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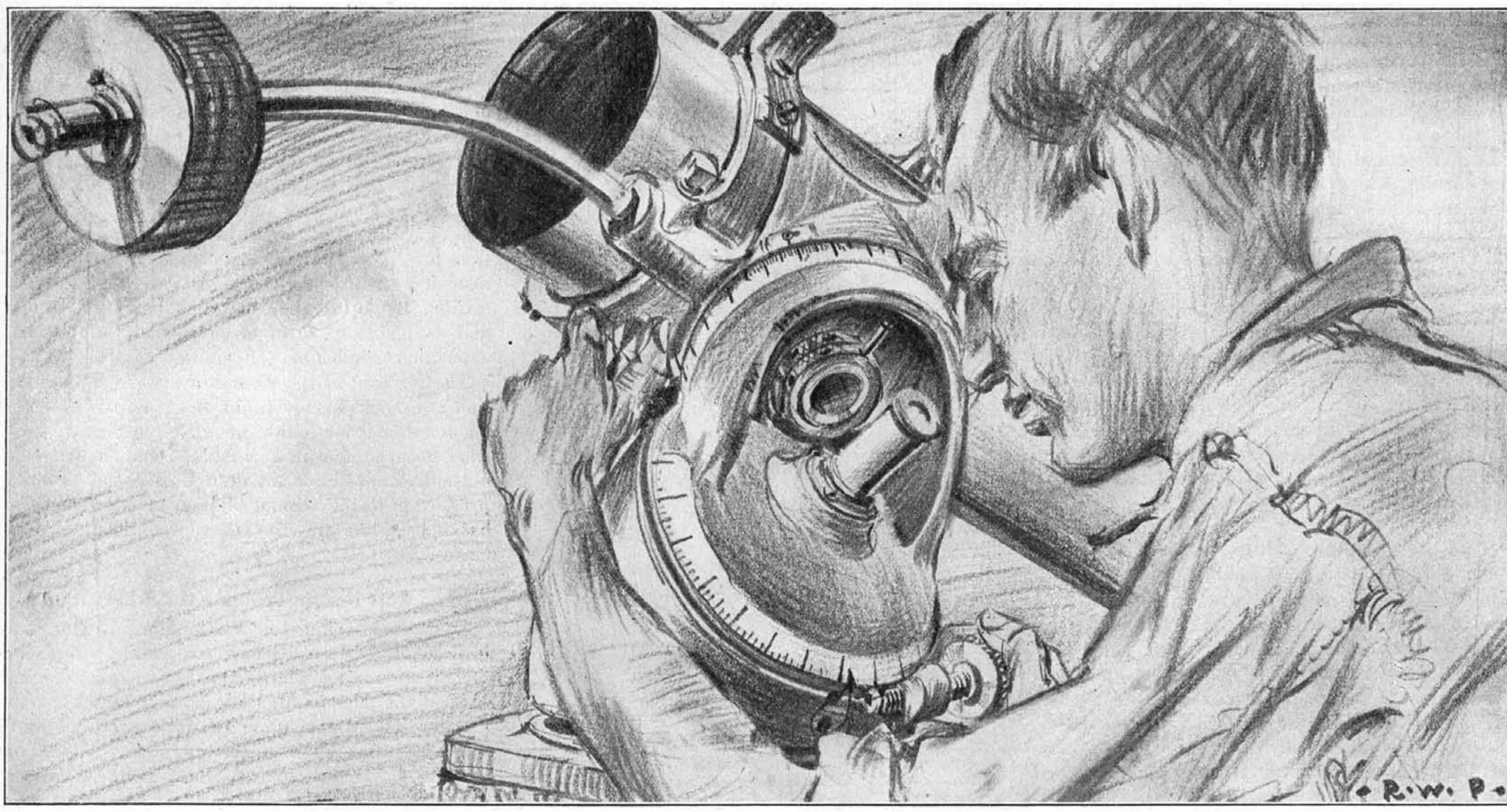


The Springfield equatorial mounting, showing its fixed eyepiece and the convenient arrangement of the slow motion controls and setting circles

Mountings for Reflecting Telescopes

By Russell W. Porter, M.S.

All Drawings by the Author

SEATED well up in the bleachers (Latitude 43° N) we amateur astronomers in Springfield, Vermont, can command a fine view of the greatest of all spectacles—the solar system. Among its planets the race is always on. The entrants gain and lose on each other as they pass us by. Until Copernicus somewhat rudely shoved us over to one side, we thought we saw the show at first from a central coign of vantage. However, the change was not all a loss, for it placed us on a movable platform where we became a real participant.

I always like to think of this old earth of ours as a gigantic piece of exquisite mechanism with which, by the aid of a mirror of my own making, I am privileged to play at will. But, before I may appreciate the beauties of this mechanism, my mirror, along with its prism and eyepiece, must be properly mounted.

