THE PASADENA LABORATORY OF THE MOUNT WILSON SOLAR OBSERVATORY[1]

By GEORGE E. HALE

The spectroscopic laboratory erected in 1905 on Mount Wilson was described in *Contributions from the Solar Observatory*, No. 10.[2] As stated in that paper, our investigations of sun-spot spectra made it necessary to supplement the equipment provided on Mount Wilson with a large electric furnace, which was installed in the Pasadena instrument shop. As the further development of our sun-spot work demanded the use of a more perfect electric furnace and as our apparatus required more current than could be economically generated on Mount Wilson, it seemed advisable to take advantage of the opportunity afforded in Pasadena to obtain electrical energy, at moderate cost, from the Edison Company. Accordingly a small laboratory, adjoining our instrument shop and standing immediately in front of the Hooker Building, was erected during the winter of 1908 (Plate XVI).

In the Mount Wilson laboratory the various light-sources are arranged on the circumference of an annular pier. A plane mirror at the center, which can be rotated about a vertical axis, reflects the rays from the light-source under examination to a concave mirror, which forms an image on the slit of a horizontal Littrow spectrograph of 18 feet (5.5 m) focal length. In the Pasadena laboratory, profiting by experience with the tower telescope,[3] a vertical Littrow spectrograph, of 30 feet (9.1 m) focal length, is mounted in a well, with waterproof brick walls, extending 30 feet below the surface of the ground. The electric furnace and other light-sources stand on separate piers, arranged in a circle about the center of the spectrograph slit. The spectrograph can be rotated about the axis of the

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 27.

[2] *Astrophysical Journal*, 24, 61, 1906.

[3] *Contributions from the Mount Wilson Solar Observatory*, No. 23; *Astrophysical Journal*, 27, 204, 1908.

collimator and light from any source is reflected into the slit by means of a plane mirror standing (at 45°) above it (Plate XVII).[1]

This arrangement determines the general plan of the laboratory (Fig. 1). The outside dimensions of the building are 32×44 feet. The walls are of brick, the floor of cement, and the ceiling of corrugated iron. The well which contains the spectrograph, $8\frac{1}{2}$ feet inside diameter, is near the middle of the principal room. As the spectrograph stands eccentrically, near one side of the well, considerable space is left in the well for other instruments requiring constant temperature conditions.

Except in one particular, the 30-foot spectrograph is precisely similar to the one used with the tower telescope.[2] In addition to an 8-inch (20.3 cm) objective of 30 feet focal length, it is supplied with a 5-inch (12.7 cm) objective of 13 feet (4 m) focal length.[3] This objective, together with an adjustable grating-holder mounted in conjunction with it, can be swung out of the axis of the spectrograph when the objective of 30 feet focal length is to be employed. Thus a considerable range of dispersion, from the first-order spectrum with the 13-foot objective to the fourth-order spectrum with the 30-foot objective, is available. Both objectives can be focused from the eye-end of the instrument and the grating can be rotated from the same point. The only gratings at present available are a 5-inch Rowland plane, having 14,438 lines to the inch, kindly loaned to us by the Johns Hopkins University, and a 4-inch Michelson plane, having 500 lines to the millimeter.

The concrete floor is continued over the well, the spectrograph ring being supported on a cylinder of concrete rising from it. The temperature at the bottom of the well is so constant that exposures of any desired length can be given, without fear of displacement of the lines arising from changes in the temperature of the grating.

A small fireproof room in the laboratory contains five transformers,

[1] The mirror support shown is a temporary one, and will be replaced later by a different apparatus, carrying also a lens, on a radial arm, to form an image of any source on the slit.

[2] *Loc. cit.*

[3] Both visual and photographic objectives of this size, formerly employed in photographing spectra with the Snow telescope, are available for use with this spectrograph.

