Engineering Aspects of the 200-Inch Telescope

By BRUCE RULE

THE principal features of the Palomar 200-inch Telescope are well known and are of considerable general interest, not only because of the huge size required to accomodate the largest reflector made, but also because of the engineering aspects involved in achieving the unprecedented accuracy and coordination of precise mechanisms. Most of the exacting engineering objectives have been accomplished by modifications of conventional methods or by development of new techniques to meet special conditions.

ADVANTAGES OF THE 200-INCH TELESCOPE

Briefly, the function of the Palomar 200-inch Telescope is to collect light from celestial objects and concentrate it at the prime focus, or, by a series of additional reflections from auxiliary mirrors, to bring the light to other focal points both on and off the telescope. The major advantages of the 200-inch telescope over other large instruments in existence are:

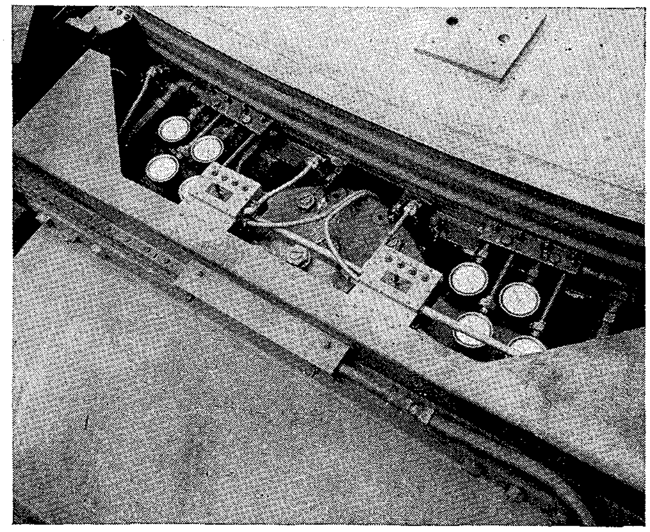
1) its considerably larger light-gathering capacity, permitting reduction in time of exposures and the photographing of more distant objects;

2) its design, permitting astronomical work directly on the telescope at the prime focus, thus avoiding the loss of light through additional reflections;

3) its flexibility by remotely operated auxiliary mirror combinations;

4) its automatically corrected drive and setting controls, which relieve the observers of unnecessary tasks and save time.

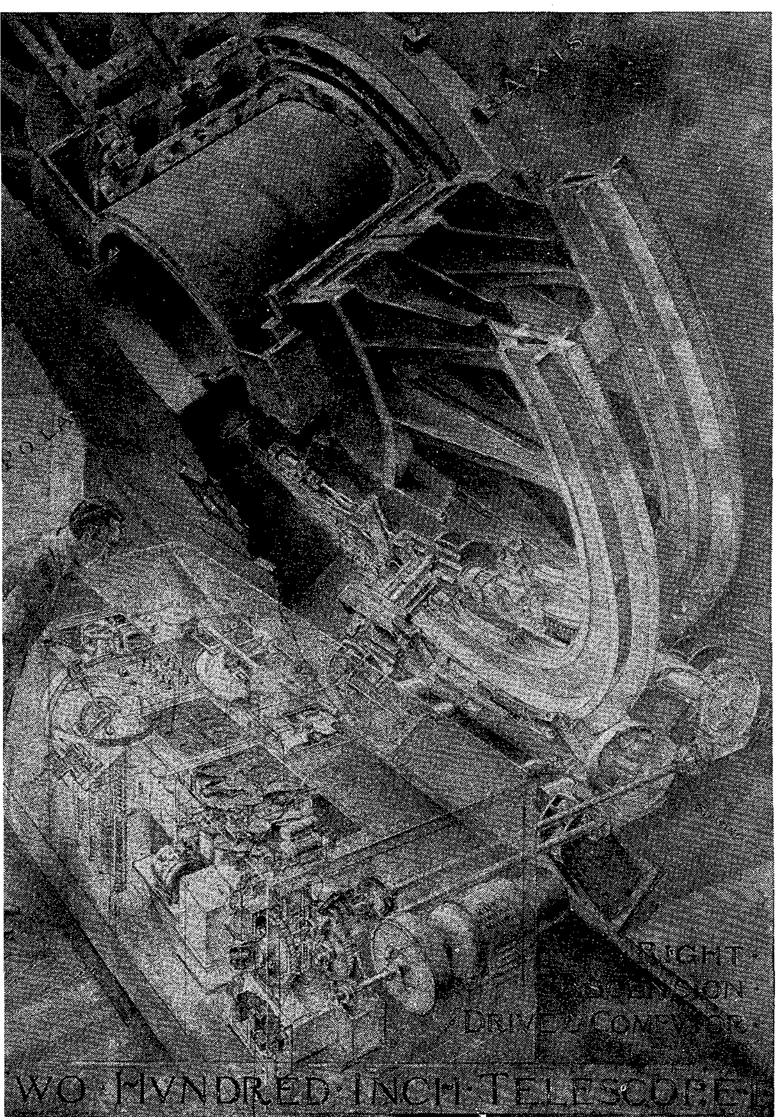
To realize the optical advantages of the 200-inch telescope, the application of many mechanical, structural, and electrical devices has been made to obtain the required coordination of the many precise auxiliary mechanisms.



