The 200-inch Telescope

By Dr. Walter S. Adams,

Director of the Mount Wilson Observatory, Pasadena, California

DURING the past few years, responsibility for the construction of the 200-inch telescope and the solution of its many problems has lain with the members of three committees organized to deal with various aspects of the project. Of these committees, the Observatory Council is the executive body making final decisions upon major questions which are brought to its attention, the Policy Committee considers general matters relating to the function of the telescope and auxiliary instruments and the future operation of the Observatory, and the Construction Committee deals with all technical subjects connected with the design and construction of the telescope. Both the Policy Committee and the Construction Committee report directly to the Observatory Council.

The membership of the Observatory Council, as at present constituted, consists of representatives from the Board of Trustees and staff of the California Institute of Technology and the director of the Mount Wilson Observatory. The members of the other two committees are from the staffs of the two institutions. Dr. Max Mason is chairman of the Policy and the Construction Committees, and since the death of Dr. George E. Hale has also been chairman of the Observatory Council. Dr. John A. Anderson is the executive officer of the Observatory Council with general charge over the optical and instrument shops, and until January 1, 1939, Captain C. S. McDowell was supervising engineer in charge of construction. The advice and assistance of numerous engineers and men of science throughout the United States have been utilized to advantage on many occasions and have been given most generously.

A review of progress on the 200-inch telescope naturally divides itself into three parts: optical figuring of the 200-inch and auxiliary mirrors; design and construction of the mounting and drive; and construction and erection on Palomar Mountain.

OPTICAL WORK

The present figure of the 200-inch mirror approximates closely that of a sphere with a radius of curvature of 111 feet. The disk was first shaped on front, back, and edges by grinding with coarse carborundum and the centre was then hollowed out to a depth of about $3\frac{3}{4}$ inches with the aid, first of a 50-inch tool, and then of successively larger tools up to the full size of 200 inches. As the spherical figure was approached, finer grades of carborundum were used so that when optical tests became necessary only a few hours of polishing were needed to give the surface sufficient reflecting power. During the first stages of work upon the disk, the cylindrical holes on the back of the mirror and the large areas between the supporting ribs were filled with plaster of Paris, and after the face and back had been made parallel the 40-inch opening at the centre of the disk was closed with a glass plug weighing about one ton. The plaster of Paris was removed when the surface had reached nearly the required form, and the mirror was placed upon rubber pads which rest on the frame of the support system of multiple counter-weighted levers. The friction of these pads was required to neutralize the strong lateral pull of the grinding and polishing tools making contact over so large a surface, and for this reason the horizontal plates of the supporting system were not engaged. The optical tests, however, were made with the mirror vertical and balanced upon the support system just as it will be when in use on the telescope. Future optical work, including the parabolizing, will be carried on with the mirror resting upon the rubber pads; but these will be removed when the figuring is completed.

From the first the optical tests of the mirror proved to be most satisfactory. No change was seen in the figure when the mirror was tipped repeatedly from a horizontal to a vertical position or when it was rotated. Also no local deformations could be detected at the points of contact of the thirty-six individual lever supports. In fact, the support system was found to be performing quite as well as had been hoped by its designers. The length of the radius of curvature proved to be about two inches less than had originally been planned, but this slight difference, amounting to about one inch in the focal length, is far within the limits allowed for in the design of the telescope, and it is probable that no attempt will be made to reduce the amount through polishing. The surface was found to be reasonably free from zones, but a small amount of astigmatism was present amounting to about 0·1 inch in the optical cut-off at the centre of curvature. This proved to be due to a slight deformation of the disk caused by the horizontal pads upon which the mirror rests, and is being corrected by a small amount of fine grinding after suitable changes in the supporting pads.

Although the final parabolic curve of the surface of the mirror will be only 0·005 in. deeper than the spherical curve, the area is so great and the process of polishing so slow that it is planned to make most of the change through fine grinding and to leave but the final stages of the figuring to the polishing tool. This procedure has already been found successful in figuring the spherical curve.