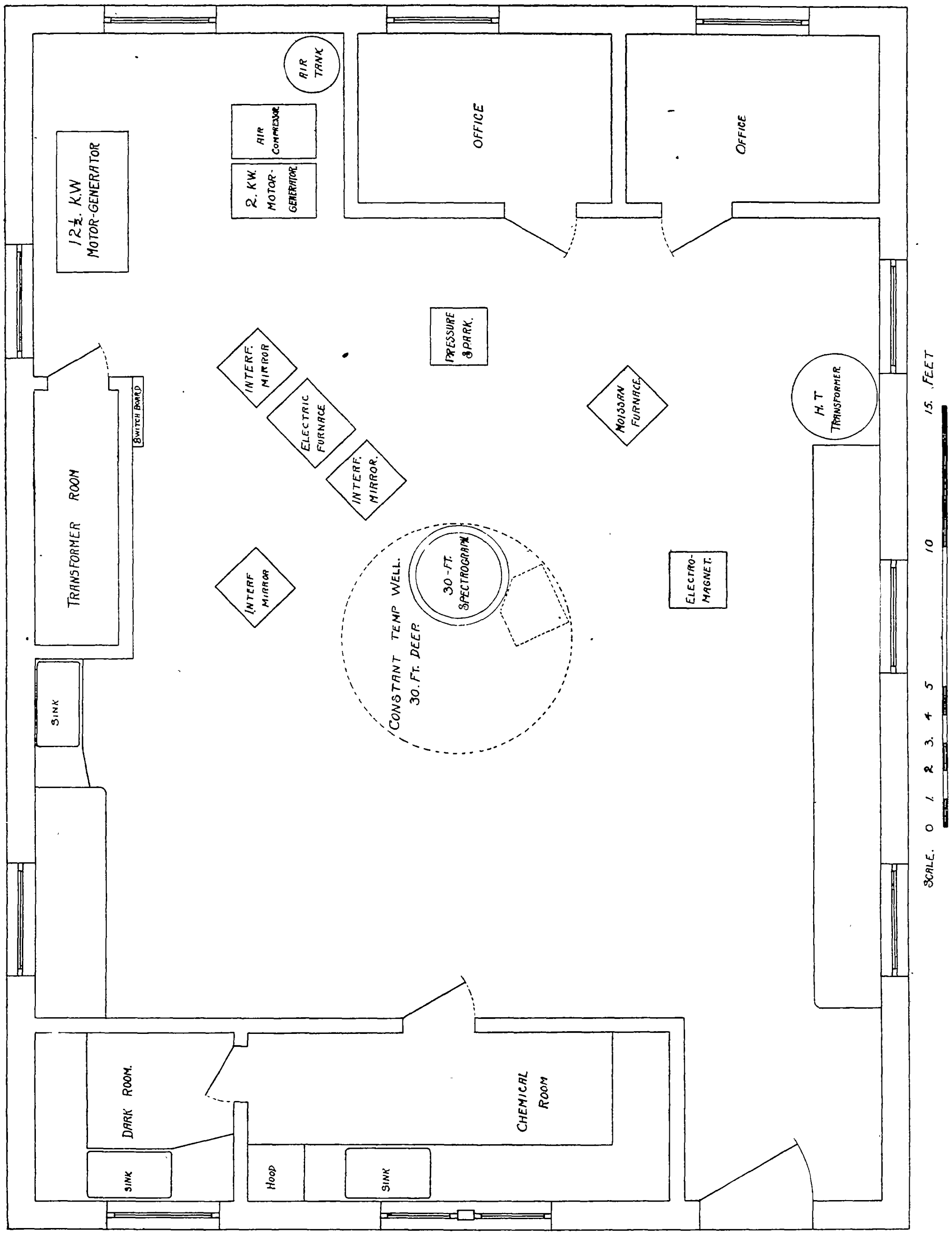


FIG. 1.—Plan of Laboratory.

connected with the 2000-volt alternating current circuit of the Edison Electric Company, as follows:

a) One low-voltage transformer, formerly used for our experiments on fused quartz, having a capacity of 50 K. W., with connections for 5, 10, 20, or 30 volts. By means of very heavy copper cables, passing through a conduit beneath the floor, this transformer supplies the resistance-tube electric furnace with current.

b) Two 30 K. W. transformers, primarily for heavy-current arc work. These may be connected either in series or parallel, giving 52 or 104 volts, with a capacity of 60 K. W., or 208 volts, with a capacity of 30 K. W.

The secondary terminals of transformers *a*) and *b*) are mounted on a slate pier in the transformer room, where they may be joined by heavy copper lugs to cables passing through conduits to the three piers designed for furnace and arc work. Thus the voltages above mentioned, ranging from 5 to 208, are available as desired at any one of these piers. The three transformers are controlled by primary oil switches, operated by cords from without the transformer room.

c) Two 15 K. W. transformers, which supply power to the machinery of the instrument and optical shops, to the motors that drive the direct-current generators in the laboratory, to the high-voltage transformer, etc.

The 5 K. W. high-voltage transformer, which stands on the opposite side of the room, is connected with highly insulated overhead wires passing across the laboratory, from which leads may be dropped to any of the piers where a spark is to be used. This transformer contains a series of step-up connections, giving 1000, 2000, 4000, 8000, 16,000, 32,000, or 64,000 volts at the secondary terminals. Within the inclosure which surrounds the transformer there are a series of self-induction coils and a large condenser, consisting of alternate plates of sheet metal and plate glass immersed in oil.

