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THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA.

James Lick, whose name has already acquired a world-wide fame as the establisher of the Lick Observatory, was born in 1798, in Pennsylvania. He led a somewhat adventurous life, and before he was thirty years old had accumulated a few thousand dollars. This he had made principally in South America, where he spent some years. In 1827 he went to California and visited the old mission town of San Francisco. The splendid harbor, the only one on many miles of coast, greatly impressed Mr. Lick, and he began purchasing land. Twenty-one years later, when gold had been discovered, and when the rush to California began, his investments acquired new value, and he ultimately became immensely rich. He was a man of very secluded habits, was a skillful mechanic, and, it is said, was especially fond of astronomy. Toward the end of his life he lived near San Jose, in the Santa Clara Valley. In 1874 he made over by deed to a body of trustees the sum of two millions of dollars for various public and philanthropic uses, and in 1875 made a revised deed to the same general effect. Besides various charitable donations, it included the following gifts: $150,000 for free public baths in San Francisco; $100,000 for statuary for the new City Hall of that city; $60,000 for a monument to Francis Scott Key, the author of "The Star Spangled Banner;" $540,000 to endow the California School of Mechanic Science in San Francisco; and $700,000 for procuring for the University of California "a telescope of greater power than any yet made." The total value of the trust fund was estimated at $5,000,000.

As the site for his observatory he selected Mount Hamilton, near his home in the Santa Clara Valley. He died October 1, 1876, aged 78 years. His body is interred under the base of the great telescope,