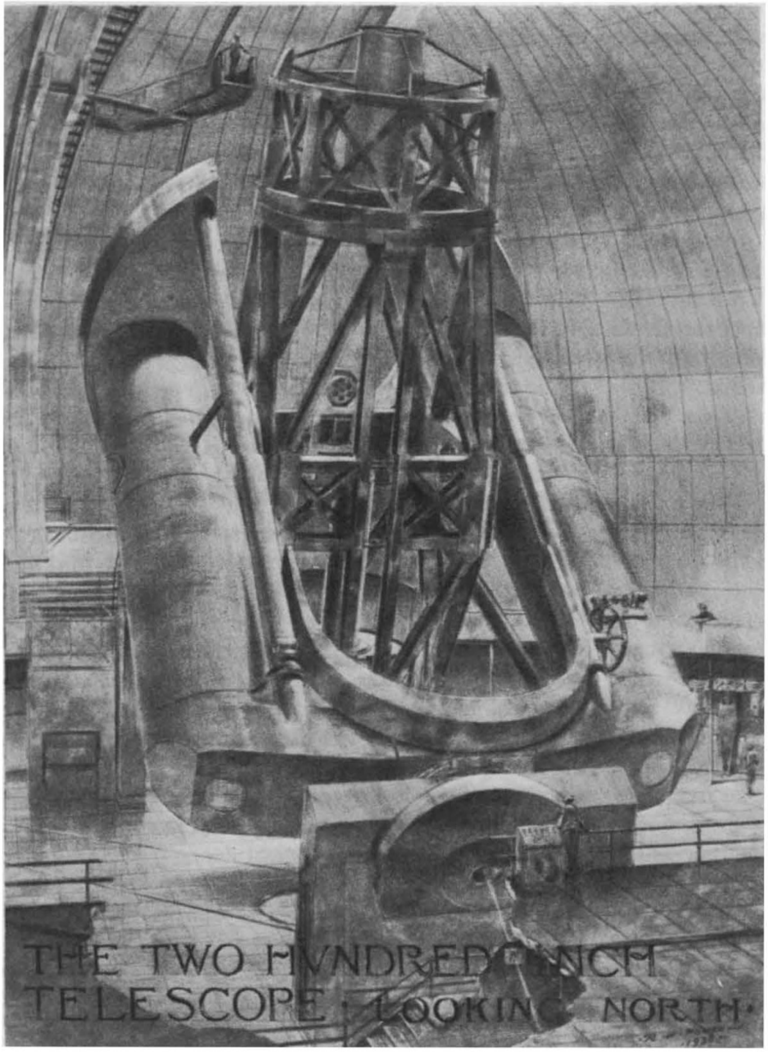

Fig. 1.

DRAWING SHOWING THE SIDE MEMBERS OF THE YOKE WITH THE TELESCOPE 'TUBE' BETWEEN THEM.

Accurate tests of the parabolic figure of the 200-inch mirror will require the use, as an auxiliary plane, of the 120-inch mirror. The completion of this mirror will be one of the next major undertakings in the optical shop. It is at present shaped on front, back, and edges, and the surface has been ground approximately flat. It is planned to figure the three auxiliary hyperbolic mirrors, one for the Cassegrainian and two for the coudé combination, by the method devised by Hindle, without the use of the 200-inch mirror. Four spherical mirrors, each about 40 inches in diameter and with a radius of curvature of 25 feet, are being prepared for this purpose, two being very nearly completed. The mirrors will be used side by side in a cloverleaf pattern and provided with adjustments for bringing their centres of curvature into accurate coincidence.

A few figures are of interest as indicating the scale of the optical work on the 200-inch mirror. About five tons of glass have been removed in the process of shaping and figuring, and about 20 tons of carborundum have been used for grinding. During the polishing, about 50 pounds of rouge an hour is the average consumption with the full-sized tool, and but a small fraction of this material can be salvaged. As a result rouge has been purchased in quantities hitherto quite unfamiliar to dealers in optical supplies.

MOUNTING AND DRIVE

The major portions of the telescope mounting have been under construction during the past few years at the South Philadelphia plant of the Westinghouse Electric and Manufacturing Company. They were completed and shipped in October and have been transported to Palomar Mountain, where erection has been in progress since November. These parts include the tube, the north and south members of the yoke, the two east and west members, each of which consists of three sections, which, when joined, form a 60-foot tube 10 feet in diameter, the declination bearings and the hemispherical south bearing of the polar axis with its oil pads. Several of the individual pieces weigh between 45 and 55 tons, and the total weight of the completed mounting will approximate

500 tons. The north and south bearings of the telescope are on oil films maintained under high pressure, while the declination bearings are of the ball type. At the present time the south member of the yoke has been placed in position on its bearings and the supports for the oil pads at the north end are installed in readiness to receive the section of the yoke which will form the journal supporting this end of the telescope. This feature of the mounting is a welded structure, shaped like a horseshoe, about 4 feet deep and 46 feet in diameter. It was machined with the tips of the crescent under tension so that it will have an accurate circular form when carrying the weight of the telescope.