Direct current is supplied from two sources:

a) A 12½ K. W. dynamo, direct connected with a three-phase motor. Both of these machines stand on a heavy concrete pier, separated from the floor and resting on a bed of sawdust. In this way the vibration is so greatly reduced that it is not perceptible in the 30-foot spectrograph. By regulating the field of the motor the dynamo gives voltages varying from 30 to about 120. Thus the Dubois electro-magnet, which is intended for use at 64 volts, can be excited without a series rheostat. The high voltage is mainly employed for powerful electric current arcs and other similar purposes.

b) A 2 K.W. generator, direct connected with a three-phase motor, both standing on a pier separated from the floor. This gives direct-current voltages ranging from 90 to 120, and serves well for small arcs and other apparatus requiring moderate currents. The motor is also used to drive an air-compressor built by Cook of Manchester, after a design kindly prepared for us by Mr. Petavel.

Both dynamos are joined to the switchboard, where they may be connected to wires passing through conduits to two of the piers.

The principal light-sources and auxiliary instruments now employed in the laboratory are as follows:

a) A carbon or graphite tube resistance furnace (on the left of Plate XVII), inclosed in a steel cylinder capable of withstanding pressures up to 200 atmospheres. This furnace, which was designed by Dr. King, is described by him in another article.[1] The highest temperature hitherto attained in it, as measured with a Wanner pyrometer, is 3015° C. It has thus served admirably for the study of the spectra of such refractory metals as titanium and vanadium, permitting the relative intensities of their lines to be recorded at widely different temperatures. This furnace is also intended for investigations of anomalous dispersion, in conjunction with a Michelson interferometer and the 30-foot spectrograph.

b) A rotating arc in a pressure chamber, formerly used in the Mount Wilson laboratory.

c) An inclined arc electric furnace (near the middle of Plate XVII), similar in type to one used by Moissan, but modified according to designs by Dr. Olmsted so as to permit the arc to be observed in an atmosphere of hydrogen or other gas. For regulating the current a large rheostat is provided. This furnace is now used by Dr. Olmsted in his work on the fluted spectra of calcium hydride and other compounds found in the spectra of sun-spots and red stars. A Geryk

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 28.

duplex vacuum pump, driven by a small electric motor, is used with the two furnaces when low pressures are required.

d) Spark terminals, mounted between the poles of a large DuBois electro-magnet formerly used in the Mount Wilson Laboratory. This apparatus, which is shown on the right of Plate XVII, is being used for the study of the Zeeman effect in the spectra of iron, titanium, and other elements that occur in the spectra of sun-spots.

e) An ordinary electric arc, used for comparison spectra, etc.

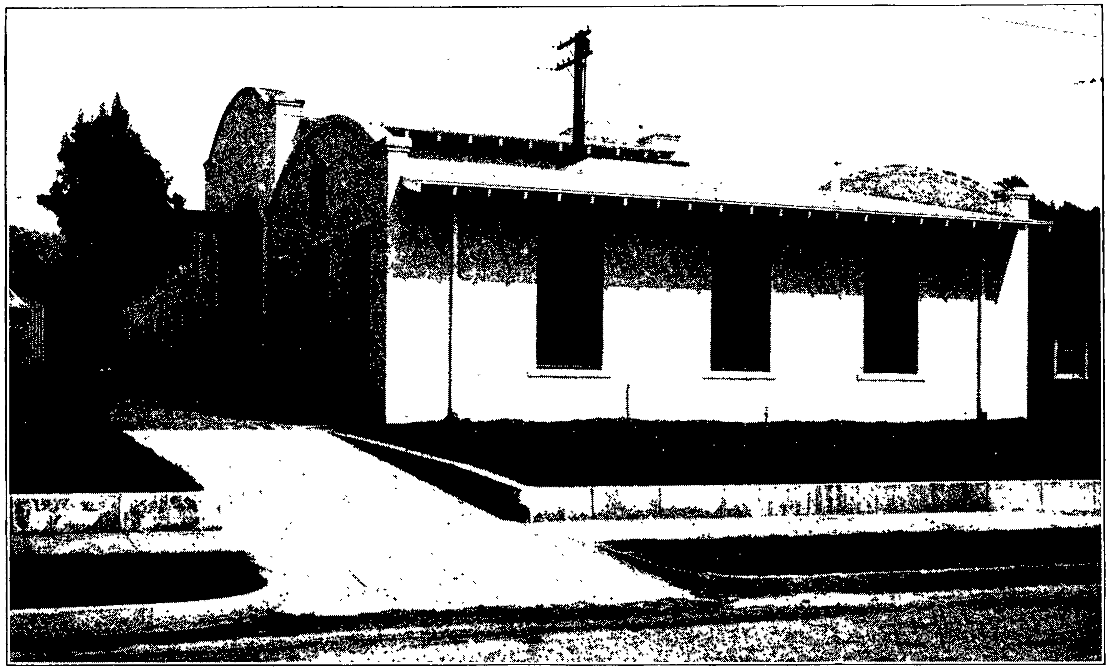
A one-prism quartz spectrograph and a direct vision spectroscope are employed for the preliminary examination of spectra. Other apparatus used in the Mount Wilson Laboratory and described in *Contribution* No. 10 is also available. A two-mirror heliostat, mounted on the roof immediately above the 30-foot spectrograph, supplies sunlight for comparison spectra. Piers for vacuum tube apparatus and other light-sources will be erected as occasion demands.

