THE IMPROVEMENT OF THE CHARLES RIVER AT BOSTON, MASS.

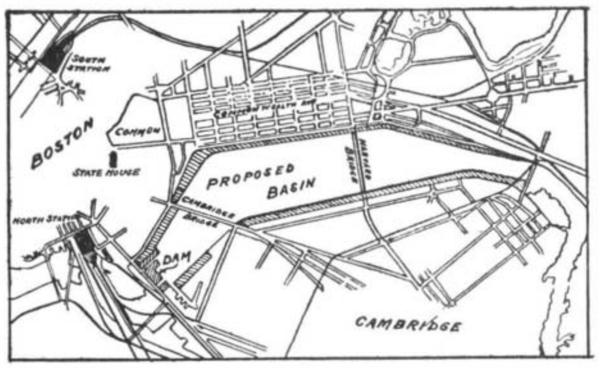
BY EDWARD C. SHERMAN, ASSOC.M.AM.SOC.C.E.

The Charles River, after flowing about sixty miles in a very circuitous route through eastern Massachusetts, finally finds the ocean at Boston. In the early days of the Massachusetts colony it served as the principal highway of the region, and it was not until it had ceased to be useful as a highway that dams for the development of power were built across it. The tidal estuary of the river extends from its mouth at the United States navy yard at Boston Harbor to the Watertown dam, a distance of about seven miles.