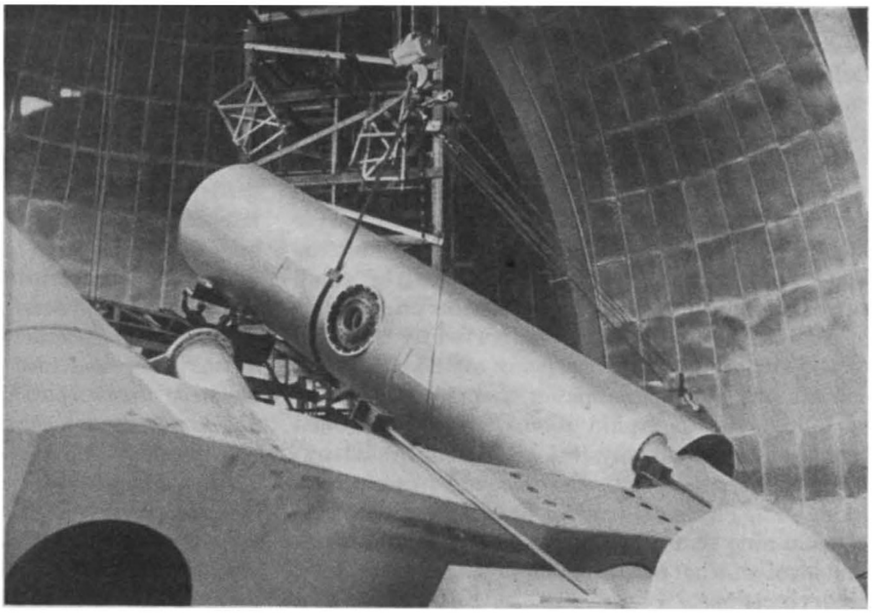

Fig. 3.
Erection in the dome on Palomar Mountain.

The large gear wheels, two for the right ascension drive and one for the declination, are 14 feet 3 inches in diameter, and are being cut and ground in the Pasadena instrument shop, where all the control mechanism is under construction. The driving control of the telescope will be electric with a five per cent range in rate, and the instrument will be provided with computing devices for automatic settings in position.

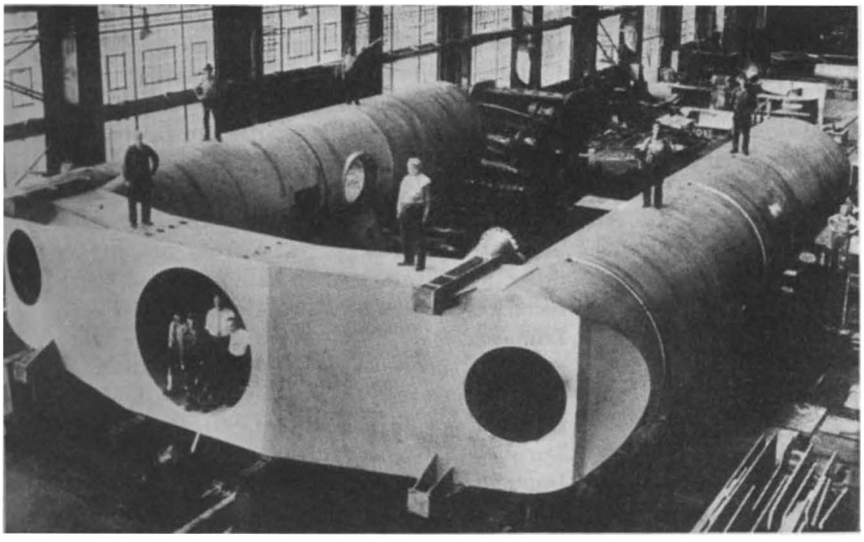

Fig. 2.
South and side members of the yoke at the factory.

