THE INSTRUMENT SHOp.

Many of the problems which confront the modern astronomer and astrophysicist require for their solution the invention of new methods of research and the construction of instruments of special design. This is particularly true in astrophysical work, and an observatory in which such investigations are to be carried on must be prepared to supply the needed apparatus. Fortunately for the progress of science in the United States, the instruments manufactured by the best firms in this country are not surpassed, if they are equaled, by those made abroad. As this is true of both the optical and mechanical parts, it is evident that no institution having the necessary funds at its disposal need have any difficulty in procuring the apparatus it requires.

The writer had found at the Kenwood Observatory, however, that while the principal instruments could be most advantageously obtained from Brashear and Warner & Swasey, it was necessary to have a workshop in which a skilled mechanician was almost constantly employed in constructing the numerous pieces of apparatus required in the solar and spectroscopic work. Those who have devised new instruments of research know only too well that it is frequently necessary to completely rebuild a piece of apparatus, or at least to make extensive alterations in it, before the expected results can be obtained. If an instrument is built under the eye of its designer, the ideas which may suggest themselves during its construction can be embodied in it at a minimum of cost. In fact, the very opportunity to see

*For previous articles in this series see the March and April numbers of this JOURNAL.*
INSTRUMENT SHOP OF THE YERKES OBSERVATORY.

PLATE XX.
each part made is not to be undervalued, for one not only
obtains in this way a very intimate acquaintance with every
detail, but is also much more likely to find important improve-
ments suggesting themselves, which can be at once realized.
For much experimental work it is also quite unnecessary to go
to the expense of purchasing a finished piece of apparatus, when
something answering equally well can be put together under
one's own direction in a very short time. Another great advan-
tage of having an instrument shop is the fact that repairs can be
made at the moment they are needed, so that an important
investigation need not suffer unduly from the results of an acci-
dent.

It seemed evident that if an instrument shop had proved to
be indispensable at so small an institution as the Kenwood
Observatory, it would be necessary to provide the Yerkes
Observatory with the very best facilities for mechanical work.
The machine tools which had been used for some years at Chicago
were an engine-lathe, a shaper, and a small speed lathe. Sub-
sequently there had been added an 8-inch Rivett "Precision"
lathe and a Brown & Sharpe universal milling machine. These,
with a large number of hand tools for wood and metal working,
were available for the purposes of the Yerkes Observatory. It
was decided to add to them at once a planer and a drill press,
together with a circular saw and speed lathes for pattern work.

It had at first been planned to have the workshop in the
power-house, but after it had been found that for various reasons
this could not be done, rooms on the lower floor of the Observa-
tory building were selected for the purpose. Professor Wads-
worth, who had been placed in charge of the work of designing
and constructing instruments, laid out the plan of the shop. A
room 18 X 54 feet, occupying the southeast quarter of the
ground floor, was devoted to the metal-working tools, and smaller
rooms, in the hall adjoining this on the east, were
fitted up as pattern shop and forge room. To lessen the effects
of vibration of the machinery, the cement floors of the shop are

1See Plate XI in the April number of this Journal.
separated from the walls by strips of soft wood. For the same reason the main shaft, which runs the entire length of the large room, and extends through the partition into the pattern shop, is not hung from the ceiling, but supported from the floor. The countershafts, also, are mounted on floor supports, no shafting of any kind being attached to the ceiling. The results of this plan are very satisfactory, and up to the present time no traces of vibration have been detected, although sensitive instruments have been used in various parts of the building.

As the photographs show (Plates XX and XXI), the heavier machinery, consisting of a 16-inch Blaisdell engine lathe, Prentice drill press, 20 x 20 Wheeler planer, Brown & Sharpe universal milling machine, and shaper, have been grouped in the west half of the large shop. In this part of the shop there are also an emery grinder, speed lathe, bench for filing and chippering, and soldering bench. The motor which furnishes the power is a transformed 70-light Weston dynamo formerly used by the writer at the Kenwood Observatory to generate the current employed in his studies of the spectrum of the electric arc. But few alterations were required to adapt it to its present purpose, for which it serves very well.

The more delicate instrument work is done at the east end of the shop in a room separated from the space just described by a glass partition. A filing bench runs the entire length of the south wall of this room, and is carried around on to the east wall. Upon this bench is mounted an 8-inch Rivett "Precision" lathe fitted with grinding attachment, Horton chuck, step chuck, and a set of split chucks. The change gears permit threads to be cut on both the English and metric systems. The shop is provided with a good collection of small tools.

