A HOMEMADE 22-INCH REFLECTING TELESCOPE*

By Geo. F. Tauchmann

Great progress has been made in astronomy in general and in the size and construction of instruments employed. Refractors have reached apertures of 36 and 40 inches (this seeming to be the limit) while reflectors rose to 60–72–80–100-inch aperture and the latest project, well along in construction, is the gigantic 200-inch reflector. All these instruments are professional and factory-built. It is an outstanding fact that amateur telescope-making has been confined almost entirely to small-sized instruments, with more or less makeshift mountings, only a few amateurs having constructed reflecting telescopes of 15 inches or more aperture. It is to be hoped that amateurs may go to higher dimensions and better construction and this is feasible.

The June, 1933, number of these *Publications* gave a description of a "Ventilated Mirror" which has a 22-inch diameter. The grinding process is described in the August, 1933, number. The mirror is polished and parabolized to F : 5.1. The polishing and parabolizing were done by the well-known methods as described exhaustively in *Amateur Telescope Making* and therefore can be omitted here.

In laying out the general plan for the mounting the leading idea was to create a model that could be imitated by any amateur who is mechanically inclined without the help of expensive factory facilities.

The first requirement is unlimited ambition and endurance. If not sure about this, do not attempt it. The second is a supply of regular machinist's tools, including lathe (if possible, screw-cutting) and a medium-sized drill press (up to 3/8-inch drills). The cost of materials, mirror not included, runs to about $125.00.

The fork type mounting was selected because it is simple, omitting an extra declination axis and counterweight; also being mounted in the center of the observatory it will point radially through the slot of the dome, thus having a most efficient posi-

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tion. This fork type is employed on the 60-inch reflector at Mount Wilson and others. After I had my layout finished and the construction started I saw a picture of the 1-meter reflector at Simeis, Crimea, Russia, also a fork type, built by Sir Howard Grubb & Parsons. I applied to the Simeis Observatory for a description of their instrument and received it, and I want to express my thanks to Dr. V. A. Albitzky of Simeis Observatory for his kind response. I could not use any of the features of the Simeis instrument aside from what I had already devised, but it proved to be a great encouragement by showing that I was on the right track.

Cell.—Referring again to the article on the ventilated mirror mentioned above, it may be stated that the bronze ring, which once held the 22-inch glass disk of some ship as a port light, came in handy as a medium to bolt the mirror cell to the octagon end of the main tube. The cell consists of a ready-made accessory to automobiles—the pan of a disk wheel. In this case it came from a Dodge car and was only a little curved on the bottom. The mirror rests on a lever system. A centerscrew from the bottom raises or lowers a rocker arm on each end of which another arm swings like a seesaw; thus four points balance each other. To these arms four free swinging end plates are hinged and provide support for the mirror, each plate located under one of the four spacer tube systems. Hooklike logs hold the bottom plate of the mirror to the four supporting plates, and, by means of screws from the logs reaching through the cell, the mirror may be tipped for focusing to the correct point. From the rim of the cell eight setscrews pressing against the four logs allow sidewise shifting of the mirror for centering.

Tube.—The cell is bolted with four bolts to the octagonal part of the tube, which measures 24½ inches over the flats and is 25 inches long. Right over the cell, but on the inside of the octagon tube, a cover is mounted to protect the mirror from moisture, dust, and injury. This cover is hinged in several directions and on opening folds into the octagon form of the tube, so as not to obstruct the path of the rays during observations.

Sheet steel 3/32 of an inch thick is used for the eight sides, made in sections and riveted to each other and the end pieces, which are made of 2" × 1½" × ⅛" angle iron. The cylindrical open-frame part of the tube is made of strips of 1/16-inch sheet steel, 1¾ inches wide on the inner end tapering down to 1¼ inches on the outer end. These strips are riveted to three main rings of 2-inch channel iron and two intermediate rings of 3/32" × 2½" sheet steel. There are over 200 rivets in this part of the tube alone. On the inside of the tube, thin sheet metal rings are fastened, spaced 7 to 8 inches apart, to break the reflection from the inside surface.