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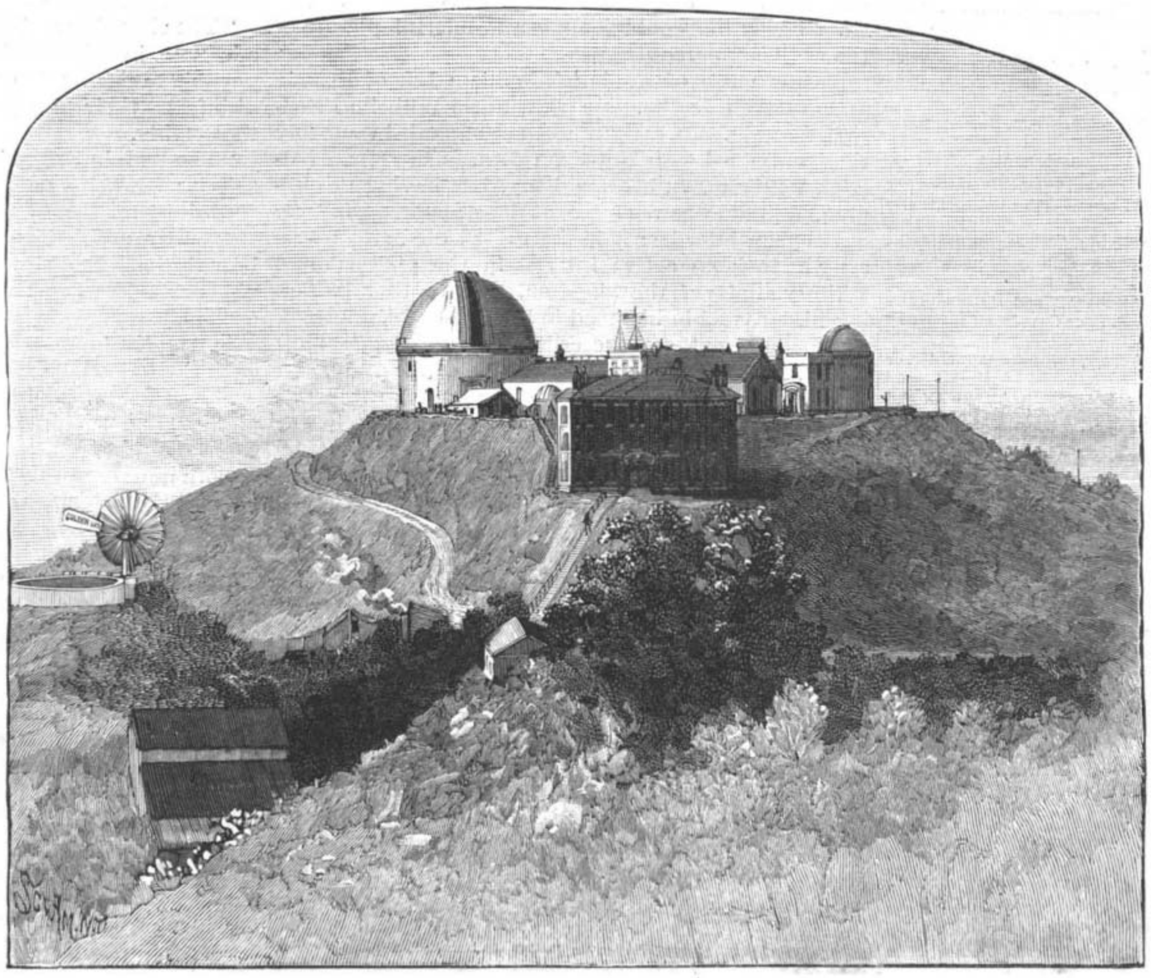
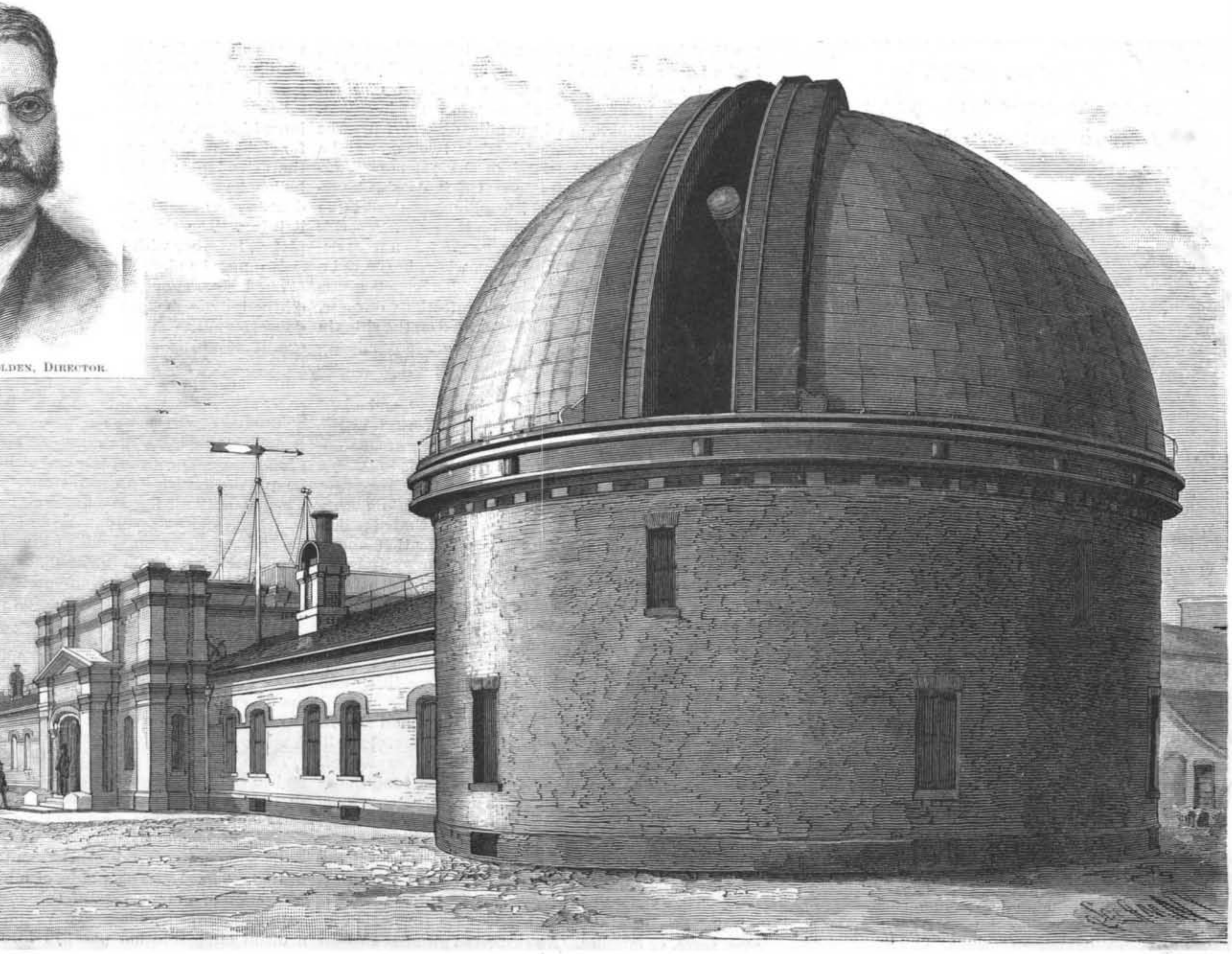


