leave the filter in a less purified state and will possess an undesirable turbidity. The filter will run longer without washing because of the slower accumulation of coagulated material, but the efficiency will be poor.

The different types of device for the control of the application of chemicals are very numerous and are all designed to be as nearly automatic as possible. The appliances which have given the best results are those wherein provision is made for the application of the solution under a practically constant head through an orifice which can be adjusted at will. The depth of solution over this orifice should not be less than 6 inches, and this depth may be maintained by allowing slightly more of the solution to be delivered into the orifice tank than is allowed to escape through the orifice, the excess being discharged back into the main solution tank through an overflow, or by means of a float valve. The overflow is by all odds the more reliable.

The sulphates of iron and aluminum have a corrosive action on almost all metals, and it has been found advisable to make all of the metal parts which come in contact with the solutions of lead, copper, or special bronze. It is sometimes found advantageous to use hard rubber piping, valves, and orifices, but the cost may preclude the use of such material. Rubber piping and valves are easily broken, and the cost of replacement may prove no inconsiderable item. Generally speaking, however, the decision as to the kind of metal to use depends on the relative cost of the cheaper iron and its correspondingly higher cost for repairs and replacements and the ease with which repairs can be made, and the higher first cost of more expensive materials and the lower cost for upkeep.

Improved Devices for Filter Operations.—As already pointed out, it was not until 1902 that marked improvement was made in the direction of making easier the manipulation of valves and other apparatus, which has so much to do with the successful and economical operation of a rapid-filter plant. Until that time all valves, without exception, were opened and closed by hand. When a filter required washing, it was necessary to close the influent and the effluent valves, and to warm up the steam wash-water pump preparatory to supplying wash water to the filter. Now the operator moves a lever at an operating table, and by means of hydraulic cylinders valves are opened or closed with practically no manual effort or loss of time. Electrically driven wash-water pumps have largely supplanted the steam pumps, and the operator starts and stops this pump merely by pressing a button at the same operating table. Air compressors, which supply air to the filters during washing for the purpose of agitating the sand layer, have in most large plants taken the place of the steam-driven rotary agitators, and these compressors are also started and stopped by pressing a button on the operating table.

As time savers these various improvements more than pay for themselves, and the neat appearance of the newer plants is a vast improvement over the older plants with their multitude of wheel stands.

Filter Washing.—When a rapid filter has become so clogged with coagulated matter that the normal rate of filtration can no longer be maintained, the influent valve is closed and the water standing over the sand layer is drawn down to the top of the wash-water gutters. The effluent valve is then closed and the wash-water pump is started. This pump forces filtered water up through the sand layer until it is freed of practically all of the accumulated matter. The pump is then stopped, the influent and the effluent valves are opened, and filtration is resumed. In some places the filters are washed by water delivered under the requisite pressure from an elevated tank.

During the process of washing a filter it is the practice in the majority of the newer rapid-filter plants to break up the sand layer with compressed air before turning in the wash water in order to facilitate and accelerate the cleaning of the sand grains. In some places, as at Cincinnati, Ohio, and New Orleans, La., no provision is made for agitating the sand layer during washing other than such agitation as induced by the upward flow of wash water. In the older plants, and in some of those recently built, wherein the filter tanks are circular in plan, the sand is agitated during washing by means of rake teeth attached to arms which revolve, driving the teeth through the sand.

When washing a filter the rate of application of wash water must not be too low, and on the other hand it must not be too high, or sand will be carried from the bed with the wash water. Ordinarily the best rate of application of wash water is about 6 to 8 gallons to the square foot a minute, which corresponds to a vertical rise of about 1 foot a minute.

This is equivalent to three to four times the rate of filtration. When wash water is driven upward through a filter bed of normal construction at these rates, the sand layer will rise from 3 to 5 inches, but practically no sand will escape from the bed except during the early stages of operation of a new filter.

Before the modern appliances for facilitating the labor of operation were installed it was not unusual for periods out of service for washing as great as 30 minutes to be recorded, and frequently the time consumed was even longer. In the more recent filters this period rarely exceeds 10 minutes from the time the effluent valve is closed until it is again opened.

Control of Rate of Filtration.—If uniform rates of filtration are required for the successful operation of slow sand filters, then uniform rates are of even greater importance in rapid sand filters. The reason for this is plain. Slow sand filters are operated at actual rates of about 3,000,000 gallons an acre daily; rapid filters are operated at rates from 30 to 40 times as high as this. A sudden fluctuation in these higher rates means a correspondingly greater shock, and impaired efficiency naturally follows.

Although within certain limits there is no particular objection to the rate of filtration in a rapid filter gradually diminishing, a sudden increase in rate will cause an almost immediate deterioration in the appearance and hygienic quality of the effluent. If the rate increases or decreases slowly and steadily no harm may result, but should the rate increase abruptly, even as much as 20 per cent., the effect of the change will usually be apparent from the inferior appearance of the filtered water.

Therefore, to maintain a constant rate of filtration in the rapid filter, automatic controllers are always used. There are many such devices, but the object of all it to maintain a uniform rate of discharge from the filter independent of the head on the outlet pipe on which the controller is located. Although many improvements in these devices have been made in recent years, the best of them subject the filter to fluctuations in rate of at least 10 per cent. Furthermore, on account of the tendency of floats and butterfly valves in these controllers to stick, such fluctuations may occur within a very few seconds. In drawing up specifications for controllers it is frequently stated that such variations from the normal rate shall not exceed 2 per cent., but this requirement is rarely if ever met. Nevertheless the controllers do practically the work required of them, and without them a rapid filter would be unable to maintain a high standard of efficiency.