Both reflecting and refracting telescopes are used in modern astronomical observatories. The advantages of the reflector are its cheapness and its perfect "achromatism" (freedom from outside colors), while the main advantage of a refractor is its permanence and freedom from trouble after once being well adjusted. The world's largest telescope is the 100-inch reflector at Mt. Wilson, Calif. A 200-inch telescope is now being built, which will have four or five times the light-gathering power of the 100-inch instrument and is expected to show more than 2,000,000,000 stars.

The magnifying power of a telescope is expressed in diameters. The focal length (*see* Lens) of the objective or speculum, divided by the focal length of the eyepiece, gives the magnifying power, and every telescope has eyepieces giving various powers. Why not use always the highest power possible? Because imperfections are magnified with the image, and the image loses in brilliancy as it gains in size. Consequently, a faint object can only be magnified up to a certain degree, because further magnification would make it too dim to be seen well. The mammoth Yerkes 40-inch refractor can be used advantageously to give 1,000 diameters, and higher powers are possible.

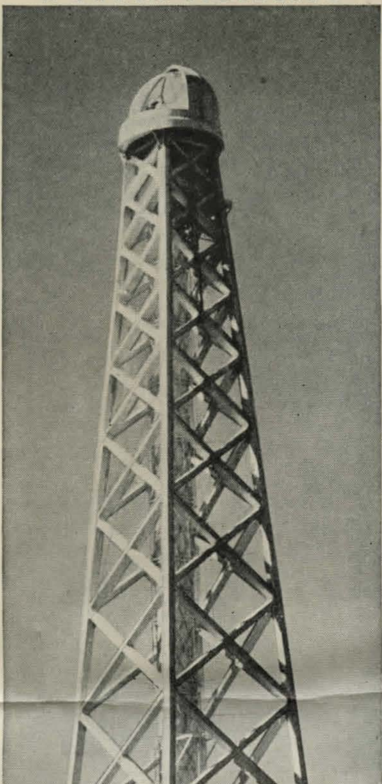
The most important part of a telescope, a great astronomer says, "is the man at the small end." Next in importance is the objective lens or the speculum; this must be made with almost miraculous precision. The surface must be accurate to a few millionths of an inch, and months, even years, of painstaking labor are required to cast and polish a single objective (*see* Glass). So sensitive to changes of temperature is the great 9,000-pound 100-inch mirror at Mt. Wilson, Calif., that the gigantic dome is insulated to keep out the heat. The mounting and controlling mechanisms of telescopes are also marvels of human ingenuity (*see* Observatory). Many modern telescopes are so constructed that measurements of objects and spaces in the field may be made in thousandths of an inch, by means of the micrometer (*see* Micrometer).

In all astronomical telescopes, the image seen at the eyepiece is inverted. In the smaller telescopes or spyglasses to be used on land, an additional lens or system of lenses has to be introduced to re-invert the image, so that it is seen in the same position as the object. The opera or field glass is a pair of small telescopes with concave lenses for the eyepieces. The most efficient and modern instrument of this type, called the prism field glass or "binocular," has two reflecting prisms in each tube. This gives it as much magnifying power as could be obtained with an ordinary field glass three times as long, besides permitting the use of a better type of eyepiece which gives a much larger field of view with better definition.

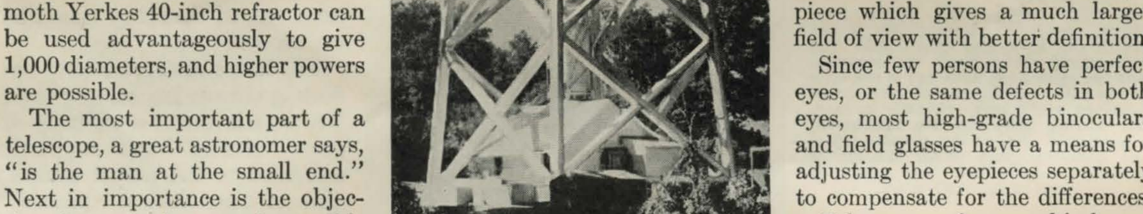
Since few persons have perfect eyes, or the same defects in both eyes, most high-grade binoculars and field glasses have a means for adjusting the eyepieces separately to compensate for the differences.

Telescopes of many kinds are incorporated in a large number of instruments, such as surveyors' levels and transits, range finders, rifle telescopic sights, and even in delicate precision laboratory