THE LICK OBSERVATORY MOUNT HAMILTON CAL.

PROF. EDWARD S. HOLDEN, DIRECTOR.



THE LICK OBSERVATORY AND ITS GREAT TELESCOPE.

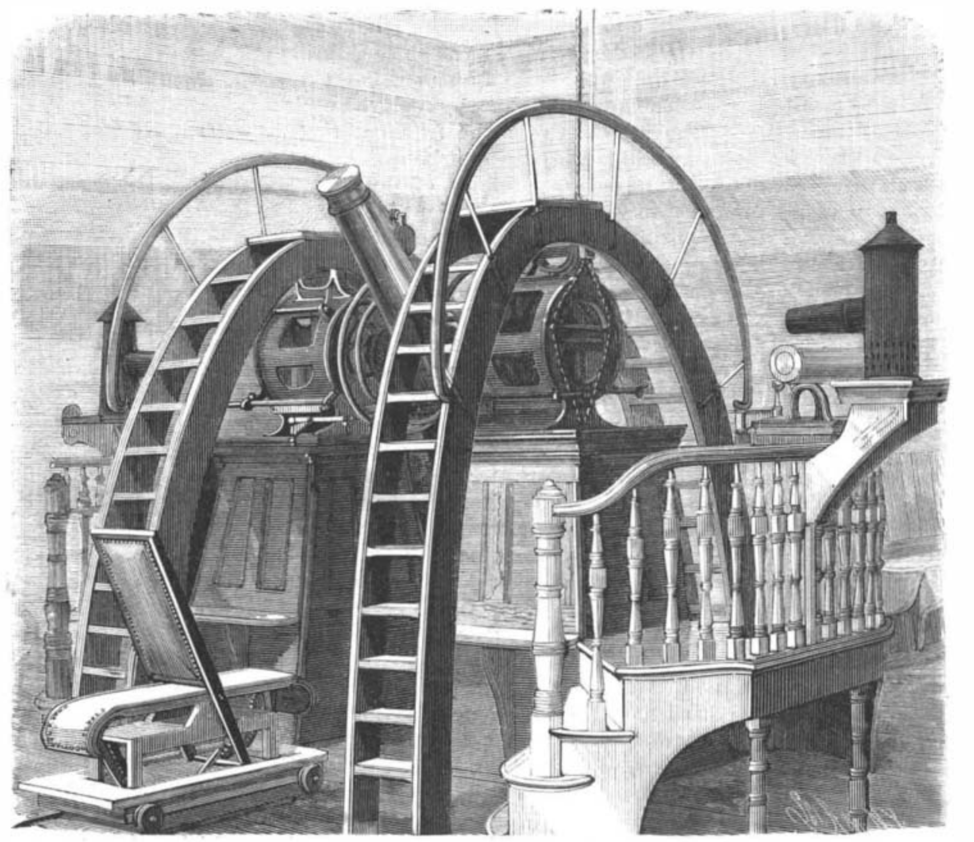
THE LICK OBSERVATORY.

(*Continued from first page.*)

which rises above his remains as a fitting monument to one of the world's greatest benefactors and philanthropists.

