the sand, gravel and underdrains; but under any given conditions it varies (within practical limits) directly as the rate. In some of the old filters, the outlet was connected directly to a clear water basin, or pump well; and the difference in level between the surface of the water in the filter and of that in the well was, of course, equal to the loss of head. Fluctuations in the draft upon the well produced corresponding fluctuations in the filtering head, and therefore in the rate, which was thus automatically adjusted to the demand. In others, however, some sort of apparatus was placed between the filter and the clear water basin by which the rate could be kept constant. This is now considered to be of the greatest importance for the reason that bacterial tests of the effluents have shown that marked deterioration invariably follows fluctuation in the rates. This is probably caused by the mechanical disturbances produced in the sand-bed and surface film. For details of such tests, see Report Mass. State Board of Health for 1894.

In the newest plants, therefore, some kind of an arrangement is always provided for the regulation of the flow. Since the rate varies directly as the loss of head, it is immaterial which is regulated. Some of these devices, therefore, regulate the flow directly, while others accomplish the same result by the indirect method of regulating the loss of head. In order that the former may be kept the same from one day to another, the latter must be gradually increased as the period of service of the bed extends, so as to correspond with the increasing resistance of the surface layer. This is effected automatically in the device which was designed by Lindley for the filters at Warsaw. The apparatus is contained in a water-tight chamber, connected on one side with the filter, and on the other with the clear water basin. The rate at which the water can pass from one to the other depends upon the depth to which the slits in the sliding pipe extend beneath the surface of the water. This is adjusted by weights at the other end of the chain which passes over a pulley. Thus the rate can be kept constant; and as the resistance of the bed increases the level of the water in the chamber will automatically adjust itself to produce the necessary differences in level or loss of head.

In the method of regulation devised by Gill for the Tege works of the Berlin water supply, the outlet from the middle chamber is through a weir; and the depth of water on its crest, and, therefore, the discharge, is indicated by the height of the float read on the scale. This is kept constant by means of the gate. The corresponding loss of head is shown by the difference of the readings on another scale. Keeping the water in the filter always at the same level, a constant rate can only be maintained by the gradual falling of the level in the right hand chamber and a consequent wider opening of the gate.

As to the limit beyond which the loss of head should not be allowed to go, the general opinion seems to be that it should not be greater than the depth of water on the bed, though the Lawrence experiments have not shown any bad effects from exceeding this limit. As a general thing it may be stated that, everything else being equal, the higher the rate the poorer the quality of the filtrate. But with fairly low rates this deterioration is slight, so that entirely satisfactory results can be obtained with rates up to 3 or 3½ million gallons per acre per day. Probably higher rates could be safely employed if very great care were exercised in the operation of the filter. The relative effects of high and low rates from a financial point of view are discussed further on.

When the clogging of the filter bed has become such as to require a loss of head greater than the prescribed limit, the inlet is closed and the water allowed to drain away until it has sunk some distance below the surface of the sand. When this has become sufficiently firm, workmen enter the bed with planks wheelbarrows and broad flat shovels. With these they carefully remove the surface layer and pile it up in little heaps, which they afterwards remove with the barrows. The depth removed varies from ½ to 1 inch, and averages about 8-10 of an inch. The surface of the sand is then raked to loosen up the packing caused by the boots of the workmen, and after smoothing down any irregularities the planks are removed and the filter is ready for another period of service. The refilling begins from below by admitting through the underdrains filtered water from another bed in action. The object of this is to drive out the air from the pores of the sand, where its presence in the form of bubbles would cause considerable unnecessary friction. When the water has risen a few inches above the surface of the sand, the lower connection is shut off, and the refilling is completed by means of the surface inlet. Before filtration proper begins the water should be allowed to stand on the bed for several hours; or the first million gallons or so should be wasted. The amount wasted can be reduced by beginning the filtration at a low rate, and gradually increasing it to the maximum. When the scrapings have reduced the sand-bed to the minimum allowable thickness, the total amount removed, which has in the meantime been thoroughly washed, is replaced at one time. Before doing so the surface of the permanent layer, which is never removed, should be loosened up by being spaded over to a depth of six inches or so. If this is not done, there is a liability of sub-surface clogging at its junction with the clean sand. When the filter is started again, it is, except for the permanent layer, in the condition of a new filter, and so requires extra care in operating it, and the filtrate should be wasted for a much longer time than is required after the scrapings. Piefke of the Berlin waterworks places this period at six days. Considering the labor necessary, and the time the bed is out of use, this replacing of the sand is an expensive operation, and should not occur oftener than can be avoided. In most plants the usual period is about once a year.

Sometimes it is possible to obtain new clean sand at less cost than is necessary to wash the old. But this is rarely the case; hence an important part of the equipment of a fair-sized filtration plant is the apparatus for the washing of the sand. The simplest of the methods employed for this purpose consists of a broad shallow box, which is set in an inclined position. The dirty sand is thrown into this box, and a jet of water played upon it from a hose. The water overflows from the lower end of the box and carries the dirt with it. This is continued until the water runs off clean. The more elaborate methods employ mechanical means to force the water through the sand. Drum-washers, operated by horse or steam power, are largely used in Germany. They are set in an inclined position, and the sand, with streams of water playing upon it, is forced from the lower to the upper end by means of revolving spiral blades. Various other methods more or less on the same principle are employed.

The "Ejector" washer is probably the most efficient of all the methods employed. It consists of a series of conical hoppers arranged in a row. At the bottom of each hopper is an ejector through which a stream of water passes under a pressure of 15 or 20 lbs. The dirty sand is thrown into the first and largest hopper. From this it is ejected through a vertical pipe into a trough, from which it falls into the next hopper. Here the same thing occurs; and the process is repeated until the water, which is continually overflowing from the hoppers, comes off clear. The whole arrangement must be enclosed in a masonry pit, from which the dirty water is conducted by drains. Six or eight hoppers are required for each machine, which will have a capacity of from 5 to 6 cubic yards per hour. Sand washers of this type are used in the new filters at Hamburg, and are to be used in the plant now under construction at Albany, N.Y. Details of the latter are given in Engineering News, February 10, 1898. The volume of water required in sand-washing varies, according to the method used, from 12 to 20 times that of the sand; the ejector machines apparently requiring the most. The question of cost will be referred to under maintenance.

(to be continued).

The annual summer class in practical surveying in connection with the faculties of applied science of McGill University, began September 1. Carillon, P.Q., is the headquarters of the class this year, and here a series of practical surveys of prospective railways and a continuation of the partial survey of the Ottawa river are being carried out. Upwards of forty-five students, who intend entering upon the courses of architecture, mining, and civil and electrical engineering, are attending the class, which will continue until the session of the Faculty of Applied Science opens. C. H. McLeod, professor of surveying and geodesy; J. G. G. Kerry, lecturer in surveying, and R. S Lea, assistant professor of civil engineering, are in charge of the work of the class.