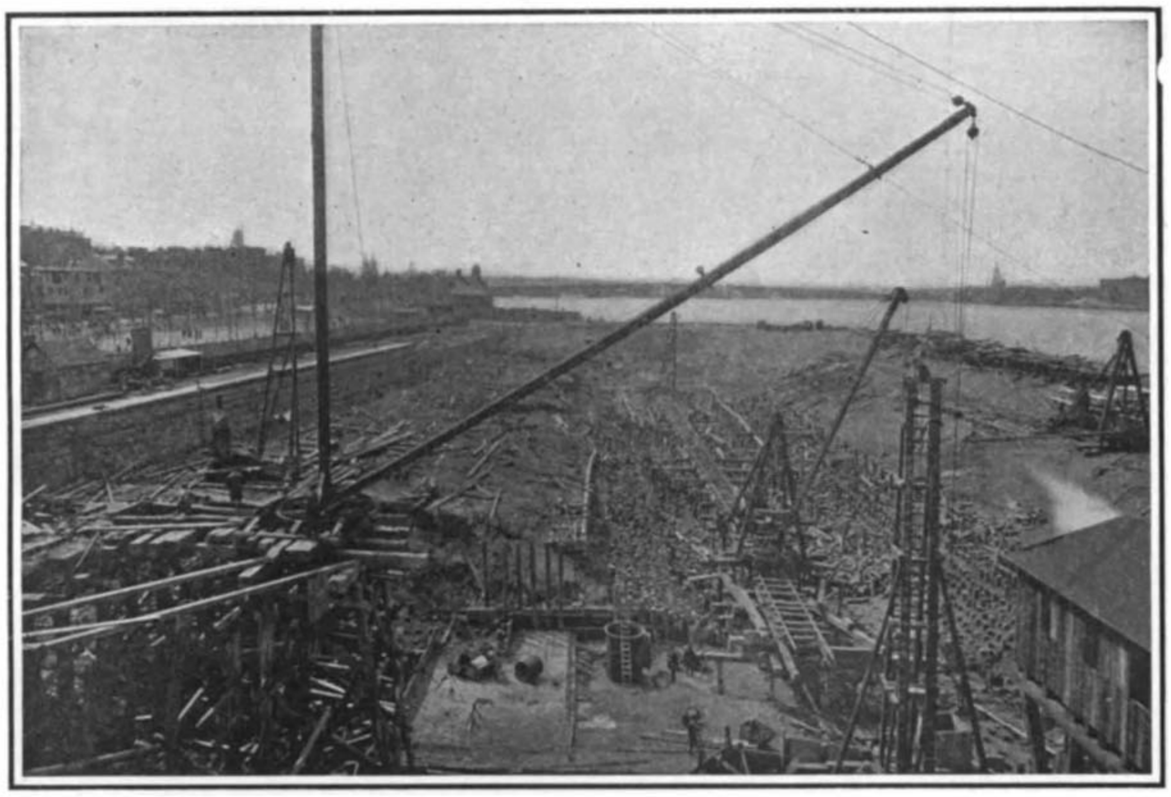
The sanitary condition of the basin, which received a considerable part of the sewage of Watertown, Cambridge, and Boston, began to attract attention a good many years ago; but it was not until the last decade of the nineteenth century that popular feeling began to be aroused, and the city of Cambridge began laying out and constructing an extensive park system along its side of the basin. Agitation for the construction of a dam to keep out the tides and to keep the offensive mud flats covered, first discussed nearly fifty years ago, was renewed, and reports favoring its construction were made to the Legislature in 1894 and 1896 by the combined boards of the Metropolitan Park Commission and the State Board of Health. It remained, however, for the able and exhaustive report of the Committee on the Charles River Dam in 1903 to convince the Legislature and the people of the sanitary need and æsthetic desirability of the dam, and in that year the Charles River Basin Commission was appointed and authorized to do the work. The site selected was that of the Craigie Bridge, a pile structure nearly one hundred years old, which was in such bad condition that it was on the point of falling into the river. It was decided to build a wide dam which would serve as a roadway across the river in place of the bridge, and which would provide an additional park, of great value to the crowded tenement districts which lie on both sides at this end of the basin. The bird's eye view of the dam, and of the river basin beyond, shows how these things were accomplished. A little way above the dam is seen the new three-million-dollar Cambridge Bridge, and farther up stream, the Harvard Bridge. The Charles being a navigable stream, it was not permissible to obstruct it until the lock was completed; and a lock was essential, since the basin is held at a constant level about 7½ feet above mean low water, while the tidal range is about ten feet. This makes it necessary for vessels at low tide to lock up, and at high tide to lock down into the basin. The lock is built of concrete, resting on spruce piles, of which a veritable forest was driven through the soft silt of the river bottom into the firm hardpan underlying it. An idea of this inverted forest may be gained from the illustration, which shows the excavation inside the coffer-dam within which the lock was built a few weeks after concrete was first placed. Most locks are required to hold back water in only one direction, and consequently the so-called mitering gates, swinging on hinges like enormous doors, may be used. But this Charles River lock is obliged at high tide to keep out the ocean, and at low tide to retain the fresh water in the basin, so that gates of a type new to the United States were designed. They are rolling caisson gates, that is, each gate is a big hollow steel caisson mounted on trucks, which is opened by rolling it on steel rails back into a recess in the lock wall. One of these gates in place weighs 325,000 pounds, and its design involved problems that would be met with in designing a bridge, a steel car, and a battleship.

One of the most interesting features of these gates is the chamber around each of the trucks on which the gate moves. This chamber is open at the bottom, but air tight at the top, and acts on the principle of a diving bell. The space is such that a man may stand between the axles of the truck some 25 feet below the level of the water outside the gate, and the air pressure in the chamber being sufficient to keep the water from flowing in from underneath, he may walk with the gate as it is moved slowly along, and be in a position to clean or inspect the track over the whole course. The gates may be used as enormous sluice-gates if necessary, being opened enough to draw the basin down in time of flood, if by any chance the regular sluiceways should be insufficient. In that case the pressure on one of the front bearings, which are set in the lock masonry, might be 560,000 pounds.