The Fundamentals of a Mounting

The essentials of an efficient reflecting telescope mounting are: that the optical train—mirror, prism and eyepiece—be held rigidly in relation to each other; that provision be made for conveniently adjusting these parts; and that the whole be supported on bearings, permitting any celestial object to be easily followed as it moves across the sky.

The first of these conditions is readily met by the use of a tube of sheet metal to which the different optical parts are attached. Since the hollow cylinder is one of the stiffest forms for its weight and can be obtained at any tinsmith in galvanized iron at moderate cost, the reasons for its use are obvious. The mirror A (Figure 1) rests in a cell B, fastened to one end of the tube C. The eyepiece F fits into another tube E called the adapter, which slides easily in a flanged piece D fastened to the side of the telescope tube. The prism G (hypothenuse side) is held against a corresponding face on member H. A stud on the rear of H fits in the sleeve I held to the telescope tube by the three knife-edges J. The knife-edges have threaded ends. They rest in slotted holes in the tube and are provided with set nuts. With this arrangement the prism may be adjusted to bring it into proper relation to the mirror and eyepiece.

THE SPRINGFIELD MOUNTING IN USE

The observer's position is fixed (note the bicycle seat). The light reaches his eye through two prisms

This solution of our first and second essential conditions is the one now in almost universal use. When taken indoors for safe keeping, the optical parts are easily removed without disturbing their adjustments. An additional refinement is a focusing rack and pinion. Sometimes a diagonal, flat piece of glass (silvered on its front surface) is substituted for the prism, but this is not advised because it adds an unnecessary silvered surface to be protected. The prism is not silvered and is totally-reflecting, owing to the acute angle which the light strikes its hypothenuse side.

What an Equatorial Mounting Is

The tube must now be supported so that it will follow the stars. Of the several ways by which this may be accomplished, one condition underlies them all—there must be provided two bearings at right angles to each other, and one of them must be capable of being adjusted parallel to the axis of our earth. A familiar instrument having these two bearings at right angles to each other is the surveyor's transit or theodolite. One of the axes (A-B, Figure 2A) is always plumb. Imagine the instrument tipped over until this axis is parallel to that of the earth (second drawing of Figure 2), and we have what astronomers call an equatorial mounting. The axis about which the telescope swings is called the declination axis.

To visualize this condition of parallelism between the polar axis of the mounting and the axis about

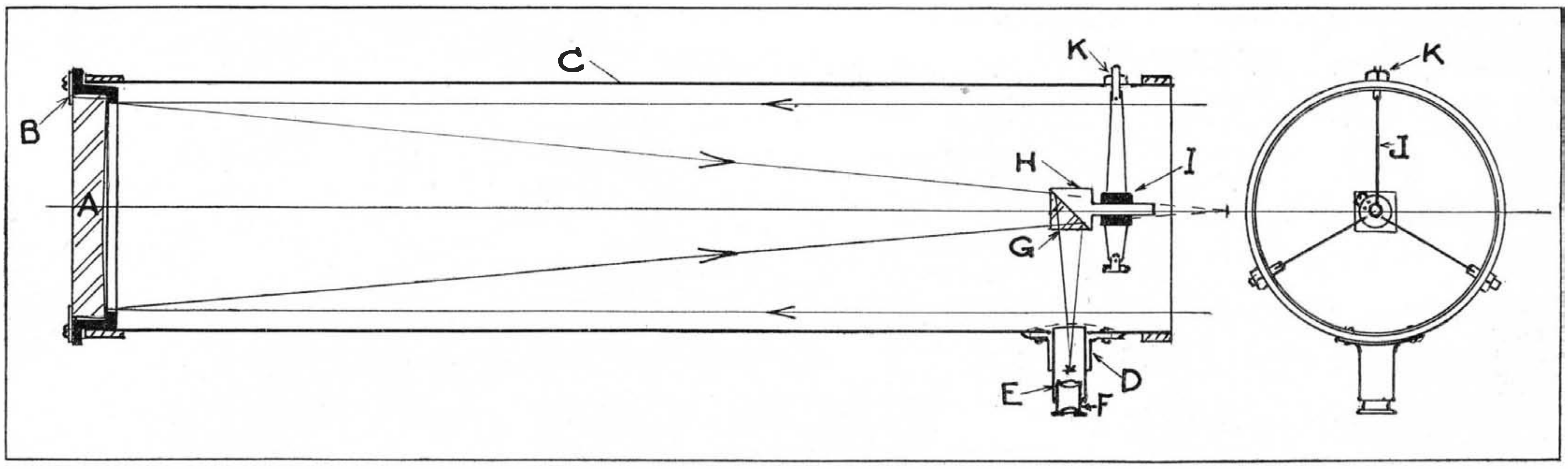
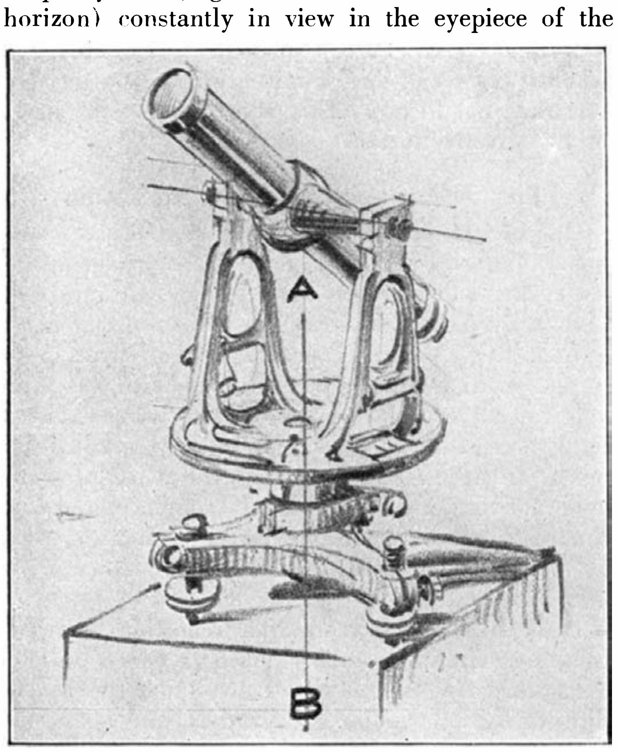