The construction of the tube required a special form. Two wooden disks of 23-inch diameter spaced about five feet apart by eight pieces of 1¾" × 5½" plank made this cylindrical form, which revolved on a 2-inch shaft to allow true alignment of the whole tube. First the rings were fastened to the form and lined up and then the strips were mounted.

The outer ring of the tube carries the 4-spoke spider holding the sleeve for the secondary mirror. For the spokes, .078 duraluminum is used. The sleeve permits tipping as well as lengthwise shifting of the hyperbolic-ground and polished secondary mirror, which is 6¾ inches in diameter. This mirror magnifies 2⅝ times. An aluminum cover lined with silver protecting cloth fits over the cell.

Another spider is stretched in the octagon tube below the eyepiece line to hold the 45° flat mirror or diagonal, also adjustable in lengthwise and in circular motion. On this spider the flat sides of the material are covered with grooves gouged out by hand to stop reflection, as the spider is so near the main mirror.

Declination axis.—On two opposite sides of the tube heavy flanges with 1½-inch studs are fastened, from the inside of the tube, specially braced by deep 2-inch channel irons. These studs, carefully lined in relation to the axis of the tube, form the declination axis. To the right side-stud or shaft is fastened a 6-inch drum for the friction and slow-motion clutch. Over this drum runs a split bronze ring lined with brake lining and opened or tightened by an eccentric lever. In an ear on the ring turns a swivel, through which goes a fine-threaded screw with a small handwheel. The handwheel end of the screw turns in another swivel, by shoulders held rigidly lengthwise. The second swivel is fitted in an ear on the bronze bearing on the fork. With the clutch open the tube swings free. Tightening of the clutch-ring fixes the first swivel to the tube and turning of the handscrew causes the slow or fine motion of the tube. A similar device works the slow motion on the polar axis. The declination dial is mounted on the side of the tube, while a vernier fastened to the fork reads to 1/10 of a degree.

Fork.—The material for the work is 1/4-inch flat machine steel. The main strip is formed in a **U** shape. The two ribs are from 2 to 3 inches wide, and on the bottom is a circular-shaped piece 3 inches wide, for the socket to take the end of the polar shaft. All pieces are electric-arc welded, this being the only work not done by me. The ends of the fork arms are shaped in an angle of about 38°, forming a horizontal flat for carrying the bronze bearings for the declination shaft. For greater rigidity an extra thickness of the 1/4-inch flat steel was riveted to the center part of the fork, where eight 1/2-inch machine bolts go through it into a 14-inch flange of the main shaft.

Polar axis.—For the polar axis it was necessary to have extremely strong material. Therefore I selected so-called "oil well casing," a steel tubing that is made in many dimensions. The main piece is four feet long of 7 5/8-inch outside diameter and 3/8-inch wall. The upper end was turned on an old-style, one-bearing-and-one-center lathe of 12-inch swing, the free end of the tube running over specially made rollers resting on the end of the lathe bed. Over the turned end of this tube was slipped another tube of 7 1/2-inch inside diameter with 3/8-inch wall about 12 inches long. I heated the outer sleeve in a fire built in the yard and slipped it on, while dark red hot, over the long tube flush at the ends. It shrunk on so fast that I could not within a few seconds shift the two to even up the ends. Yet to make it doubly safe, I riveted through both. The thicker part was turned in the same lathe to accommodate the socket of the fork, next to the bearing surface; then a part for the big driving worm gear with clutch, and finally for the hour circle. The lower end of the tube takes up a reducing bushing in which is inserted a piece of 2-inch shafting extending 12 inches beyond the end of the tubing, making the overall length of the polar axis 60 inches.

