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 draw-bridge 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 inter-locked 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.

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

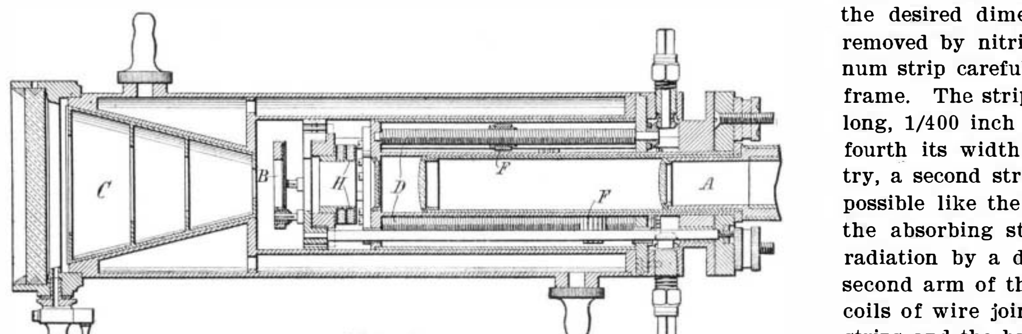


Fig. 1.

Fig. 2.

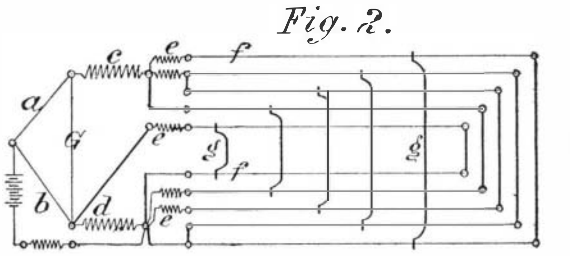


Fig. 3.

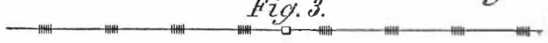


Fig. 4.

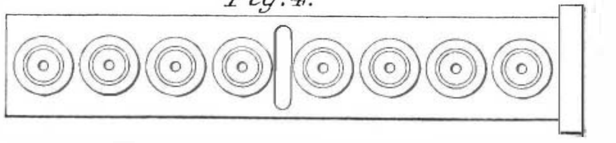
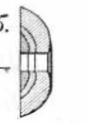


Fig. 5.



A SENSITIVE THERMOMETER.

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.

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 groups of six each, shown in Fig. 3, and with sixteen coils as in Fig. 4, the arrangement for each coil being as in Fig. 5. On the glass stem carrying the 48 magnets there is a small mirror. The whole system is very light and weighs no more than 10 milligrammes. With atmospheric pressure in the bolometer case, a deflection of 1 millimeter on a scale at a distance of 1 meter is produced by a current of 5×10^{-9} ampere. With the air exhausted to 0.2 millimeter pressure, a current of $2 \times 10^{-12} \left(\frac{2}{1,000,000,000,000} \right)$ ampere can be recognized with certainty. Such a galvanometer was used by Prof. Abbot and the writer in a recent attempt to measure the heat of stars.

To measure the heat of the solar corona at the total eclipse of 1908, a bolometer was mounted at the focus of a concave mirror 20 inches in diameter and only 40 inches in focal length. A glass plate three millimeters thick was fixed close to the bolometer between it and the mirror so as to limit the radiator to waves less than 3μ in length. About 4 inches in front of the bolometer was a self-closing blackened metal shelter so that the bolometer was exposed to radiation only when this shelter was open, and between this shelter and close to the glass plate was a special screen of thin asphaltum varnish which, when interposed in the beam of light, cut off nearly all the visible part of the radiation, while transmitting nearly all of the infra-red rays that can pass through glass. The bolometric apparatus was carefully set up on Flint Island in the Southern Pacific by Prof. Abbot and was in perfect adjustment on the day of the eclipse. Many improvements were made over the apparatus used in 1900 at the eclipse at Wadesboro, N. C., chief among which were that one mirror replaced seven, that radiations were limited to those transmissible by glass, and that a direct means was at hand for comparing the radiations from the sun, sky, and corona.