Figure 1: A typical Newtonian mounting, showing how the mirror, prism and eyepiece are attached and adjusted

which the earth rotates, I have drawn Figure 3. In this schematic diagram a mounting is shown placed on the earth's surface in about the middle latitude of the northern hemisphere. Its polar axis and the earth's axis are seen to be parallel to each other. At right angles to the polar axis is the declination axis about which the tube swings, allowing it to be pointed at any angle with the observer's horizon.

The earth, turning in the direction of the arrow, gives the stars an apparent motion in the heavens in the opposite direction, and a slow motion of the polar axis spindle of just the right amount will keep any star (regardless of its elevation above the horizon) constantly in view in the eyepiece of the



THE SURVEYOR'S TRANSIT
Figure 2A: Mounted as shown, the vertical axis is not parallel to that of the earth. But see Figure 2B

instrument. When the telescope is pointed toward the pole of the heavens, stars move slowly across the field of view. *Polaris*, for example, seems hardly to move during an entire evening. But, as the tube is swung down toward the celestial equator, the apparent motion of the stars is accelerated. Thus, the motion of the moon in a high-powered eyepiece is so rapid as to give an almost overwhelming realization that the earth is turning over in space.

Were the mounting to be erected at the poles, the polar axis would of course be *vertical* to the observer's horizon; if placed anywhere on the equator, it would be *horizontal*, or parallel to one's vision. In any case the polar axis of one's mounting makes an angle A with his northern horizon, equal to his latitude, for the two angles A, A are always the same, as is evident from the two triangles shown.

The most common type of mounting is known as the German mounting. The tube (Figure 4) fits into a ring A to which is attached a spindle B. The bearings C, C for this spindle are at one end of spindle D, and D's bearings, E, E are part of the casting fastened to the pier F. When D is adjusted by the screws G parallel to the earth's axis, any object in the telescope eyepiece will be held in the center of the field by revolving the instrument about D just fast enough to counteract the daily rotation of the earth.

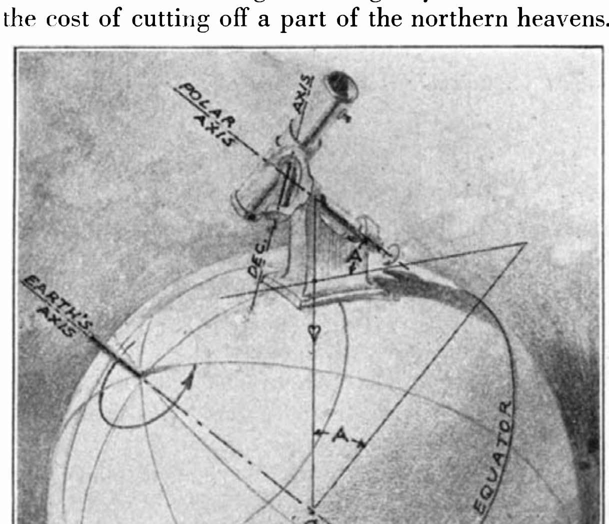
Four Common Types of Mountings

The German type of instrument is completely counterbalanced. The tube is gripped at such a point that it will remain pointing in any position without clamping. Since it overhangs one side of the polar axis, sufficient weight H is added to the opposite end of the declination spindle to bring the center of weight into the polar axis near its upper bearing. The total weight is, therefore, inside the base and is equipoised. Usually for convenience in following a star, a worm and worm wheel are provided on the polar spindle.