In administering their trust the custodians met with legal obstacles and suits brought by his relatives. These delayed the carrying out of his plans, but eventually a settlement was reached. On June 30, 1883, the corner stone of the observatory, to which this article is devoted, was laid, and to-day the work is practically complete. When Mount Hamilton was selected as the site for the Lick Observatory, in order to test its atmospheric conditions, Professor S. W. Burnham, the discoverer of many double stars, was invited to observe there in 1879. Owing to the dryness of the air, and its excellent quality for astronomical work, his six inch telescope described many stars, catalogued by Professor Otto Struve as double, into triple stars. Mr. Lick died in 1876, and the original plans for the observatory were determined by Captain Richard S. Floyd, president of the trustees, and Mr. T. E. Fraser, superintendent of construction, acting under the advice of Professor Edward S. Holden, and Professor Simon Newcomb, of the Naval Observatory, in Washington. Many noted astronomers have been interested in the work, and this will probably be the most famous observatory in the world. It owns about 1,550 acres of land, a portion of which will eventually be made into a public park, and the graded road of twenty-six miles leading to the summit of Mount Hamilton from San Jose may, perhaps, become a direct route to the Yosemite Valley. Since 1880, when the work was first begun, 7,000 tons of rock and earth have been removed to level a plateau upon which the buildings stand. They are constructed of solid masonry, and are of simple but effective architecture, and include the main building—287 feet long—containing the directors' and secretary's offices, the library, clock rooms, etc., with the large dome at its southern end for the large telescope, and a smaller dome for the 12 inch equatorial at the northwest corner, the meridian circle house, the transit house, the photographic laboratory, and several temporary wooden workshops. The dwelling house of the astronomers, 63 × 60 feet, stands below the summit and is connected with the plateau by a bridge. The surrounding peaks have been named from several famous astronomers.

In speaking of the outlook from Observatory Peak, which is 4,302 feet in height, Professor Holden says: "It would be difficult to find in the whole world a more magnificent view than can be had from the summit just before sunrise, on one of our August mornings. The eastern sky is saffron and gold, with just a few thin horizontal bars of purple and rosy clouds. The sharp outlines of Copernicus and Kepler are seen in sharp profile against the brilliant background. Orion, Procyon, the Twins, Sirius, are in the morning sky, and Venus is brilliant and steady against the stars. The instant the sunbeams touch the horizon the whole panorama of the Sierra Nevada flashes out, 130 miles distant. Toward the south and west the beautiful valley of Santa Clara lies, dotted with farms and vineyards, and bordered toward the sea by Loma Prieta and the Santa Cruz Range. The winding road to San Jose, which takes twenty miles of twisting to accomplish the thirteen miles of air line, lies like a dusty snake at your feet. The Bay of San Francisco looks like a piece of a child's dissecting map, and is lost in the fogs near the city. The buildings of the city seem strangely placed in the midst of all the quiet beauty and the wild strength of the mountains. Then you catch a glimpse of the Pacific in the southwest and of countless minor ranges of mountains and hills that are scattered toward every point of the compass, while, if the atmosphere is especially clear, you can plainly see to the north Mount Shasta, 175 miles distant."



