angle of incidence, the parallel, arriving rays will be reflected approximately to a focus whose length may be regarded as one-half of the radius of curvature, C-A, Figure 1.

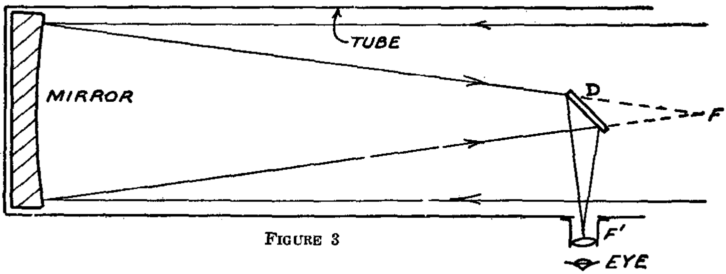


FIGURE 3

FIGURE 3. WHY A DIAGONAL IS NEEDED. *Without it the rays would come to a focus at F. But then the observer's head would eclipse the light from the object. The diagonal mirror, or a prism, reflects them to F'.*

Enlarging the mirror of Figure 1, A, we have in Figure 3 the essentials of the Newtonian, reflecting telescope. Light from a distant object falls down the tube to the mirror, and normally would, by reflection, produce an image at the focus, F. The converging rays are, however, intercepted at D by a small diagonal mirror or prism that delivers them to a lens called an eye-piece at the side of the tube, where the image is examined.

I will take as our standard, a mirror six inches in diameter, having a four-foot focal length. The beginner is not advised to essay a larger mirror for his first effort, since his difficulties will be found to multiply quite disproportionately as the diameter increases. If two flat glass disks (A, Figure 2) are ground together, one over the other, with an abrasive between, lo and behold!—the upper one becomes concave, the lower one convex. This is because the pressure per unit area, and therefore the amount of abrasion, is increased on the central portions of the upper disk and outer portions of the lower one when the upper disk overhangs as in *B*.

A straight, back-and-forth stroke, in which a given point on the upper disk moves across one-third the diameter of the lower, has the property of holding the two surfaces spherical. This is due to the fact that spherical surfaces are the only ones which remain in continuous contact at every point when moved over each other in any direction. This fact is a veritable godsend to the amateur—and to the professional, too, for that matter—for he may go confidently forward through the different stages of grinding and

FIGURE 4

PREPARING THE PITCH LAP

Melted pitch is being poured on the convex, upper face of the tool. Note the temporary collar of wet paper, which acts as a retaining wall for the pitch until it cools. Tool and mirror should previously have been placed in luke warm *water. If pitch is poured on a cold tool it will "set" so rapidly that there will be little time to make it conform to the curve of the mirror. But if the two disks are somewhat warm, there will be about ten minutes time in which to make a lap that will preserve good contact. Thus the worker may "take it easy" and do it correctly. Keep cold drafts away from the job. Warm water striking cold glass is not likely to break it, but cold water striking warm glass may.*

polishing with the knowledge that his mirror will come out nearly as it will be when it is finally deepened into a paraboloid.

The depth of the curve increases with grinding, and it is gaged with a template of the proper radius. Since by our rule, the radius, A-C, Figure 1, of the curve of the glass is twice its focal length A-F, a template is made from tin, with a radius of twice 48 inches, or 96 inches. Therefore a stick of wood (not a string, which would be elastic) should be tacked to the floor at one end so as to pivot, and a knife point held at the opposite end, or a sharpened nail driven through at the proper distance, should be used to scratch the desired curve to which the tin should be cut. For our six-inch mirror the hollow will come to about .05 inch deep.

The lower disk of glass is fastened to a pedestal or to a weighted barrel so that one can walk around it in grinding, or it may be held be-

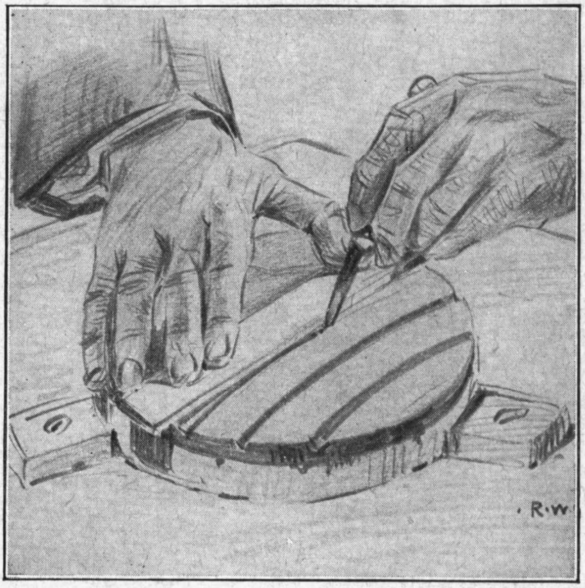


FIGURE 5

CUTTING CHANNELS IN THE PITCH LAP

Use a flexible straight-edge and a sharp knife. Keep everything wet, to minimize sticking of the pitch. In spacing the channels, precision serves no particular purpose. Do not center them, in any case. After the lap is formed and the channels are cut, leave the mirror on the lap until the tool, pitch and mirror have regained uniform room temperature. It should then be "cold pressed," or weighted, to insure the establishment of an even contact, which may have been disturbed during the cooling process.

tween one removable and two fixed buttons on the corner of a stout bench or table. (See frontispiece.) Using melted pitch, a round handle is attached to the upper disk, which is first heated slowly in water to a slightly unpleasant warmth for the hand, taking care that no cold water drops fall on the warmed disk, for they might break it.

The grinding is done by placing wet carborundum grains of successively