In the English or fork type (Figure 5) the tube is swung in a yoke attached to the upper end of the polar spindle, but considerably overhanging the pier. It has the advantage of requiring no additional counterweights.

This excessive overhang of the tube in the fork form is overcome in a third type (Figure 6) where the tube is brought within the two bearings of the polar axis, whose spindle is enlarged into a double yoke within which the telescope swings in declination.

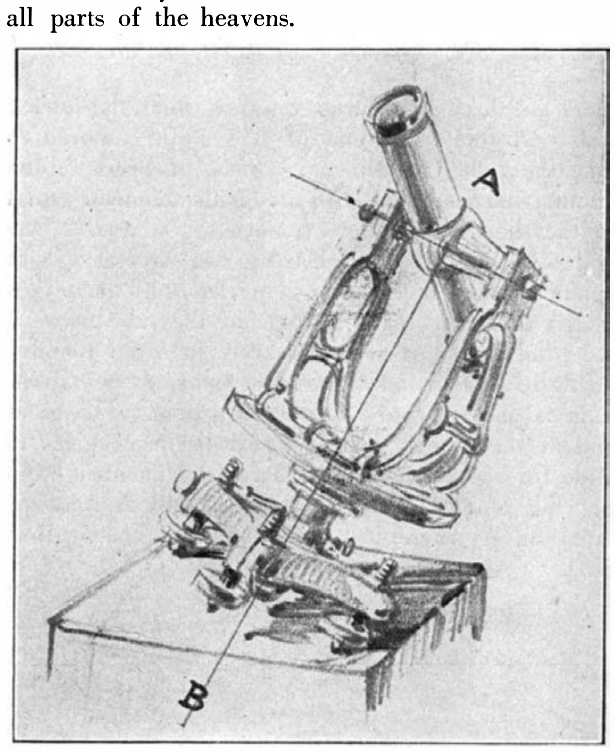
However, all forms of mountings are compromises, and in this case the gain in rigidity is obtained at the cost of cutting off a part of the northern heavens.



THE "WHY" OF THE EQUATORIAL MOUNTING
Figure 3: Its polar axis having been made parallel to that of the earth, the telescope will now follow the stars

This was the form adopted to carry our greatest of all mirrors, the 100-inch reflecting telescope at Mount Wilson, California.

Still another form of mounting is made by expanding the upper bearing of the polar axis to a large equatorial ring E (Figure 7) within which the telescope swings on its declination axis, the lower polar bearing being a thrust bearing at F. The large ring turns on the two rolls R, R. This mounting is very stable, the center of weight of the moving parts being well within the supporting rolls and thrust bearing. Part of the equatorial ring E is cut away in order to allow the tube to reach all parts of the heavens.



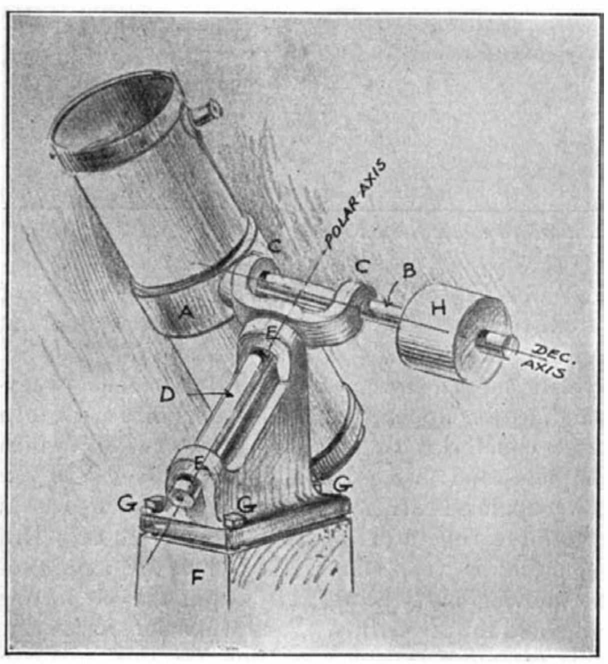
THE EQUATORIAL MOUNTING
Figure 2B: The transit of Figure 2A has been tilted. Its axis, A-B, is now parallel to the axis of the earth

In all of these mountings considerable machining of parts is required, also special castings, running into amounts of money beyond the means and capabilities of most amateurs. The Springfield Telescope Makers selected the first of them, namely, the German form. But these men had access to the resources of the machine shops here and were all skilled mechanics. I shall, therefore, at the risk of possible criticism, describe a wooden equatorial mounting containing the essential features, but which may be easily put together from materials available anywhere. When the mirror maker has given his glass a good tryout with this mounting he will either be satisfied with it or will become so enthused with its performance, that he will attempt something better in metal.