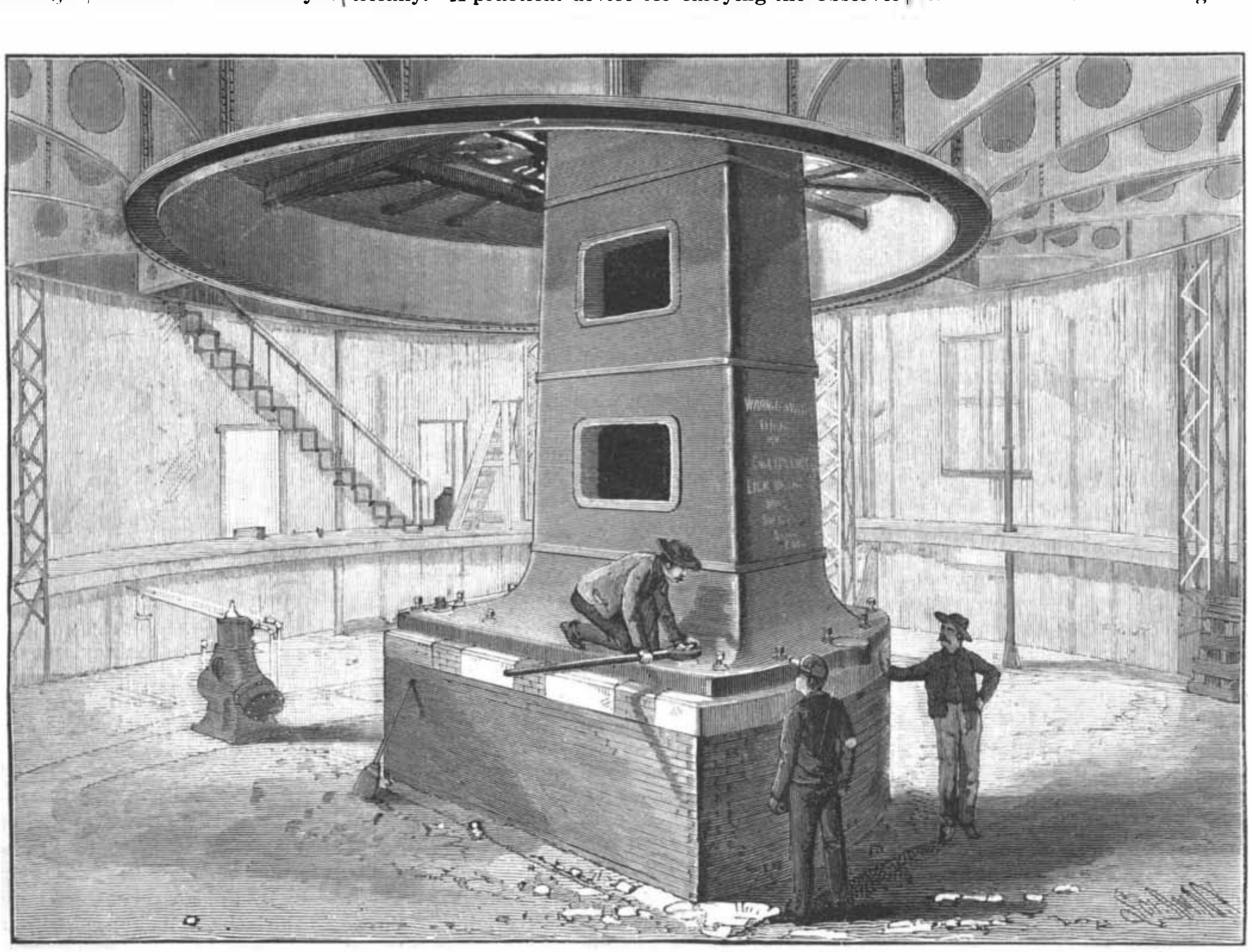
LICK OBSERVATORY—THE MERIDIAN INSTRUMENT.

The large dome, built by the Union Iron Works, of San Francisco, is 75 feet in diameter and its moving parts weigh 100 tons. It revolves upon wheels which run on hardened steel balls. A man merely pushing against it can move the entire dome. The usual motive power is obtained from a water engine which can rotate the dome 360° in less than 9 minutes. Its diameter changes ½ inch in the extreme change of temperature, and its track is given a smooth and oiled surface to slide upon. The observing slit is 9½ feet wide, and the pintle of the shutter is placed eccentrically. A practical device for carrying the observer to the eyepiece of the telescope, which at times is far above the base of the dome, was planned by Sir Howard Grubb, of Dublin. This is an elevating floor 61½ feet in diameter, weighing 50,000 pounds, and is moved up and down through a space of 16 feet. It is highly probable that the present system will not be sufficiently powerful to raise the flooring rapidly enough, but in this event the hydraulic system can be altered, or steam or electricity substituted. The actual speed required can only be determined after a series of experiments have been made.

The dome for the 12 inch equatorial is 25 feet wide, weighs 8 tons, and its observing slit, which extends beyond the zenith, is 3 feet wide. The meridian circle house is 43×38 feet. Its walls are double, the outer frame of galvanized iron, the inner one of California redwood. Between these is an air space 24 inches wide, which encircles the buildings. There is also an air space above the ceiling, which communicates with the room and with the air spaces of the walls, and on the west there is a ventilating tower two stories in height, which connects with the room of the meridian transit instrument. By these means the temperature of the building is kept the same as that of the external air. The transit house adjoining the meridian circle house is built of iron, with a wooden lining, and is arched by a curved shutter, which is controlled by levers, planned by Sir Howard Grubb. The photographic observatory, north of the transit house, is a small wooden building, with brick foundation. The tube of the photoheliograph telescope enters this house, and a brick pier supports the photoheliograph. A room in the second floor of the main building is also fitted for photography.