The machine tools in the pattern shop consist of a circular saw with iron tilting table, and a large face-plate lathe of nine feet swing designed for pattern work and built by our own mechanicians. There is also a cabinetmaker’s bench and a good assortment of wood tools. The adjoining forge room

1 Not completed when the photograph reproduced in Plate XX was taken.
INSTRUMENT SHOP OF THE VERESES OBSERVATORY.
contains a forge with hand blower, and a blacksmith's anvil with the necessary small tools.

The shops have been fitted up during the past winter by Professor Wadsworth and the two mechanicians. Although this has necessarily taken up much time, opportunity has nevertheless been found for other work. Among the machines and instruments constructed may be mentioned the 9-foot pattern lathe, planer chuck, large spectroscope,\(^1\) rotating shutter for solar photography, set of universal clamps and supports for the laboratories, and an alt-azimuth mounting for a 24-inch reflector.\(^2\) The 12-inch telescope of the Kenwood Observatory has been remodeled to adapt it to the higher latitude and different conditions of work of the Yerkes Observatory. The large spectroheliograph has also been partly rebuilt, and a grinding machine for the optical shop is now in process of construction. In addition to this much repair work has been done.

Two skilled mechanicians are employed in the shop. A recent gift from a friend of science in Chicago for the express purpose of constructing a machine for ruling gratings, designed by Professor Wadsworth, will now render possible the employment of a third mechanician, whose entire time will be devoted to this work. An interferometer will be required in perfecting the adjustments of the ruling machine. This will be constructed first in order that it may also be employed in Professor Wadsworth's determinations of the absolute wave-lengths of lines in the infra-red spectra of the elements. In addition to the ruling machine the most important instrument now being built in the shop is a 24-inch heliostat, castings for which are shown on the engine lathe and planer in Plate XXI.

**THE OPTICAL SHOP.**

According to a well-known saying, a reflecting telescope can be successfully used only by its maker. While this is of course not strictly true, the history of the larger reflectors has been

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\(^1\) Shown in Plate XVII in the April number of this Journal.

\(^2\) Shown in Plate XV in the April number of this Journal.
such as to emphasize the meaning which it is intended to convey. No one can appreciate so well as the maker the peculiar sensitiveness of specula, and no one is so well prepared to overcome the difficulties encountered in their use. As the light-grasping power of specula depends upon the condition of the reflecting surface, it is of great importance that the silver film be kept highly polished, and that it be replaced by fresh silver when necessary. Recognizing from the outset the superiority of reflectors for stellar spectroscopic work,¹ the writer has always planned that the Yerkes Observatory should be provided with a large reflecting telescope as soon as circumstances would permit. It was thought best to secure the services of an optician to grind and polish the mirror at the Observatory, and subsequently to keep it in good condition. There was much other work for an optician to do, and it will be gathered from what follows that this plan of supplying our own needs, so far as it can be done to advantage, has not proved unprofitable.

Mr. G. Willis Ritchey, at one time assistant in the Cincinnati Observatory and later in charge of the woodworking department of the Chicago Manual Training School, was engaged in the spring of 1896 as optician. For many years Mr. Ritchey had carried on optical work as an amateur, and at the time of his appointment he had completed an excellent speculum of twenty-four inches aperture and only eight feet focus.² A 24-inch speculum of the same focal length as the Yerkes telescope (61 feet) now used in the writer’s bolometric work, was made by Mr. Ritchey in a few weeks. This mirror well illustrates one of the most important advantages of the optical shop. For obvious reasons a professional optician frequently objects to sending out work which he regards as in any sense incomplete. As a bolometer one-sixth of an inch wide was to be used at the focus of this mirror, it is evident that it was wholly unnecessary to go to the expense of parabolizing. The desired spherical

²Now temporarily used on an alt-azimuth mounting in the heliostat room.
figure was obtained in a very short time, and the total cost was only a small fraction of the regular optician's price for a finished parabolic mirror of the same dimensions. Later, if it is desired to use the mirror for other purposes, the parabolic figure can easily be obtained.