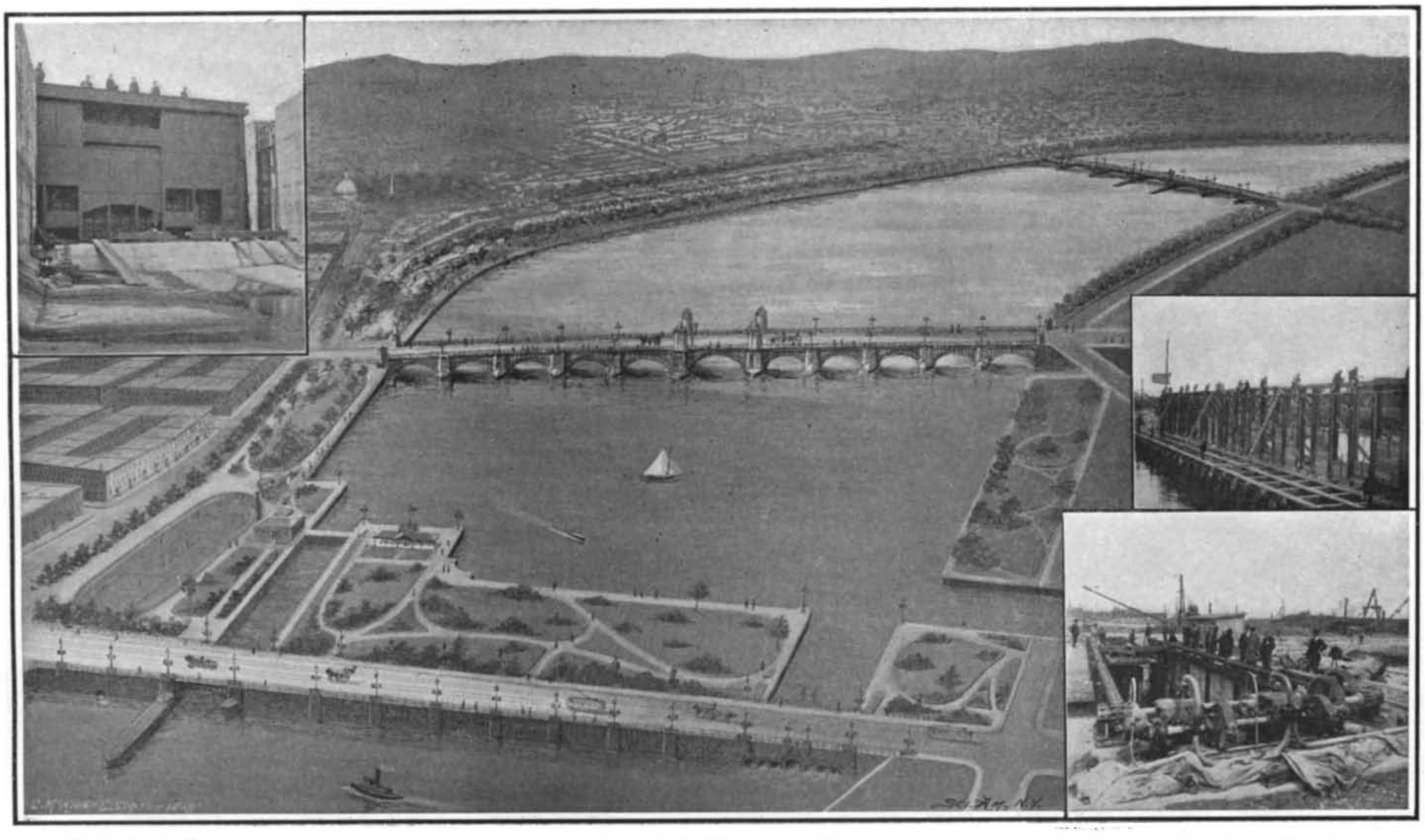
The operating machinery for one of these gates, which may be called upon to pull it open under some head, can exert a pull on



Plan showing location of the Charles River basin.



Foundations of lock.



Upper lock gate.

Charles River dam and basin.

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Closing shut-off dam.

Lock gate machinery.

the operating chains greater than the tractive force of the largest and most powerful freight locomotive used on the Boston & Maine Railroad. Each machine consists of two 50-horse-power electric motors, with a train of gears transmitting their power into two endless chains working over sprocket wheels. The gate is attached to the chains by a whiffletree, or equalizing beam, and moves in or out of the recess according to the direction of rotation given to the motors.

The lock is filled and emptied by means of bronze-mounted iron sluice-gates, electrically driven, which are mounted upon the lock-gates. These filling gates are readily seen in the illustration, which shows the upper lock-gate, the smaller of the two, as it looked from inside the lock before any water had been let in.