The large telescope, which embodies the expressed object of the $700,000 donation, was mounted by Warner & Swasey, of Cleveland. The tube is nearly cylindrical, and is 60 feet in length. There are three finders, 6, 4, and 3 inches in aperture, and in addition to these the 12 inch equatorial can be quickly attached, as a pointer, for photographic work if the controlled driving clock does not work satisfactorily. The lens is 36 inch clear aperture, being the largest object glass in the world, and has a 678 inch focus. The flint disk was obtained from Feil, in April, 1882, and after nineteen failures the crown glass disk was cast successfully in September, 1885. The third photographic crown lens was purchased from Feil in 1886, and broke while in the hands of the Clarks. The trustees of Yale University then offered their 27 inch flint glass to the Lick Observatory, but this was too yellow, and in 1887 Mr. Alvan G. Clark bought in Paris, from Feil, the crown glass, which is worked into a third lens. In addition to its magnifying power and its perfect definition, *i. e.*, neatness, accuracy, etc., this telescope has great light-gathering power, and stars may be seen thro' it which are 30,000 times fainter than the faintest seen by the naked eye, and the moon will appear under the same conditions as if it were seen by the naked eye at about 200 miles from the earth.

It is interesting to compare this telescope with the simple instrument made by Galileo in 1609, consisting of a single leaden tube with a plano-convex lens at one end for an object



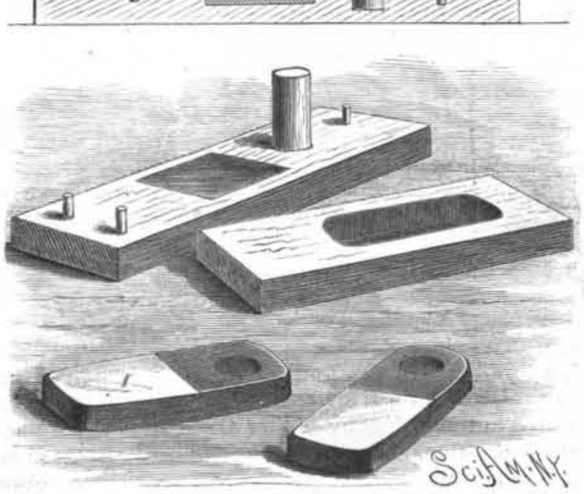
THE ELEVATING FLOOR—RAISED—AND THE GREAT TELESCOPE PIER.

glass, and a plano-concave lens at the other end for an eyepiece, and magnifying three times. Ever since Galileo's brilliant discoveries with this "optick tube," described by Milton in his visit to Padua, the growth of the telescope has been of steady progress, in spite of the opinion of a cotemporary professor of Galileo in the University of Padua, who argued that "things invisible to the naked eye are useless and do not exist." In tracing its development briefly we find that the difficulties in obtaining good glass led Newton to construct a reflecting telescope in 1688, which magnified 39 times, the speculum or mirror being made of an alloy of copper and tin. Improvements followed which finally resulted in Herschel's finely constructed instruments, in the large six foot reflector in its gigantic frame, made by Lord Rosse, and in the celebrated reflectors of the present time. The reflecting continued to supplant the refracting telescope until about 1753, when Dolland, an English optician, showed that lenses of flint and crown glass could be combined in such a manner that their dispersive powers would neutralize each other, and this is the principle of construction of the achromatic objective now in use, consisting of an outer double convex lens of crown glass and an inner lens nearly plano-concave of flint glass.

The 12 inch refractor, which was originally made for Dr. Henry Draper's private observatory at Hastings, N. Y., by Alvan Clark & Sons, is of the finest construction. The object glass of the 6½ inch equatorial was also made by the Clarks, and is provided with a portable mounting made by Warner & Swasey. The 4 inch comet seeker, made by Alvan Clark & Sons, has a focal length of 33 inches. The rays fall on a reflecting prism, and are bent into a horizontal plane. The eye of the observer moving in azimuth while the telescope is in altitude can cover the whole sky. The motion is effected by turning a crank. This was bought on Prof. Newcomb's recommendation.