Bearings.—The main bearing was originally built with four 2½-inch rollers revolving on ¾-inch center pins and supported in pairs by 1-inch pins. Owing to the great weight (approximately 800 pounds) resting on this bearing, the friction was very noticeable, causing a rather sluggish motion of the polar shaft. Therefore another system replaced the first. The polar shaft has a diameter of 8.4 inches at the bearing, and I made a regular ring of 24 rollers of 9/16-inch drill rod, each 2 inches long. These rollers are held evenly spaced by two brass rings, bearing studs, which enter the rollers on their ends, as in the usual roller bearings. The half-circle race or track is made as follows: two pieces of ½-inch boiler plate 11½ × 12 inches were fastened to the face plate of the lathe and bored out to the size of the shaft, plus 2 diameters of the rollers (i.e., $8.4'' + 2 \times .6875'' = 9.775''$). After this the two plates were each sawed in half and folded together so as to make a track $4 \times \frac{1}{2}'' = 2$ inches wide. This track has a leaning position of 52° (the complementary angle of the 38° angle of the polar axis). Therefore the brass rings had to be of outside diameter large enough to overlap the track and to be guided by the same. The rollers enter the track on the lower half of the circle and run idle on the upper half. As the rollers, while going through the track, might shift lengthwise, there are springs provided on the ends of each roller, to push the roller into central position while running idle. The performance of this new bearing is perfect.

The outer end of the polar shaft (the 2-inch end) rests in a double row, self-aligning, heavy-duty ball bearing, such as is used in line shafting for machinery. The housing of this bearing is mounted adjustably in vertical and horizontal directions for perfect setting of the polar axis. Finally a thrust ball bearing carries the end pressure of the main shaft and has a heavy setscrew for endwise adjustment. This bearing really has to hold down the end of the shaft owing to the heavy weight resting in the end of the fork.

The driving mechanism.—The driving power is taken from a 1/30-horsepower induction motor. It is commonly considered essential to have a synchronized motor. But since variations in the frequencies of the electric current do not guarantee an absolutely even speed, an induction motor will be sufficient for observation by vision; but for photographic work, more accurate regulation would be necessary. The motor shaft is coupled to a gear box, wherein a number of odds and ends in gears from former experiments were utilized, reducing the speed about 100 times. This reduction could be accomplished with one worm and worm gear, but the advantage of this gear box is the ability to have two speeds. That is, at a certain point of gear engagement where there is a 27-tooth gear engaged to a 52-tooth idler, a 26-tooth gear is coupled with the 27-gear, thus the 52-tooth idler sliding from one side to the other permits a quick shift from the regular motion for star observation to the motion for observation of the Moon.

Both motor and gear box are mounted on a bakelite plate, sponge rubber being used to reduce noise and vibration. From the gear box a 1/4-inch shaft connects with a cross shaft running under the main worm gear. On each end this cross shaft carries a worm, engaging two 96-tooth worm gears, which turn two vertical shafts. On the upper end of each shaft is fastened a worm. These two worms running in opposite directions and against thrust bearings actuate the big worm gear from two sides, one pushing, the other pulling. I do not know of an instance where two worms have been applied to the driving gear, even of the biggest telescopes, but it is undeniable that it is safer and easier to drive an automobile with two hands on the wheel than with one hand, so why not drive a telescope with two worms, especially a big one?

There is a very important advantage in this system. The big worm gear has a diameter of about 14 inches. Engaged by two worms the effective distance between the critical working points is 14 inches, while with one worm it would only be from the center of the worm gear to the rim, that is, 7 inches. In other words I would have to use a 28-inch gear using one worm to have the same accuracy. The 14-inch worm gear required a pattern. This I turned on the above-mentioned 12-inch lathe by blocking up headstock and rest 1¼ inches to increase the swing to over 14 inches. The casting also was turned the same way, and now I come to the real job of cutting the teeth.