The whole operation of the lock is controlled from a room in the top of the tower of the house over the downstream lock-gate recess. Electric gages show the operator, at a glance, the water levels in the basin, the lock, and the harbor, and indicate to him at once what gates may be moved. Throwing a switch opens or closes the filling gates, while glowing lamps tell him when they are in the desired position. The drawbridge is raised or lowered and the lock-gates are moved by the manipulation of electric controllers of ingenious design. All of this apparatus is so interlocked and protected by automatic limit switches and cutouts as to be practically "fool proof."

While the lock was being constructed at the Boston side of the river, the "sluices" were being built at the Cambridge side in a much smaller and more shallow coffer-dam. These sluices form the outlet for the river, and are of sufficient size to carry off a larger storm flow than has yet been recorded. Each is provided with a positive sluice-gate, electrically operated, which will always be closed when the tide is higher than the established basin level, and opened at low tide sufficiently to keep the water in the basin drawn down to that level. There are eight sluices, each 7½ feet by 10 feet, four on each side of a larger passageway, which is designed to serve as a lock for small boats, for which it would not be desirable to operate the big lock.

The tidal range at Boston averages about ten feet, and twice every day 2,416,000,000 gallons of salt water flowed from the harbor into the basin and out again. With this enormous quantity of water ebbing and flowing, it was impossible to deposit the earth to form the dam and have it remain in place, so that a shut-off dam, which could be closed all at one time, had first to be constructed. This dam shows in the larger bird's eye view, extending from the lock in the foreground to the sluices on the other side of the river.

As soon as the lock was completed so that vessels might pass through it, all river traffic was transferred thereto from the old channel. Then, across the river, bents of piles were driven and braced, and a line of 6-inch yellow pine sheeting was driven between the coffer-dams in which the lock and the sluices had been built, forming a solid timber wall clear across the river. This sheeting was cut off, as fast as driven, at about 3½ feet below mean low-tide level. The lock and the sluices were left wide open during this construction, so as to relieve the shut-off dam as much as possible by allowing the tidal currents to pass through them. The sheeting was cut off as evenly as possible, so as to make a close joint with the gates which, as an additional precaution, had a piece of rubber hose nailed to the bottom edge.

On October 20, 1908, at a signal from Governor Guild, the ropes holding the gates were cut, and seven seconds later they were all in place. The wedges for holding them down were then driven, and a few minutes later a large number of dredges were busy heaping earth against the structure. While the work at the dam was progressing, the new Boston Embankment, extending about 1½ miles upstream from the new Cambridge Bridge, was being built. It varies in width from 100 to 300 feet. Before it was begun, and before the dam prevented the mud flats from being exposed at low tide, the river bank was most unsightly. Even in the Back Bay region, where live many of the oldest and proudest families of the old Bay State, the shore of the river was disgraceful.

This is all being changed, and in a few years, when trees have grown, the beauties of the Embankment will excel those of the Charlesbank, which was built many years ago.

Mention has been made of the sewage which formerly found its way into the river. Most of this is now discharged elsewhere, but still in times of heavy storm, when the sewers have been filled to their utmost capacities, some overflows have poured their sewage into the river. It was feared that when the basin had become a fresh-water lake, even this diluted discharge might be objectionable and unsanitary, and to avoid the danger which pollution would bring, marginal conduits have been built on both shores to take the surplus into tidewater below the dam.

All of the masonry structures required for this improvement of the Charles River have had to be built on piles, and many acres of forest have been called upon to furnish them. Could all the piles used in the work be laid end to end they would extend 100 miles, and the sheet piling used would have sufficed to build a plank walk one inch thick and two feet wide from Boston to Worcester.

With the tidal currents stopped, the water in the basin is gradually becoming fresh. In the midst of a great city is a lake where skating and ice-boating may be enjoyed in winter, and on whose waters will soon float one of the largest fleets of motor boats in the world. The work is being carried out under Mr. Hiram A. Miller, M.Am.Soc.C.E., as chief engineer.