The photoheliograph is mounted south of the transit house. The transit instrument determines the axis of the photoheliograph, and this is also used as a collimator for the transit. The 6 inch Repsold meridian circle was delivered in 1884, after having been inspected by Profs. Auwers and Krueger, of Berlin. The declinograph was made under the supervision of Dr. Johann Palisa, of Vienna, to fit either a 12 inch or 6 inch equatorial. The universal instrument made by Repsold consists of a telescope containing a prism, into which the rays of light are reflected. Its aperture is 2·15 inch. The horizontal circle reads by two microscopes to 2", and the circles are 10 inches in diameter. This is a perfect geodetic instrument, and together with a 6 inch equatorial and a chronometer can be easily packed for astronomical expeditions. There are several chronometers made by Negus, and a thermometric chronometer by C. Frodsham. The most important of the minor instruments are the filar micrometer for the 36 inch telescope by Fauth & Co., the duplex micrometer by Grubb, and a star spectroscope made by Brashear from designs of Mr. Keeler. Plans for a large solar spectroscope are being worked out by Prof. Holden and Prof. Langley. The other instruments are a delicate sphereometer by Fauth & Co.; resistance coils; galvanometers; a disk photometer; spectroscopes; a lever trier of refined construction; and an engine for measuring photographs, scales, etc., made by Stackpole & Bros., from designs of Prof. Harkness.

The meteorological instruments are: Self-registering rain gauges, wind gauges, barometers, and a number of thermometers. There is a complete set of apparatus for registering earthquakes, provided by the Cambridge Scientific Instrument Co., consisting of a horizontal seismograph with clock and driving plate, the clock being started by an electric contact at the beginning of a shock, and the two rectangular components of the horizontal motion then registering on a moving plate; a vertical seismograph to register vertical motions on a dial plate; a duplex pendulum seismograph to give independent records on a dial plate, the pencil being free to move in any azimuth; and a chronograph, which is set in motion at the beginning of an earthquake and records its duration upon a clock. The staff of the observatory consists of Prof. Edward S. Holden, director and chief astronomer; Samuel W. Burnham, James E. Keeler, John M. Schaeberle, and Edward E. Barnard, assistant astronomers; and C. B. Hill, secretary, librarian, and occasional observer.

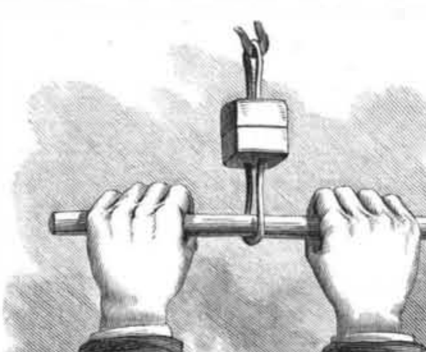


LEAD COHESION BLOCKS—THE MOULD.

Early in 1886, Prof. Holden made contracts with the Southern Pacific and other railroad companies for supplying time from the observatory by automatic electric signals. This regular time service, of which Mr. Keeler has charge, has been in operation since January, 1887. A great part of the apparatus used in this service forms an integral part of the observatory's equipment. The system which has thus been introduced has been of great service to that particular section of the country, as well as to the railroad companies.

JAMES LICK.

Instruments for recording earthquake shocks have been constructed by a company in San Francisco, and are sold at a very low figure. It is designed in this way that records of any seismic movements shall be procured by private individuals in different parts of the State, and plates upon which the movement has been recorded may be sent to the observatory, where a record will be kept of all such data, and blue prints will be made of the diagrams and copies of this sent to the person from whom the plate has been obtained. Although this is quite independent of the regular work of the observatory, it will doubtless lead to the accumulation of data which will be most important in formulating statistics for future use.



COHESION—BLOCKS SUSTAINING DIRECT STRAIN.

The great telescope has been mounted for several weeks, and several satisfactory tests of its capacity have been made. It was first directed to the sky on the evening of January 3, 1888, and a few observations were then made for the partial adjustment of the object glass, but the observation was abbreviated by the skies becoming cloudy. The next observations made were on the evening of the 7th. On this occasion Saturn was observed, and Mr. Keeler, who conducted the observation, says with rapture that it was "the most glorious telescopic spectacle ever beheld." He exclaims: "Not only was he shining with the brilliancy due to the great size of the objective, but the minutest details of his surface were visible with wonderful distinctness."