At the west end of the building there is a small chemical laboratory and a photographic dark-room. At the east end are the offices of Dr. King, superintendent of the Physical Laboratory, and Dr. Olmsted.

A more detailed account of the instruments used in the laboratory will appear in subsequent papers.

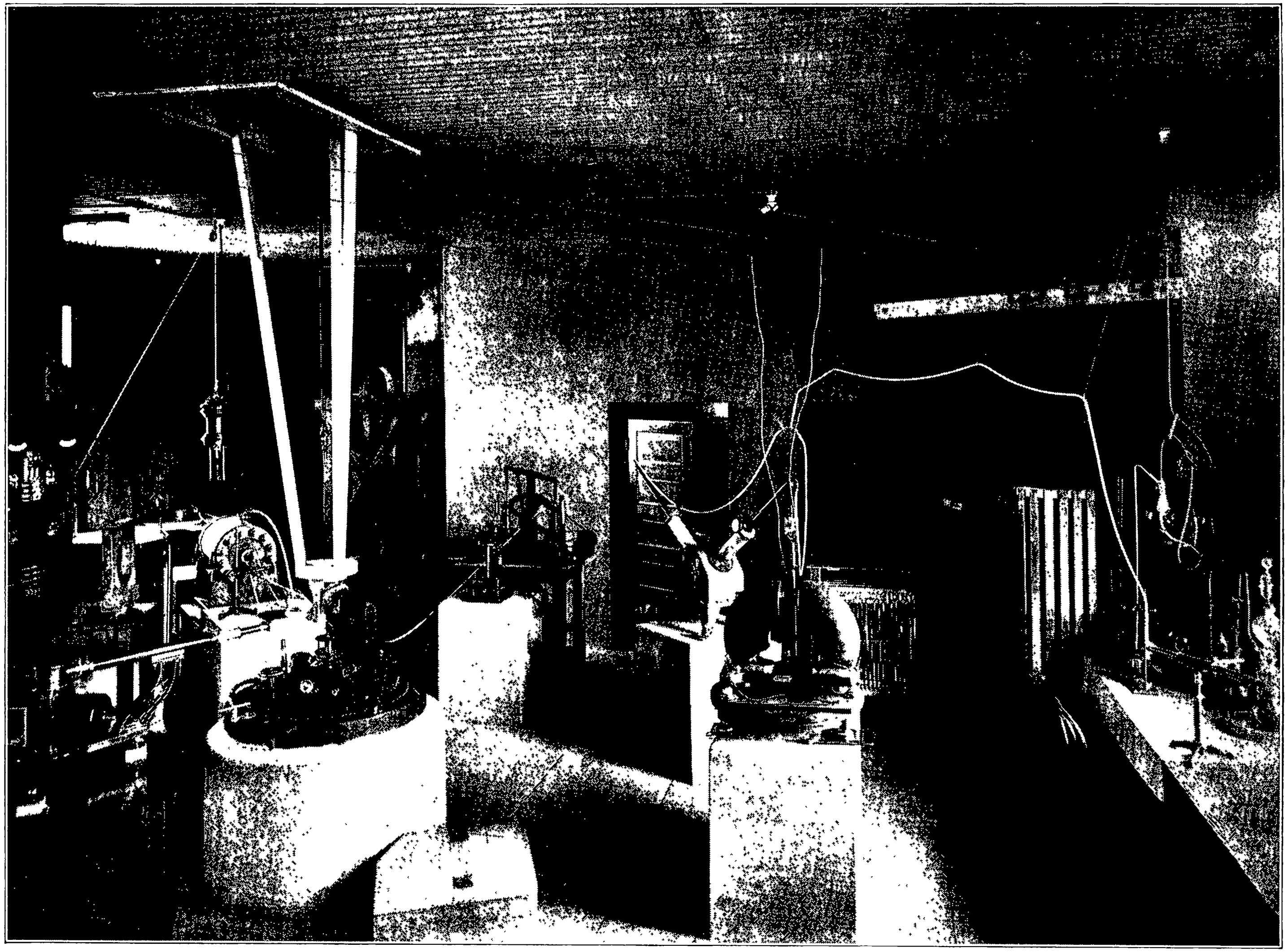
Mount Wilson Solar Observatory
August 1908

PLATE XVI



THE PASADENA LABORATORY

PLATE XVII



Interior of the Pasadena Laboratory