To hold the optical parts, a clear straight-grained plank of pine or spruce A, (Figure 8) 1½ inches thick, 6 inches wide at the mirror end and tapering to 2 inches at the other is used. The mirror rests in a 1-inch board, 6½ inches square, screwed to A, as shown, and recessed for the mirror to a depth of ½-inch.

In order to prevent the possibility of the mirror falling out of its cell, wooden buttons or brass clips may be distributed around the edge of the recessed board.

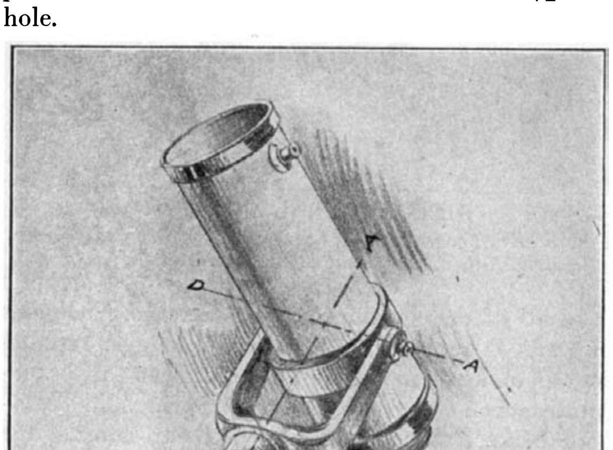
At the back of the shelf which has been formed



THE GERMAN TYPE OF MOUNTING

Figure 4: This is the commonest of the equatorial types. It has many advantages and comparatively few drawbacks

there are three adjusting screws on which the mirror rests. At the other end of A a hole is bored to take the tube C. This is a piece of brass tubing about 6 inches long, with an inside diameter equal to the diameter of the eyepiece to be used. One end of C is cut down, leaving two ears at I with enough spring in them to grip and hold the 1-inch totally-reflecting prism. Some of the tube between the plank and prism is cut away in order to offer no more obstruction to incident light on the mirror than is necessary to support the prism. The other end of the tube is slotted to allow the eyepiece to slide for focusing. So much for the member holding the optical parts. When assembled, find the point on A where it balances and bore a ½-inch hole.



THE ENGLISH OR FORK TYPE

Figure 5: It dispenses with counterweights but it is not as steady as some others, due to its long overhang

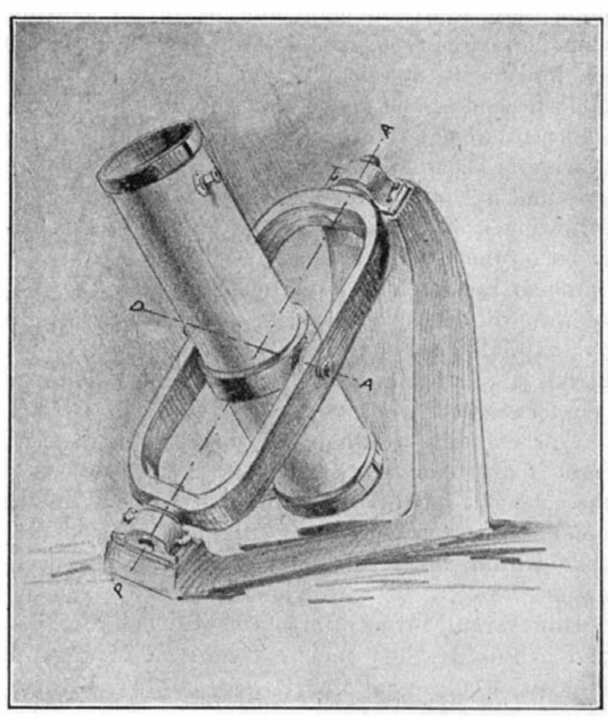
D is a block of wood 6 inches square, and 2½ inches thick. Part of one side within a 4-inch circle is recessed one-eighth of an inch. Two holes, respectively ½-inch and 1-inch in diameter are now bored through the block, as shown. When finished the latter is attached to A with a ½-inch bolt 4 inches long, provided with washers and a butterfly nut.

An Approximate Equatorial Mounting

The polar axis is a piece of 1-inch shafting about 2 feet long. Have the blacksmith bend over 6 inches of it until it makes an angle with the rest of the shaft about equal to the complement of the observers' latitude.