North oil pad bearing and film gauges.

THE MOUNTING

The mirror is now supported in its 530-ton mounting within the 137-foot-diameter welded and insulated dome, so that it can be directed with minimum effort toward any point of the celestial hemisphere and moved automatically and continually to follow the apparent motion of the stars, due to the earth's rotation. The angular rate of motion of any telescope

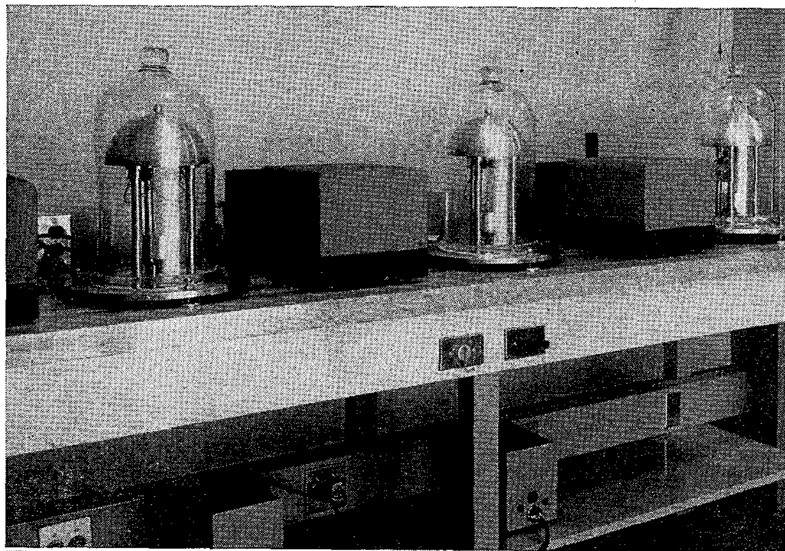


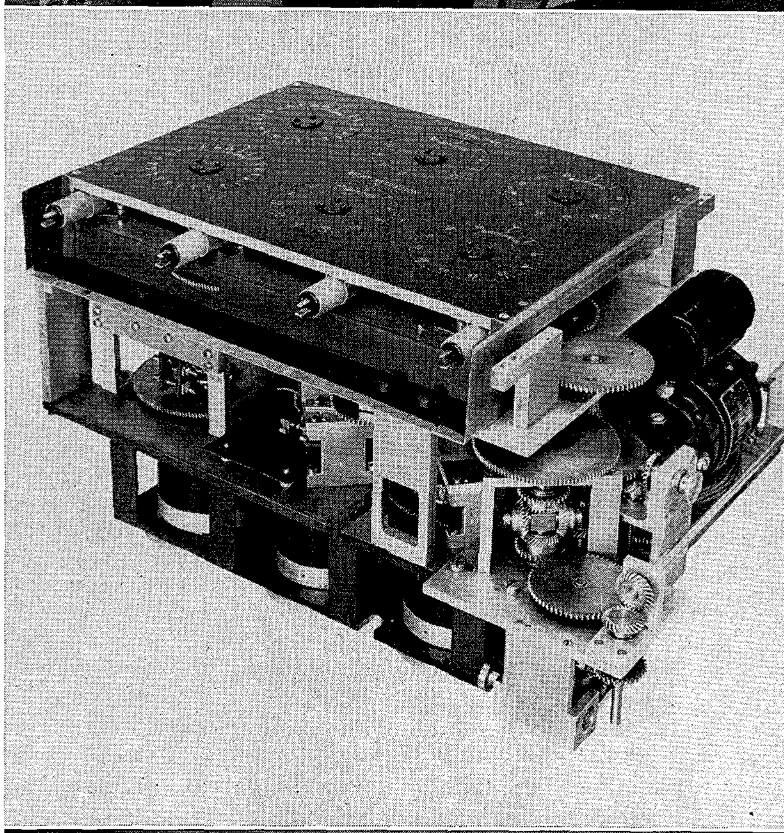
Two 14-foot worm wheels drive the telescope in right ascension. The upper one, for "tracking", turns at celestial rate, just fast enough to keep the telescope on its objective, while the photographic plate is being exposed. The lower "slewing" gear permits fast turning of the instrument. The computor below compensates for atmospheric conditions and flexure of the telescope. Drawing by R. W. Porter.