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A SENSITIVE THERMOMETER.

BY PROF. S. A. MITCHELL, COLUMBIA UNIVERSITY.

The delicate researches carried out in the science of physics have demanded an exceedingly sensitive instrument to measure small quantities of heat. The most accurate thermometers at present in use can hardly be relied upon to more than one-hundredth of a degree, an accuracy sufficient for most chemical experiments, but not satisfactory for the more refined physical investigations. There are many methods used for determining temperatures which differ in principle and in the accuracy attained. In measures of a line on the earth's surface, such as are carried out by the United States Coast and Geodetic Survey, where it is desired to know the length of a base accurately to about one part in a million, it is necessary to know the exact lengths of the measuring bars, and these have been determined with great precision, by combining together two rods of different metals, as zinc and iron, and finding the temperature by measuring their differential expansion. This, however, is more for the purpose of determining the average temperature throughout the measuring bars than an attempt to increase the accuracy of the temperature determination. Degrees of heat are thus measured by the expansion of the mercury and its measurement in a glass tube, or by the increase in the length of one rod over the other.

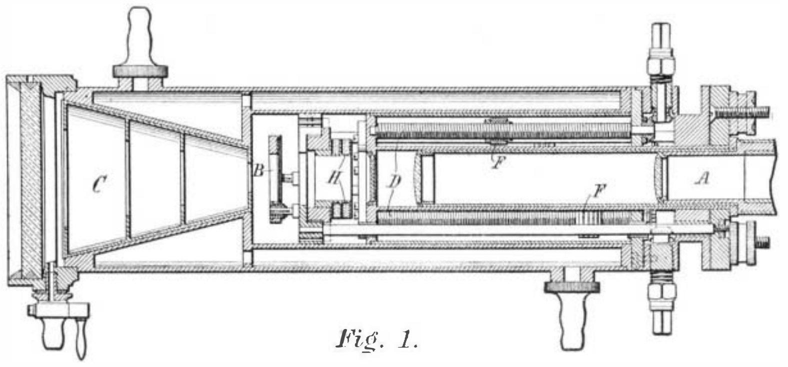


Fig. 1.

Fig. 2.

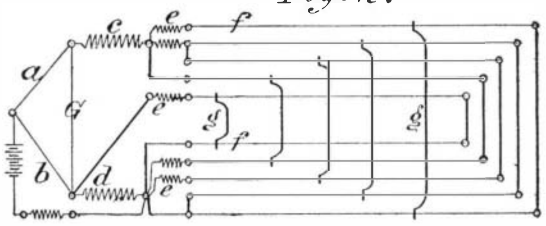


Fig. 3.

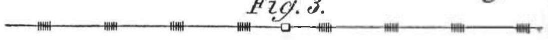


Fig. 5.

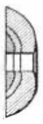
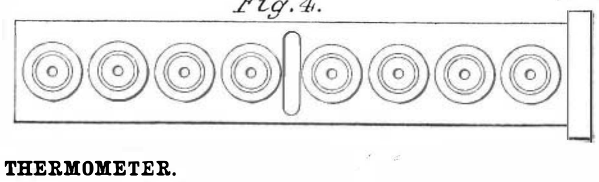


Fig. 4.



A SENSITIVE THERMOMETER.

A totally different principle for measuring the amount of heat is that involved in the thermopile. This consists of a pile of plates of bismuth and antimony, insulated from one another and joined up to a galvanometer. When heat strikes the thermopile it alters the resistance offered to an electrical current passing through it, and this change of resistance is measured by the galvanometer. The thermopile surpasses the thermometer a hundredfold in the accuracy of measures of small quantities of heat.

Still another method is that involved in the radiometer, which all are familiar with in opticians' show windows; the small vanes blackened on one side, inclosed in a glass case exhausted to a partial vacuum, persist in rotating as long as the sun's rays fall upon them. Though ordinarily considered merely as a toy, the radiometer in skilled hands becomes a much more refined thermometer even than the thermopile. Prof. Ernest Fox Nichols of Columbia University has been able to detect and measure differences of temperature as small as one-millionth part of a single degree, or even more accurate than that, to the ten-millionth part of a degree! Such accuracy is sufficient for most physical investigations. To attain this degree of sensitiveness, it is necessary to make the vanes exceedingly small and light and suspend them on a fine delicate quartz fiber.