In the SCIENTIFIC AMERICAN July 25, 1908, was shown how nearly the observers came to adding another disappointment to the already long list of eclipse failures through clouds coming at an inopportune moment. For fifteen seconds before totality it was raining. In spite of the nerve-racking moments of preparation, Prof. Abbot's measures with the bolometer were beautifully carried out, with the following interesting results, where the radiations are compared with that of the noon-day sun. On the same scale where the strength of the solar heat is the large number 10,000,000, that of the moon (i. e., reflected solar radiation) is only 12; or in other words, the sun shines with an intensity 800,000 times that of the moon. Again, on the same scale, the intensity of the corona at 1.5 millimeter from the sun's limb is represented by 13, at 4 millimeters from the limb by 4, and at 12 millimeters no deflection whatever was recorded by the galvanometer, i. e., the corona has no measurable intensity. (Zero intensity was likewise observed from the middle of the moon during the eclipse.) From these figures it appears that the corona of 1908 equaled only the moon in brightness—the most brilliant part of the inner corona, and that this brightness decreased very rapidly.

These measures are most exceedingly interesting to the astronomer, and taken with other observations of the corona lead us a step nearer to solving the mystery of the beautiful crown of glory about the sun which can be seen only in the few fleeting moments of a total eclipse. What have we already found out concerning the corona? First, the spectroscope shows the bright "coronium" lines which indicate that the corona in part consists of an incandescent gas; second, the spectrum also shows the dark Fraunhofer lines, and accordingly the corona consists in part of matter in a finely divided solid or liquid state which can reflect ordinary sunlight. The corona, for some reason or other, assumes different shapes which depend on the number of spots on the sun, being square when spots are at a maximum, but with a long fish tail on either side of the sun's diameter when spots are at a minimum. What is the meaning of this connection between spots and corona? At the eclipse of 1901, Perrine found a big disturbance in the corona immediately above a large sun-spot, and a long thread-like prominence emanating from the same region. What is the explanation? The Swedish scientist Arrhenius explains these matters by assuming that the corona is an electro-magnetic manifestation, and that the sun's rays exert a pressure on the finely divided matter of which the corona is composed, with the result that the small electrified particles are driven away from the sun, forming the corona. (This same theory explains the formation of comets' tails, and the aurora borealis.) It is a most beautiful theory, and one which we are ready to accept as soon as it is based on the solid truth of observational facts. But such a time has not as yet come. With our present knowledge, how are we best to explain the action of the corona of the sun so as not to take too much for granted? The observed facts discovered by the spectroscope together with the newer measures of the corona obtained by Prof. Abbot lead him to believe that the brightness of the corona is due mainly to the reflection of ordinary sun rays by matter close to the sun modified to some extent, however, by radiation of incandescence and perhaps also luminescence.

Correspondence.

MR. LARSEN'S PHOTOGRAPHS OF LIGHTNING.

To the Editor of the SCIENTIFIC AMERICAN:

In your issue of December 12 there appeared an article by Mr. James Cooke Mills, describing certain experiments made under the auspices of the Smithsonian Institution by Mr. Axel Larsen. As the impression is given in this article that many new facts have been ascertained from these experiments, I cannot let it pass without a word of protest. In the first place, lightning has been photographed with a moving camera, and the multiple nature of the discharge shown many times in past years; the dark flashes have been photographed almost from time immemorial, and the spectrum of lightning was secured by Prof. Pickering several years ago.

The cause of the dark flash has been known for the past ten years. Mr. Clayden showed that feeble flashes always came out dark on the plate if the plate was subsequently fogged by a feeble light of any sort. This light usually comes from the clouds illuminated by other flashes, or in some cases from a faint twilight sky. Mr. Clayden obtained the effect in the laboratory with electric sparks. If the fog is produced before the spark is impressed, no reversal takes place. The theory advanced in Mr. Mill's article, that the dark flash emits very short wave lengths, which decrease the sensibility of the plate, is absolutely false. There is nothing peculiar about the light from lightning except the brevity of its duration. A very brief flash of sunlight impressed upon a photographic plate, which is subsequently fogged by feeble candle light, will come out dark, as I showed nine years ago. I made at the time a rather extensive investigation of the Clayden effect, and found that it was due to the fact that an intense light of very brief duration, a light shock I called it, decreases the sensibility of the photographic plate. Reversals were obtained with shocks of as long duration as 1/1000 of a second, though in this case the intensity of the fogging light and the time of development had to be very carefully regulated. With shocks of a duration of 1/10,000 of a second, reversals could be obtained without difficulty. A full description of the experiments can be found in the Astro-physical Journal for June, 1903; still earlier experiments in the Journal of the Philadelphia Photography Society, November 8, 1899. R. W. WOOD.