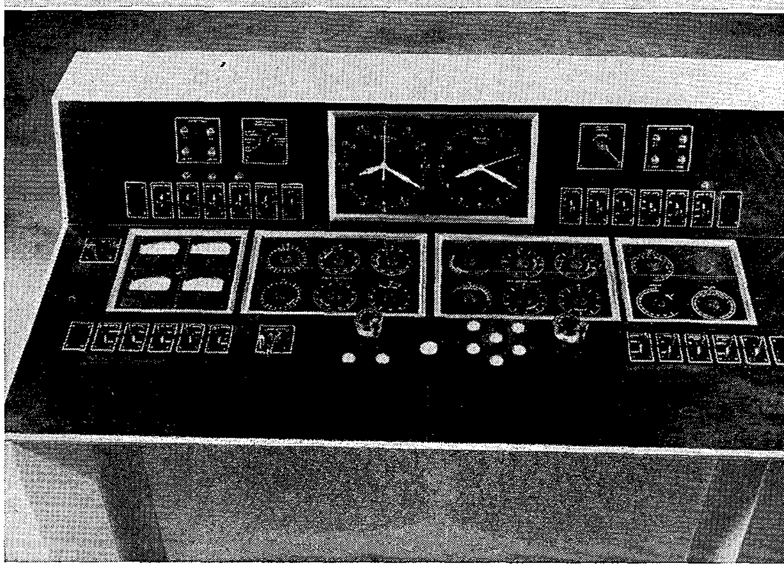
UPPER: Vibrating wire time standard eqipment.

CENTER: Right ascension indicator and sidereal time unit.

LOWER: Main 200-inch control desk.







in "unwinding" the earth's rotation is not uniform, but, nevertheless, very exact and requires compensation for the apparent motion of the star image. This star image must remain stationary on the photographic plate, or the spectrograph slit, for the entire period of exposure, which may be for several hours. The drive at celestial rate is by means of a synchronous motor supplied with power from an accurate yet variable vibrating wire frequency standard. This is in contrast to the usual mechanical governor-type of drive for telescopes. Variation in drive rate as determined by mechanical computers automatically adjusts the frequency of the standard to provide the proper rate.

The weight and size of the telescope mounting are not overwhelming, compared with modern structures, but the high optical and drive accuracy required makes the problem unusual. For example, while a comparable structure may safely deflect several inches under load, the telescope tube must not deform in any position more than 1/16 inch, and must operate in such a way that the optics remain collimated with the face of the mirror held perfect to within two-millionths of an inch.

ENGINEERING REQUIREMENTS

The engineering requirements were determined largely by the optical accuracy necessary. Not only is each mirror mounted on the structure to prevent rotation with respect to other mirrors, but each support system is gravity compensating yet rigidly defined in all positions. The aperture ratio of f 3.3 set severe mechanical alignment tolerances since mounting and instrument equipment is large in size, but deflections tolerable are less than for most smaller telescopes. Not only are "dead weight" deflections important, but also secondary effects such as torsion, temperature, unbalance, vibration, and driving friction torques. One of the early questions of overcoming the obvious enormous friction that 530 tons would create on the polar axis bearings was resolved by the use of forced feed oil film at pads of the north and south bearings, which reduced the friction torque a thousand times over that possible with a roller bearing system, besides permitting the yoke to be driven from one end without requiring excessive torsion in the yoke structure.

Other factors of design were dictated by the operating and control requirements. Because of the size and location, most mechanisms must be remotely operated and self-aligning with servo follow-up or indicating systems where motions are required. The controls are centralized at various stations where of necessity operations are carried on in complete darkness during