A TOWER TELESCOPE

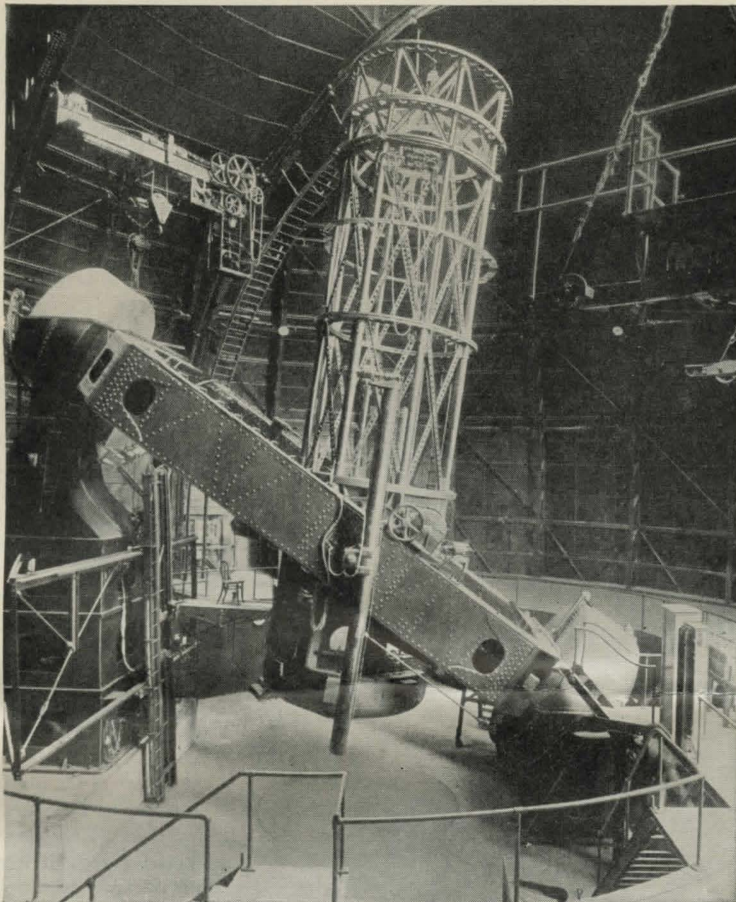


The instruments are fixed on the ground, and a mirror in the top of the tower reflects the image of the sun down the tube to them. The tower is part of the Mt. Wilson Observatory.



This diagram illustrates how the astronomical telescope works. Let us suppose we are viewing the moon or one of the planets, represented by the arrow (AB). The object glass (O) brings the image of AB to an inverted focus at F, where it is viewed by the enlarging eyepiece (EP), which represents it to the eye as though it were a large near object (B'A'). The radiating lines from B indicate how light rays are focused by the object glass. Viewed with the naked eye, comparatively few of the rays from B would be seen, but with the lens (O) in the way, virtually all the light from B which strikes the surface of that lens is brought together again at the upper end of F. The larger the lens, of course, the more light it collects and the more powerful it is for astronomical purposes.

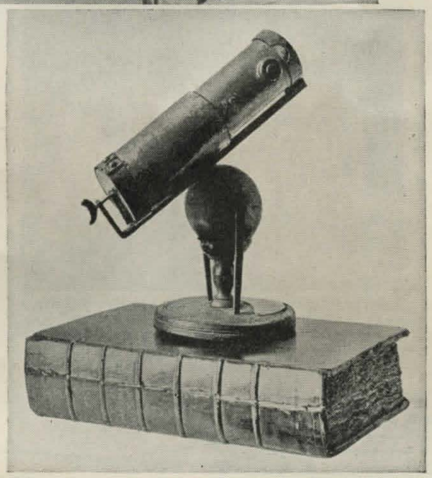
REFLECTORS OLD AND NEW



The huge 100-inch Mt. Wilson telescope, above, is so delicately poised that it can be moved by a touch. The instrument really floats on mercury, and the cylindrical housings at the ends of the axis contain two spherical thrust bearings which carry virtually no load, but merely keep the big instrument "lined up." Notice the circular top of the hydraulic jack under the mirror mounting, on which the mirror is lowered for resilvering.

balances, where all readings and manipulation must be made from a distance to avoid disturbances due to the heat of the worker's body.

While the Hooker reflector at Mt. Wilson was long the largest telescope of any kind, at least two such instruments superior to it in size are under way. These are a 105-inch telescope in France, and a 200-inch giant for the California Institute of Technology.



The errors of early refracting telescopes led Sir Isaac Newton to invent this, the first reflecting instrument. Its size may be judged by comparing it with Newton's book, 'Principia'.

The latter telescope is planned for a tube more than 20 feet in diameter, the mirror being 16 feet 8 inches wide and weighing about 20 tons. The total weight of the telescope and mounting runs over 450 tons.

The 100-inch telescope has a mirror 8 feet 4 inches in diameter, weighing about 5 tons. Twice a year it is lowered on a hydraulic jack through the floor to be resilvered. Some idea of the delicacy of this operation may be gathered when we remember that the surface of such a mirror is finished to a few millionths of an inch; one careless motion, one false movement, in polishing the surface would ruin a costly instrument.

The grinding and polishing, or "figuring," of such lenses imposes a terrific strain on the workers. It is not unusual, in figuring a large lens, to polish for three minutes, and then wait for an hour while the glass cools from the heat given it by the delicate polishing operation. Much more time is spent in cooling and testing such surfaces than goes into the actual polishing.

The largest telescopes must be of the reflecting type, since the practical limit of casting a large refractor seems to have been reached in the 40-inch lens of the Yerkes telescope. These lenses are made of several pieces of glass, and their weight mounts enormously when their size is increased. Aside from the great difficulty of grinding and polishing large lenses of this type, their own weight would cause serious distortion when mounted, so that they would be useless.

The latest design for large reflecting mirrors is a built-up one; that is, the mirror is built up of glass "girders" and supports, cemented to the actual thinner glass on top, which is "figured" to make the mirror. The great 105-inch mirror designed in France is of this type, which can be made much lighter and with a greater degree of certainty.

When completed, it is expected that the 200-inch telescope will penetrate more than three times as far in space as the 100-inch instrument, and permit the exploration of a sphere having 30 times the volume of that now known to astronomers. The study of distant nebulae, now limited by the present telescopes, will be tremendously aided. With modern telescopes, cameras and spectroscopes have practically replaced the old-time observer.