The only instrument for the measurement of heat more sensitive than the radiometer is the bolometer, the invention of the late Prof. Langley. In his hands and in those of Prof. C. G. Abbot, the director of the Atrophysical Observatory at Washington, the bolometer has been brought to a very high degree of refinement, and with it many exact observations have been made, one of the most important of which is the measurement of the heat of the solar corona at the recent eclipse of the sun on January 3, 1908. As is well known, the bolometer consists of a thin metal strip or strips forming part of a Wheatstone bridge, for the electric balance of which a very sensitive galvanometer is used. By decreasing the sensitiveness of the galvanometer, the bolometer as a measurer of heat has been made more and more delicate, till at the present time it is possible to divide down to the one-hundred-millionth part of a single degree, or in other words to measure the heat of an ordinary candle at the distance of four miles! But it is a far cry from the first invention by Prof. Langley in 1880 to the finished product of Prof. Abbot. If the bolometer had been a commercial enterprise, the splendid improvements in it would have been cornered by a long list of patents; but in scientific work all comers are permitted to emulate and copy as they please.

The complete bolometric apparatus consists of three separate parts: The bolometer proper, the resistance for balancing the Wheatstone bridge, and the galvanometer. In order to procure a metal strip thin enough for use in the bolometer, a piece of silver-coated platinum wire is drawn fine and hammered to the desired dimensions; the silver is then removed by nitric acid and the naked platinum strip carefully soldered upon its copper frame. The strip used is about half an inch long, 1/400 inch wide, with a thickness one-fourth its width! For the sake of symmetry, a second strip of platinum as nearly as possible like the first is used to one side of the absorbing strip, but shielded from the radiation by a diaphragm. This forms the second arm of the Wheatstone bridge. Two coils of wire joined with the two bolometer strips and the battery circuit form the third or fourth arms of the bridge. Measures are made by balancing up the current as it flows through the separate arms of the Wheatstone bridge, and then noting the deflection of the galvanometer needle when the heat to be measured falls on one of the bolometer strips.

Those who have ever used a galvanometer to measure an electrical current know the difficulties involved in causing the needle to remain quiet or in "balance." When the sensitiveness of the galvanometer is highly increased, these difficulties multiply, but in spite of this, Prof. Abbot has devised and made a wonderfully remarkable set of resistance wires for balancing the galvanometer. All are included in a cylindrical case shown in Fig. 1, three inches in diameter and fifteen inches long. The energy from the source under investigation enters through the left end, and after passing through diaphragms in the conical piece *C*, falls on the bolometer strip at *B*. These two strips are joined up electrically with coils placed at *H*, and these in turn with wires forming part of the slide wire resistances. (The detailed scheme of these wires is shown in Fig. 2.) Sliders *F* work on screws *D* turned from without. The arrangement for two out of the five slide wires is shown in Fig. 1. Small keys fitted on the outside make it possible to turn the sliders quickly from one end of their run to the other. The galvanometer (shown at *G* in Fig. 2) is always balanced by the use of the first three slide wires. A glass plate at the left of the figure and another between *D* and *H* makes it possible to have the bolometer strips in a vacuum, by exhausting the air through a cock seen at the left below. Water may be circulated around the coils. Thus they may be kept at a constant temperature by joining up with two cocks shown one above, the other below. An eyepiece may be inserted at *A*, so as to examine visually the source of energy, such as a star, which is focused on the bolometer strip *B*. With this, the exceedingly tedious operation of balancing is rendered very simple and rapid, and the whole process is at all times under the perfect control of the observer. This simplified balancing apparatus is one of the best of the many improvements devised by Prof. Abbot. The galvanometer ordinarily used is a modified Thomson reflecting instrument consisting of 48 magnets arranged in eight