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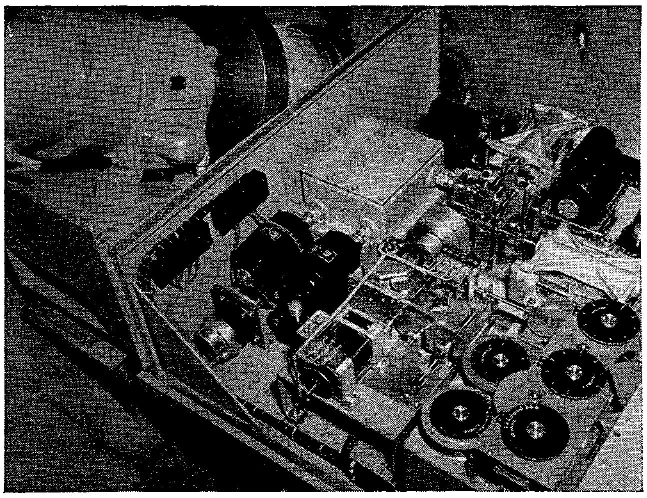

Declination drive unit in west tube of the Hale Telescope.

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exposures. Consequently operations must be reliable, simple, and safe. Mechanisms must function correctly under conditions of wide range of temperature, humidity, and position. Several driving speeds covering a range of 36,000 to one from fast slewing to correcting rates are provided with driving accuracy tolerances of 1/10 of seconds of arc per 5 seconds of time for celestial rates, to 5 seconds of arc accuracy for automatically setting the telescope to a selected field of view. The drive rates and setting control functions must eventually compensate for the residual structural deformations, periodic driving gear errors, errors due to atmospheric refraction, and other operations which are functions of hour angle (about the polar axis) and declination angle.

Since for the first time the observer will "ride" on the telescope, the usual graduated circles for reading declination angle and hour angle were modified to allow him to ascertain the telescope setting while working at the various stations. These and other conditions led to the adoption of a 68-Selsyn remote indicating system of high accuracy for position indicators at each observing station.

Coordinated with the telescope positions are the operations of other, auxiliary, equipment, such as the rotating dome, prime focus elevator, wind screen, hoists and moving platforms, each involving some unusual problems. These are examples of but a few of the many problems confronting the engineers.

To justify such an instrument, every moment of good "seeing" time must be used to its fullest extent in getting data with no time lost in set-up operations. Thus special attention has been directed to reducing the time necessary to change the auxiliary mirror combinations for working at different focal points. All auxiliary mirrors are permanently attached to the telescope and are swung into or out of position by means of motorized mechanisms remotely controlled. These operations extend the usable time of this large camera and give the flexibility desired for a wide range of uses to meet present and possible future astronomical problems. The choice of equipment and methods was determined by the criteria of telescope use for a long period of time but at low operating and maintenance cost.

With the finished and aluminized 200-inch disk in place at Palomar, the telescope appears complete. Its size, however, masks the remaining auxiliary instrument assemblies that are being installed within the structure. The mechanical drives and most of the auxiliary mirrors are now being operated and adjusted in the course of overall optical tests. When mirror adjustments and camera equipment are completed, preliminary operations will begin. Solutions of the unusual design and manufacturing problems encountered on this telescope project have required the close cooperation of engineers and scientists of the California Institute of Technology with many manufacturers who have made their facilities available, assisting in the accomplishment of Dr. George E. Hale's vision of twenty years ago. The Palomar telescopes will give mankind new concepts of the universe. The dedication, therefore, is a logical beginning further to satisfy man's quest for a small understanding of the evolution of our system, as well as a tribute to those scientists and engineers whose labor, experience, or encouragement made possible this instrument.

Bruce Rule

Bruce Rule, project engineer for the Palomar Observatory, has been working on the development of the 200-inch at the Institute since 1937. In addition to his work at Caltech he has been electrical and mechanical consulting engineer at the University of California's Lick Observatory, Mt. Hamilton, for the past year.

Prior to the war, Rule had considerable experience with services and industries in Southern California, including electrical testing with the Los Angeles Bureau of Power and Light, and as superintendent of the meter and testing division of light and power for the City of Vernon. He was engineering consultant for the Cooperative Development Co. of Los Angeles and the Hydril Corporation; and while an undergraduate in 1931 and 1932, helped in the Caltech Electrical Engineering Department on the design and construction of Institute buildings. In 1932 he received his Bachelor of Science degree from the California Institute.

From 1933 to 1938 he taught adult education classes in Los Angeles on radio theory and practice, electricity, sound, amateur radio, and vocational arts. In the war years Rule did research at Caltech on the development of anti-submarine devices, projectiles, and rockets, and worked on special contracts in connection with aerial cameras and optical instruments. In 1945 he received the Merit Award badge and Development Award for Exceptional Service from the U. S. Navy Bureau of Ordnance. He belongs to the American Institute of Electrical Engineers in Los Angeles and is a member of Sigma Xi and Tau Beta Pi honorary societies.