The remainder of the mount consists of a 2-inch steam pipe 2 feet long, cast vertically into a concrete pier. When the bent end is adjusted parallel to the earth's axis by lining it up on *Polaris* some evening, cement is poured into the steam pipe and allowed to set, the block D is dropped down over the shafting in the hold provided for it, and the mount is finished.

The butterfly nut will give the desired pressure between A and D so that the telescope will turn, but will remain fixed at any required declination. If D is slotted as shown, the wood screw M will take up any looseness of the bearing of the polar axis. The mirror is adjusted in its cell until its optical axis passes through the center of the prism J (Figure 8), and this is tested by placing the eye well behind the prism and noting whether the reflection of the prism is in the center of the mirror. Should it be found, say, at K, unscrewing the screw L will make the reflection move toward the center.

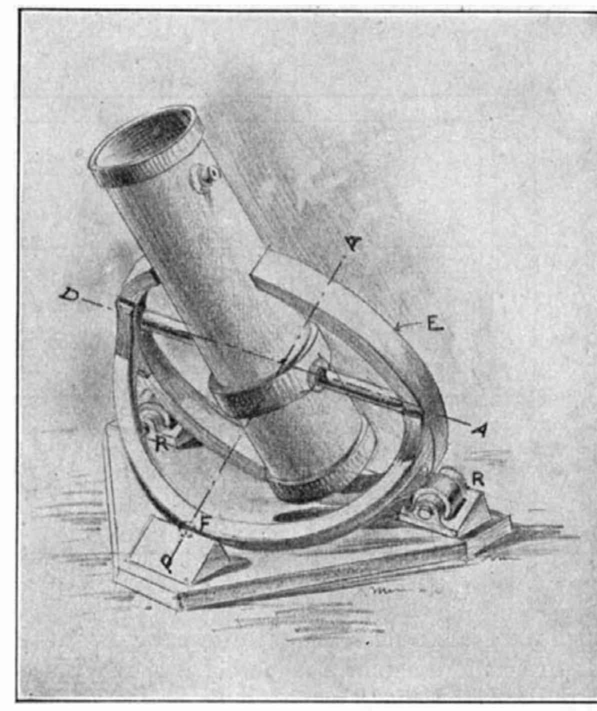


THE DOUBLE YOKE TYPE

Figure 6: Compare this with Figure 5. Having two bearings this type is very steady

The prism is adjusted by taking out the lenses of the eyepiece and looking into the adapter. The reflection of the mirror will be seen in the prism. The reflection of the prism should be central and must be made so by filing the seat of the prism. A slight movement of the prism between its ears will cause the reflection of the mirror to move and will indicate where the seat should be altered.

The focal length of the mirror has previously been found during the knife-edge tests. It is one-half of its radius of curvature. The distance from the surface of the mirror to the center of the adapter tube will therefore be this focal length, less the distance from the center of the prism to the focus of the eyepiece—(about 5 inches). For a glass of four feet focal length, the distance from mirror to adapter



THE EQUATORIAL RING MOUNTING

Figure 7: This type has many advantages, particularly that of steadiness. Here as elsewhere the polar axis is P—A

would be 48—5=43 inches. The focal plane of a negative eyepiece is somewhere between its component lenses; of a positive eyepiece it is just in front of the field lens.

The wooden part of the mount should be well painted and the polar axis should be kept slushed with hard grease. The wooden member can be lifted off the polar axis and taken indoors as a whole, for it is quite light. A cap of some sort (a piece of window glass will do) should always cover the mirror when not in use. This is to preserve the luster of the silvered surface.

The Accurate Springfield Mounting

One of the most convenient of equatorial mountings (Figures 9 and 10), and the one producing the most satisfactory results here, has the advantage of a fixed eyepiece. It is true, a second prism is required. This, however, permits the observer to sit in one position looking comfortably down the polar axis for all celestial objects. The two controls in right ascension and declination are within easy reach (see page 164), the setting circles are large and need no verniers. The tube is counterpoised and can reach all parts of the heavens. Loss of light by the additional reflection through a second prism is negligible.

Light from the mirror, after reflection from the usual prism A in the tube (Figure 9) passes through the hollow declination stud B, to another prism C, directly over the polar axis stud D, and below the eyepiece. In addition to its fixed eyepiece a distinctive feature of this mounting is the manner in which the two axes are maintained. Instead of two spindles held in bearings at their extremities, the bearing surfaces consist of large areas held together with small central studs, that of the declination axis being hollow. This arrangement permits very rigid forms to the three castings I, II and III. The setting circles c and d are cut on member II in convenient positions for reading.