For this purpose I built a fixture using a piece of 3-inch channel iron three feet long. I fastened a ⅝-inch stud to it, to revolve the gear blank. A 192-tooth gear doweled to the blank turned on the same stud. With a 60- and an 80-tooth gear I timed the 256 : 192 or 4 to 3 relation to produce a 256-division on the big blank. The fixture was hooked to the slide rest for feeding the chucked single-blade cutter into the blank, which was slightly tipped to the angle of the thread, the other end resting on another support. After gashing the single teeth, I disconnected the gears to allow the big gear to spin freely on the stud and in level position finished the thread with three successive hobs, made from the same acme-thread screw as the two worms. The job was a complete success. The worms stuck in the thread when placed there. Now the big worm gear was bored out to fit the sleeve of the polar axis. A 1½-inch-wide shoulder on the big gear takes care of a brake ring, split, with an eccentric lever for tightening, and is brake-lined, the same as on the declination shaft only larger in diameter. The slow-motion screw connects the brake ring to a tight ring on the main shaft. Now the free revolving big gear is always engaged to the driving mechanism and the polar shaft is in turn coupled to the power by the tightening of the clutch. Still, a slow motion is effected by the turning of the screw. A worm gear and worm allow a much finer adjustment on this screw in right ascension than in declination, and a shaft in sections along the fork reaches up to the left tip of the fork. Now I have my declination fine adjustment in my right hand and the right ascension in my left hand while looking into the eyepiece. Very convenient.

It may be mentioned that the frame carrying both worms is free to follow the worms in relation to the center of the polar axis, that is, up and down, if any irregularity in the division of the big gear should cause binding. In circular direction the frame is held rigid by a tongue guided by two setscrews on the main mounting.

Hour circle.—The hour circle has a diameter of 24 inches and is divided to 720 lines, that is, to two minutes of time. This fine circle is a gift of the well-known firm of A. Lietz Company in San Francisco. I wish to express my thanks to this firm and particularly to their shop manager, Mr. C. P. Stuebgen, for their keen interest in my work and their kindness. A few small electric lights in specially made containers give enough light to the dials in the dark observatory without disturbing the "seeing."

Mounting support.—The main bearing and the lower end bearing are supported by 4-inch channel iron and 3-inch angle iron legs, 8 to 10 feet high, braced in different directions. Here is where the hardest work had to be done. Several days of hack-sawing and filing of this heavy material is tiresome but gives great satisfaction. The same may be said of the setting of the concrete pier to which the legs are bolted.

The main concrete pier is about five feet wide at the base, three feet over, and two feet in the ground and weighs approximately three tons, not counting the 4-inch concrete floor of the building with which it forms a solid piece.

In closing, a few words on the optical condition of the telescope are required. As mentioned at the beginning of this article the main mirror was originally made under the consideration of having a low-priced mirror, such as amateurs in most cases could afford to have. Several years after making this mirror I can state that the expectations in regard to resistance to temperature changes were justified, since observation under such changes showed only small, if any, distortions. The cementing (bakelite cement) did not lose its adhesive power even under fairly rough handling. Therefore I am satisfied that this mirror is to be recommended as amateur equipment.

There is only one point of which to be careful: that is if common plate glass is used, there is the possibility of its being of uneven hardness or having strains. This happened to be the case with my glass. In polishing, the surface became irregular with zones, therefore I did not carry the procedure to a high point of perfection, but rather, used the mirror in a medium state to get the telescope as a whole finished. Now that the instrument has turned out to be excellent mechanically, I will bring it up to the same high standard optically, therefore I have already ordered a 22-inch blank of Jena Low Expansion Glass, which will be ground and polished to the same 5 : 1 focus.

The eyepiece holder has an opening of 3¾ inches and I made one eyepiece with a 3⅝-inch front lens and an equivalent focus of about 7¼ inches, which gives a low magnification of 41 times and has a field of 50 minutes of arc, showing the full face of the Moon with a good margin around it. Another eyepiece of 100 fold and one of 200 fold magnification are made. For a finder, a small refractor with 2⅞-inch objective is used.

Later the telescope will be fitted for observation in the Newtonian focus and other attachments will be made.

It is my sincere hope that this report may encourage my fellow amateur telescope makers to great accomplishments.

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