Johns Hopkins University, Baltimore, Md.

THAT AEROLITE AGAIN.

To the Editor of the SCIENTIFIC AMERICAN:

In your issue of November 7 last appeared a letter from myself giving an account of the supposed flight of a great meteor over the section of Tennessee lying between Tullahoma and Altamont or Beersheba in the eastern part of the middle section of the State—which occurrence happened at 10 o'clock A. M., September 8. The noise and vibration caused by the flight of the meteor were so great, and were noted over such a wide territory, that the matter was deemed by me and others to be worthy of being noticed in the press, especially as such notice might lead to the discovery of fragments of the meteor, in case any of them reached the earth.

In your issue of November 28, E. B. Hoyte, in a letter dated November 14, Nashville, says among other things: "He" (myself) "declares that from his position the crash of the impact was as a great explosion of dynamite accompanied by a slight vibration of the earth." And again, "I find that on September 8, at about 10 A. M., a shipment of dynamite was exploded at Wartrace, Tenn., on the N. C. & St. L. Railway"—which was near Estill Springs, where I was at the time.

A reference to my communication will show that I did not say that the sound was that of an explosion of dynamite. I did not express that opinion, but only said that, among the many causes (indicated) by different persons, some thought at the time that there had been an explosion of a shipment of dynamite. I did not myself think anything of the kind, and did not say that I did. Persons came to and fro from Wartrace to Estill, and no one spoke of such an explosion. I think I can safely say that no explosion of a shipment of dynamite took place at Wartrace, or at any other point within at least fifty miles, or indeed in the State.

I took the trouble last week to make sure on this point, and, among other things, wrote to the postmaster at Wartrace. I inclose to you his reply, in which he says that no such explosion has taken place.

In your issue of December 12, a letter signed A. M. Button, dated Waterford, N. Y., says that he, Mr. Button, was at Winchester, Tenn. (near Estill Springs and Tullahoma) on September 8, and at 10 A. M. that day saw what appeared to be a large pyramid of yellowish white flame passing with great speed high up in the sky, followed by a sound such as I described.

I will add that soon after I wrote my original letter to you, I learned that at least a dozen reliable men in that vicinity, whose names I heard, reported that they saw the object very much as Mr. Button describes it.

PARK MARSHALL.

Nashville, Tenn., December 25, 1908.

ARE FILTERING BEDS CORRECTLY CONSTRUCTED?

To the Editor of the SCIENTIFIC AMERICAN:

I do not believe that you can expect very much from a person who says: "I have never studied engineering in any of its branches, but I believe that our engineers are entirely wrong upon a subject which has been studied for years and years, and upon which millions of dollars have been expended." For this person to be right and the engineers wrong is certainly against the rule. I therefore expect to be corrected, and ask you and those of your readers qualified to give an opinion on the subject to kindly point out wherein I am mistaken in my ideas, and I thank them in advance for the same.

The question is: Are our filtering beds constructed correctly or on correct principles? I believe they are not, and these are my reasons, and also a possible remedy:

The object for which filtering beds are constructed is to furnish pure water, and not to obtain all the foreign matter held in suspension by the water, and then when you have obtained the same, to know that you have something that you absolutely do not want and some pure water. As far as I know, and in a general way, filtering beds are constructed by placing conducting pipe having broken joints on the bottom of a reservoir, or by covering them with some suitable material having perforations, and upon this layers of broken stone of large size, broken stone of smaller size, gravel, coarse sand, and lastly a bed of fine sharp sand. These several layers to be about one foot in depth, but the last one from three to five feet. Water having foreign matter in suspension is pumped upon this bed and allowed to pass through, and the water then used for final distribution through the city's mains. When one portion of water has passed through another is pumped on, and so on until the surface of the bed becomes clogged or choked up from the foreign matter held in suspension, and which has accumulated from day to day for a variable time, according to the condition of the water. The surface of the bed is then scraped off, and either washed and replaced or is replaced with entirely new sand. This bed certainly catches all the foreign matter held in suspension, and if this was the object for which it was constructed, it would work to perfection; but as the object is to furnish pure water, it does not furnish all the pure water, but only a portion. The object is to furnish all the pure water, and no foreign matter or dirt. The water placed upon the filtering bed must pass through the same; there is no other outlet. Now, if the water could pass through the filtering bed, and at the same time have an outlet for the foreign matter held in suspension, then there would be no accumulation of foreign matter.

Therefore, as a remedy I would suggest that instead of building a reservoir and placing conducting pipe on the bottom thereof, the conducting pipe be placed directly on the bottom of the source of supply, be it lake, river, or whatever, and then cover them in the same manner as described above. Then the water would pass through the filtering bed just the same, and the foreign matter held in suspension would follow the lines of least resistance, and flow over the filtering bed. In this way there would be no accumulation of foreign matter held in suspension, and it would not have to be removed from time to time. You would obtain all the pure water and none of the foreign matter held in suspension, for which you have no earthly use any way unless it was as a fertilizer, and then it would be a mighty expensive article. There would be no trouble caused by the ice in winter, and would therefore not require covering or housing. Nor would there be as much wear and tear on the valves of the pumps caused by the sand and other matter. In the cost of construction there would be no expense for the land on which the filtering bed is located, in itself a large item in many cases. Neither would it cost anything for paving the bottom and the sides and the retaining walls. Nor would it cost as much to place the several layers of stone, etc., in place in the lake or river as it would if placed in a reservoir on the land. The size of the filtering bed I would suggest to be proportioned for every million gallons of water to be used every twenty-four hours, to be one acre of surface. This would cause a flow through the filtering bed at the rate of about one yard a day. When the current in the lake or river is only one mile a day, the proportion in the flow would be one to seventeen hundred, that is, the water would flow one thousand seven hundred times faster over the filter than through the filter, and where this was the case, there would surely be no depositing of foreign matter on the filter, at least I so do think it. Now, if I am right in my ideas, there is no reason whatever why all the cities in the United States, and all over the world for that matter, located on the shores of our many lakes and on the banks of our rivers, could not have all the pure water they wanted at a cost no greater than that of the mere pumping of the same, and in some cases not even as much; that is, filtered water could be had for less money than it would cost to pump unfiltered water, of course not considering the first cost of installation.

It is only upon the ground that exceptions prove the rule that I venture to make the foregoing statement, and I hope that in rendering judgment, my judges be not unmindful of leniency and mercy.

PAUL F. BUSSMAN, M.D.

Buffalo, N. Y., December 24, 1908.

[You suggest that by placing filter beds (underlaid by the usual outlets) "directly on the bottom of the source of supply, be it lake, river, or whatever," the clear water would pass out just the same, and the foreign matter would be held in suspension and "*flow over*" the filter beds. Now, the foreign matter eliminated by filter beds is largely so light and impalpable that it would be little affected by flow; and if there were enough current for water to pass through the beds, *some* foreign matter would be retained in them. Your speaking of "flow," however, presupposes a current, and does not mention what would happen in the case of a lake with *no* current. In this case surely the action of the filter beds would be exactly the same as in reservoirs, with the exception that after the cost of draining a lake in order to lay conduits and filters in its bed, the same expensive process would have to be gone through to change the filtering material. In the case of a river, supposing the flow to retard the deposition of foreign matter, the filters must necessarily be placed in a deep and consequently fairly still part, exactly where detritus from the banks brought down by every flood would accumulate, rapidly choking the filter. The whole point, however, is that your principal object seems to be to prevent the accumulation of foreign matter in the filter beds; and if the filtering material does *not* catch and accumulate foreign matter, what is the object of having it at all?—ED.]