Control in motion is as follows: the two tangent screws a and b (Figure 9) bear against spurs on the edges of two thin sheet steel discs inserted between castings I, II and III. Figure 10 shows the detail of slow motion about the polar axis. The spur on the periphery of disc D, bears in the circular groove C of screw B. Sufficient friction is maintained between the bearing surfaces of the discs so that not only will the tangent screws produce slow motion to either axis, but will also allow the telescope to be swung quickly through large arcs of the heaven in both declination and right ascension. This arrangement makes a very good substitute for the expensive worm wheel drives.

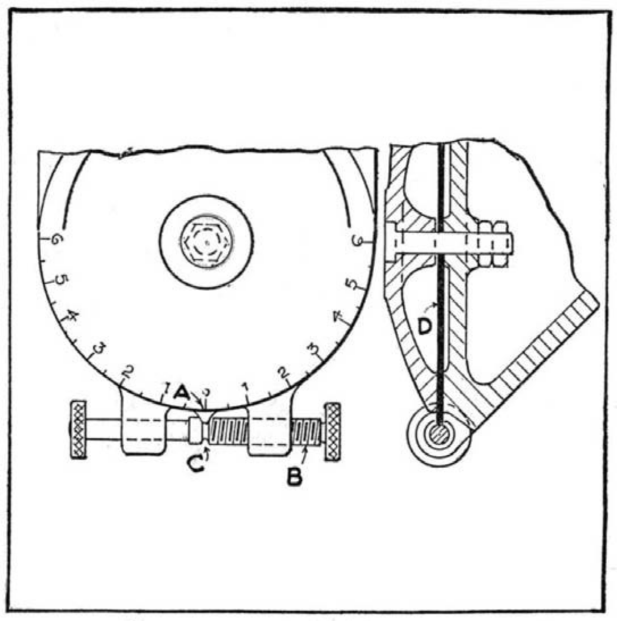
The Hartness, Turret Telescope

Of the many designs of mountings which enable the observer to sit in comfort in an enclosed and warmed room, space here forbids treatment. The most notable of these among amateurs is the Hartness turret, described in the Scientific American, March 9, 1912, in which the roof of the building, made of cast iron, rotates on rolls, carrying the optical parts and delivering the light from a ten-inch objective to an eyepiece inside the room. Bell, in his book, "The Telescope," describes this and several similar mountings.

Mention only, has been made here of the Newtonian reflecting telescope. There are, however, others, but they are not as practicable for the amateur as this type. In the Gregorian type a small, concave mirror just outside of the focus is substituted for the prism. It reflects the light from the mirror to a secondary focus lying behind the mirror, through a hole in the center of the glass. The Cassegrainian type is similar, except that it interposes a convex mirror just inside the focus. Both of these combinations greatly increase the virtual focal length of the mirror without increase of tube length, but they are useless for day work on terrestrial objects and they require the figuring of an additional optical surface.

With an equatorial mounting providing with setting circles one can select any celestial object (above the horizon) by looking it up in the Ephemeris and setting the circles to the correct declination and hour angle. One also sets his watch to running on star time. If he has made no blunder in his calculations and the instrument is in fair adjustment, the object will appear in the field of view of the eyepiece. It may be an obscure double star, or a nebula, or a cluster, or a comet, wholly invisible to the naked eye and impossible of locating in any other way. Thus the desirability of owning a mounting provided with circles is seen, if one wishes to delve into the great storehouse of hidden wonders above us.

On the other hand, the simple wooden mounting which I have described will enable one to pick up all of the apparent celestial bodies—the moon, planets, sun spots, bright double and multiple stars, two nebulae visible to the naked eye, and one or two star clusters.



HOW THE STARS ARE SLOWLY FOLLOWED
Figure 10: Detail of the slow motion, front and side elevations. This is a part of Figure 9

Care must be taken in observing the sun, for the mirror makes a powerful burning-glass. It works best for this purpose while still unsilvered, but if it is silvered, cover the glass with a cardboard in which an inch hole has been cut. The safest way is not to use the eye at the eyepiece but to project the sun's image on a card placed outside the eyepiece.

It is hoped that the amateurs will not copy these mountings slavishly, and partly for this reason set dimensions are not given except in a few instances. When controlled by a clear comprehension of the principles of the mountings used and some mechanical judgment, the exercise of the amateur's individuality in planning his telescope is highly desirable. This suggestion will, it is hoped, obviate the production of a large number of telescopes, as like as a lot of peas. For example, Mr. Clarendon Ions, of Miami, has built an ingenious equatorial mounting almost entirely from discarded parts of a Ford car.

Eyepieces or oculars for astronomical telescopes are usually the Hyghenian type in 1¼-inch tubes. Their powers vary according to their equivalent focal length *(e.f.l.)*. For our telescope of 4-foot focal length an eyepiece of 1-inch *e.f.l.* would give 48 magnifications (the focal length of the mirror divided by the equivalent focal length of the eyepiece). A ½-inch eyepiece would give 96 magnifications and a ¼-inch, 192 magnifications, respectively This makes a good battery of eyepieces for range of powers. They cost from about six to ten dollars apiece.