The outlines of the rings were very sharply defined. The most curious feature was the structure of the outer ring; at about one-fifth of its width from its outer edge, a fine dark line was discernible, which marked the beginning of the dark shading, diminishing in intensity up to the black line. The inner ring did not shade off gradually into the gauge ring, as often represented, but the line of separation was distinct. The space between its inner edge and the planet was perfectly black.

Much of the data given in this article was procured from Prof. Holden's report in the *Sidereal Messenger* and Mr. James E. Keeler's notes on his own observations in the same journal. The observatory with its apparatus and appurtenances is to be transferred, upon its completion, to the University of California, and will in future be under the government of the regents of that institution. Prof. Holden resigned the presidency of the University in order to become director of the observatory.

COHESION OF LEAD.

T. O'CONOR SLOANE, PH.D.

It has long been known that perfectly clean surfaces of lead, when pressed together, would adhere to each other with some force. The experiment ranks as one of the classics in simple science. A very good way to show it is with bullets. Small surfaces, flat and clean, are prepared on two bullets by cutting off a little slice with a knife. When pressed together with a wrenching motion, the two will remain attached. A third bullet may now be fastened to one of the pair, and in this way a string of bullets, six or more in length, can be built up.

As the phenomenon depends on the absolute cleanness of the surfaces, and as it is a case of adherence of like to like, it is often invoked as an illustration of cohesion. Pure India rubber shows the same tendency, but in a far stronger degree relatively speaking. Whether it is true cohesion or not is uncertain, especially in the case of lead.

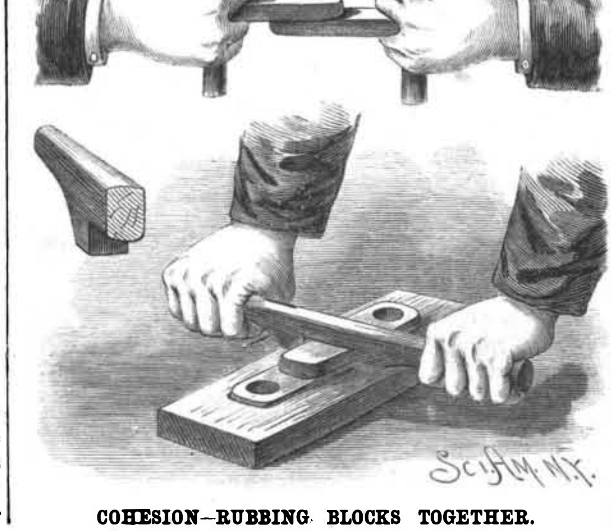
The method of obtaining this cohesion by employing mechanically prepared surfaces is a far less attractive method than the one which Faraday used in his lectures. He melted the lead and poured it out in two pieces upon a flat stone. After they had cooled, he pressed together the smooth lower surfaces of the lead, and thus obtained strong attachment. The flat plane on which the lead rested gave the essential true surface, while during the cooling it was perfectly protected from oxidation or dust. When lead is thus treated, even the upper surfaces which have been exposed to the air will answer for the experiment.

To make the phenomenon really impressive, it may be carried out on a larger scale. In the illustrations the necessary apparatus for conveniently doing this is shown. As mould for the face of the lead a polished block of metal is used. All things considered, this appears to work better than marble, which is the most available stone surface. A block of steel answers very well, and with use becomes slightly colored, as if by formation of magnetic oxide, and resists the rusting action of the atmosphere very well.

The metal block is set into a wooden base, so as to lie with its face even with the surface of the wood. Through a second piece of wood an oblong hole is cut. This should be about twice as long as it is wide. Its width should be equal to that of the metal block, or a shade less. When this is placed upon the base piece, so that the metal block lies at one of its ends and within the opening, the body of a mould is formed. Toward one end a round pin of wood is inserted. If lead is poured into the mould, it will assume an oblong form. Near one end will be a hole, and a face more or less smooth will be formed at its other end.

As regards size, a metallic block 1¼ inches square will answer for the face. The cavity of the mould should be about twice this length. A depth of from one-half to three-quarters of an inch is ample. The lead is melted and poured into the mould. As soon as solid the mould may be taken to pieces, the lead placed to one side to cool, and a second piece cast. This gives two corresponding pieces of lead.

Another piece of wood is provided, which contains a



COHESION—RUBBING BLOCKS TOGETHER.