Construction and Auxiliary Instruments on Palomar Mountain

The dome to house the 200-inch telescope is 137 feet in diameter and has been built and erected. The building is of double construction throughout with an air space between the two walls and heavy insulation on the inner wall. The insulation of the steel dome is by means of aluminium foil set in panels 5 inches thick, which cover the entire interior surface including the 35-foot split shutter. It is expected that the daily temperature range within the dome will not exceed 3 degrees. The outer shell of the dome is of monocoque construction, consisting of three-eighths-inch steel plates welded together and stiffened by an interior framing of girders and arches.

The dome weighs about 1,000 tons and is mounted on thirty-two trucks with spring adjustments and forged steel wheels. The rails are welded to avoid joints and have been ground to a bevel so that the motion of the dome gives very little vibration. The driving mechanism consists of two motors, 180° apart, which operate through reduction gears to turn rubber-faced driving wheels which are held by springs against the vertical flanges of the rotating dome. This design has proved effective, and the friction of the rubber faces provides a brake against rotation of the dome, by high winds.

A travelling crane with a capacity of 60 tons is attached to the main arches of the dome, and the platform for carrying the observer to the small turret in the centre of the tube at the prime focus of the telescope will also be supported by this part of the structure. The basement of the dome will contain the large aluminizing chamber, a number of offices, photographic rooms under controlled temperature, small physical and chemical laboratories and the pier of the large coudé spectrograph room. The electrical control boards are housed on a mezzanine floor, and above this but just below the level of the telescope mounting is the main observing floor.

It is essential in the case of the 200-inch telescope, in which the field of sharp definition at the centre of the photographic plate is limited and the value of observing time is extremely high, that the observational programme be defined as accurately as possible through survey work and identification of objects with instruments having wide angular fields and great light efficiency. Two Schmidt telescopes have been planned for this purpose, one of which, with an effective aperture of 18 inches and a focal ratio of 2·0, has been in operation for about three years. It has been most productive in studies of nebulæ and the discovery of supernovæ. A second instrument of this type, with an effective aperture of 48 inches and of focal ratio 2·5, is now under construction. The 45-foot dome has been erected on Palomar Mountain and the 72-inch pyrex disk for the spherical mirror has been received from the Corning Glass Works. The figuring and support of the 48-inch Schmidt correcting plate, which will not exceed one-half inch in thickness, will present some interesting optical and mechanical problems.

The Cell Theory

Its Past, Present and Future

AMONG the important meetings held by the American Association at Richmond, Virginia, in December, were those dealing with the cell theory—its development, its present status, and its future possibilities. These meetings were in the nature of a symposium and combined the best thought of the three sections of the Association, on history, botany, and zoology, which collaborated in the programme.

Seven outstanding papers by eminent scholars were presented in two sessions, morning and afternoon of December 27. Those taking part were: Prof. L. L. Woodruff of Yale University; Prof. J. S. Karling of Columbia University; Prof. E. G. Conklin of Princeton University; Prof. G. A. Baitsell of Yale University; Prof. Paul Weiss of the University of Chicago; Prof. Franz Schrader of Columbia University; and Prof. C. E. McClung of the University of Pennsylvania. The discussion and attendance throughout were exceptionally good, more than a hundred and fifty being present at the afternoon meeting.

The morning session, which was devoted to historical aspects, brought some surprising results, especially as bearing upon the two men, Schleiden and Schwann, who up to the present day have generally been given most credit with respect to the origin of the cell theory, which they were supposed to have enunciated a century ago [see also NATURE of February 18, p. 293].

There was apparent agreement in the scholarly papers presented by Profs. Karling and Conklin that the cell theory was projected some time prior to the appearance of the works of Schleiden and Schwann, that these two men added nothing either in content or in clarity with respect to the theory as such, and that they in fact lent support to a general view of cell formation which was completely erroneous.

Prof. Woodruff dealt with the preceding period and with the influence of the microscope. One hundred and seventy years before 1838, Robert Hooke had described little boxes or cells seen under the microscope, and from his day onward other significant observations on cells had been recorded by such men as Malpighi, Grew, Wolff, and Lamarck. With the beginning of the nineteenth century, the cell theory came into sharper focus and received fairly clear and explicit delineation at the hands of Mirbel (1802–1809), Dutrochet (1824), Turpin (1826), Meyen (1828–1838), Brown (1831), Demortier (1832), Purkinje (1835), Mohl (1835–1838), and Valentin (1838).

All these significant contributions preceded the works of Schleiden and Schwann. Why then, it was asked, have the two men been called the