Were I to have but one eyepiece at first, it would be the low power, viz, 1-inch *e.f.l.* The Hyghenian eyepiece is not, however, achromatic, and the color is quite noticeable in a mirror telescope. I have used almost exclusively the Hastings, three-lens, positive oculars, which give a beautiful, flat and colorless field.

Eyepieces from old microscopes are not to be despised and they work very well with a mirror. They are usually of low power and are useful for terrestrial observation. It is not advised to use a higher power than ¼-inch *e.f.l.*, as the atmospheric disturbances and the quality of the mirror surface set a practical limit to the magnification.

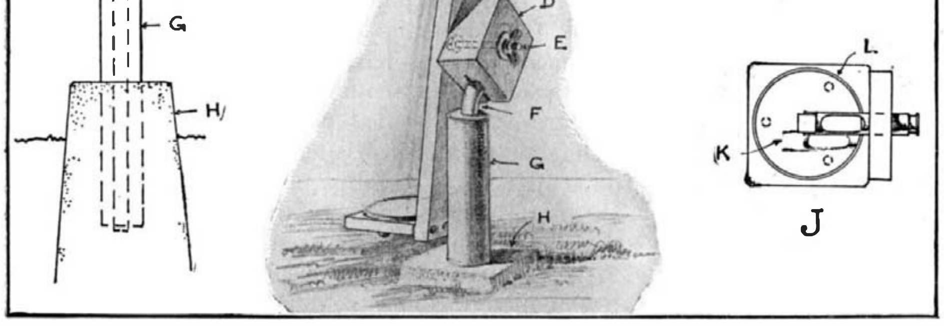
Literature and Materials

A finder is a small telescope fastened to the eyepiece end of the telescope as an aid in pointing the tube to any desired and visible object. They are undoubtedly a convenience in picking up a star quickly, although we usually get along here by sighting along the tube itself. Of course, with one's mounting provided with setting circles, in good adjustment, a finder is unnecessary.

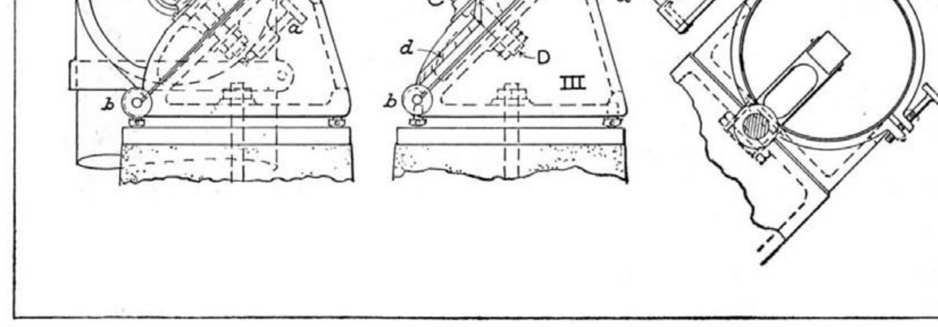
Literature on mountings includes the following: "The Polar Reflecting Telescope," by R. W. Porter, *Popular Astronomy*, May, 1916. "The Enclosed Observing Room," by R. W. Porter, *Popular Astronomy*, May, 1917. "A New Form of Telescope Mounting," by R. W. Porter. "The Telescope," by Louis Bell. "The American Ephemeris and Nautical Almanac" (Supt. of Docs., Washington, D. C.) "The Amateur's Telescope," by Ellison (reprinted by the Scientific American Publishing Company).

Materials may be obtained as follows: Prisms and eyepieces from the J. B. McDowell Company, 1954 Perrysville Avenue, Pittsburgh, Pennsylvania; also, the Spencer Lens Company, Buffalo, New York. Working blueprints of an equatorial mounting for a reflecting telescope with a fixed eyepiece; also prisms, eyepieces, from John M. Pierce, 11 Harvard Street, Springfield, Vermont.

¶ *Later in the year it is hoped that photographs of the various telescopes made by our readers, with their makers included, will be received for publication. With the publication of these pictures in view the individuality displayed should be of great interest.*



A WOODEN, EQUATORIAL MOUNTING THAT ANYONE CAN MAKE
Figure 8: A fair approximation of the equatorial type is obtained, simply by bending the metal shaft F, until it is roughly parallel with the earth's axis



TWO ELEVATIONS OF THE SPRINGFIELD, EQUATORIAL MOUNTING
Figure 9: This is the mounting shown on page 64 and on the cover. Since it is equipped with setting circles, a star may be located with the aid of the Ephemeris