Almost the entire work of fitting up the unfinished north room (20 X 70 feet) which was chosen for the optical shop, has been done by Mr. Ritchey. Two rooms were partitioned off for the grinding machines. The larger of the two (20 X 21 feet) is to contain a machine designed by Mr. Ritchey for grinding and figuring a 60-inch glass disk. This large grinding machine is designed so as to allow the mirror, which lies horizontally during the grinding and polishing, to be quickly inclined to a nearly vertical position when it is to be tested. Two cranks, with adjustable throw or stroke, are used to give the desired motion to the grinding and polishing tools, the mirror, as usual, revolving slowly beneath these tools. The arms which communicate the motion of the cranks to the tools, can be lengthened or shortened while the machine is in motion, thus allowing changes in the position of the tools upon the glass to be made with ease and smoothness. One of these arms also carries the mechanism which rigorously controls the slow rotation of the grinding and polishing tools; and the same arm carries a lever for counterpoising a part of the weight of the tools during the process of grinding and polishing. Since the large disk of glass for the 60-inch mirror weighs nearly a ton, and the grinding tools several hundred pounds each, a strong lever, properly mounted and counterpoised, is necessary for lifting the glass and tools on and off the machine. The metal parts of this machine are being made in the instrument shop, and the heavy wooden frame is to be built by Mr. Ritchey.

The smaller room, 12 X 20 feet, contains the grinding machine used in making the two 24-inch mirrors already referred to. Mr. Ritchey will soon make on this machine a 24-inch flat mirror for the new heliostat. A line shaft running near the floor under a long bench by the windows is driven by an electric
motor. The grinding machines are connected with this shaft by means of a set of friction disks, so arranged that the speed of the machines can be varied through a wide range by the simple motion of a lever. Thus a variation of from 6 to 60 strokes of the tool per minute can be obtained while running.

The optical shop was prepared for use by covering the brick walls with two thicknesses of heavy building paper, separated from the wall and from each other by wood strips, thus leaving two air spaces. The lapped joints of the paper were firmly fastened with outside wood strips, and the whole was varnished. As a further means of maintaining the temperature constant, and of excluding dust, the windows of the grinding rooms are provided with a second inner sash, built in practically air tight. The line shaft is carefully boxed in, and the cement floor is painted. Both grinding rooms have doors in their west walls, which are opened when mirrors are to be tested by Foucault's method. By opening doors in the adjoining halls, a space 175 feet long becomes available for testing purposes. The room next the smaller grinding room contains the electric motor, and is fitted up with table and sink for silvering, the preparation of pitch tools and similar work.

A disk of glass 60 inches in diameter and 8 inches thick is expected to arrive shortly from the plate-glass works of St. Gobain, France. As soon as the large grinding machine is finished, this will be made into the large speculum for stellar spectroscopic work referred to above.

THE POWER HOUSE.

Power is needed in the Yerkes Observatory for many purposes. The motions of the 40-inch telescope are produced by five different electric motors, and the rising-floor and 90-foot dome are operated by two motors of greater horse-power. As has been stated, the instrument and optical shops receive their power from electric motors and the entire building is lighted by incandescent lamps. In order to furnish suitable means of generating power at a distance from the Observatory, Mr. Yerkes
has provided a separate brick building (Plate XXII) for the power and heating plant. The equipment of this building, all of which was generously presented to the Observatory by Mr. Yerkes, consists of two 8x10 Ideal engines, each carrying a direct-connected Siemens & Halske dynamo, with a capacity of 200 amperes at 125 volts. The switchboard is so arranged that either dynamo can be used to furnish both power and light while the other is idle. Steam is supplied by two 14x48 tubular boilers, equipped with Gulickson smokeless furnaces and grates. A duplex feed pump, connected with a feed-water heater and oil separator, furnishes the boilers with water. A well under the power-house, 165 feet deep, fed by springs, insures a constant water supply. From it a deep-well pump forces the water to three large receiving tanks in the Observatory building. The further equipment of the power-house includes automatic appliances for the control of steam and water, so arranged that the engineer can tell at a glance the condition of the entire system.

The chimney of the power-house is about 750 feet from the center of the large dome, in a direction (north of east) from which the wind very rarely blows. Up to the present time the small amount of smoke emitted by it has not given the slightest inconvenience. In case it should do so the efficient smoke consumers attached to the boilers could be brought into service. It has been found that they will almost instantly reduce a heavy cloud of black smoke to a hardly visible vapor.

The steam-pipes for heating, electric cables for power and light, and the water pipes are led underground from the power-house to the Observatory. Mr. E. N. Myers is the engineer in charge of the heating and power plant.

Yerkes Observatory,
April 1897.

(To be continued.)