the filter, being evenly distributed by means of the strainer system. The material which has accumulated on the top of the sand is thus washed out, and the dirty wash water overflows into the gutters, thence to pass to the sewer. Such a washing operation ordinarily consumes about 10 minutes from the time the filter is closed down until it is again thrown into service.

The rapid filters just described are the type more commonly used; they are known as "gravity" filters and are contained in open tanks.

There is another type, known as "pressure" filters. Such filters are contained in closed steel shells. This type of filter is more extensively employed for household and industrial use, and in some places it is found to be more economical and convenient than the gravity filter. The largest municipal plants of the pressure type are located at Davenport, Iowa, capacity 9,000,000 gallons daily, and at San Diego, Cal., capacity 5,000,000 gallons daily.

Coagulating Chemicals.—The chemicals most commonly used for the coagulation of water are compounds of aluminum and iron, and of these potash alum sulphate of alumina, alumino-ferric, and sulphate of iron are the most extensively employed.

The manufacture of alum is of great antiquity, and for many centuries this chemical has been used in far eastern countries for coagulating water as an aid to clarification. The manufacture of aluminum sulphate from bauxite and alum clay is of more recent origin. The process of making alumino-ferric from bauxite was patented by P. and F. M. Spence in 1875. The sulphate of iron used in water coagulation is for the most part a by-product of iron and steel industries.

The choice between the different coagulating chemicals is properly based on their efficiency as coagulants, and this refers directly to the percentage of available aluminum or iron which they contain. Potash alum, sulphate of aluminum, and alumino-ferric cost about 1 cent a pound; sulphate of iron costs about half a cent a pound. In this country sulphates of aluminum and iron are the most widely employed in water purification, but at the waterworks at Tokyo, Japan, potash alum is used. Sulphate of aluminum is the coagulant in the works at Alexandria, Egypt, and also in practically all rapid filter plants in Europe, India, and Egypt, except at the waterworks at Calcutta, India, where alumino-ferric is used.

In composition these chemicals show considerable variation, but they may be bought on a basis of a guaranteed percentage of available alumina or iron oxides. The essential feature is that the chemical shall be basic, that is, shall contain more aluminum or iron than the equivalent of the sulphate radicle present. The approximate composition of these chemicals now on the market is as follows:

Approximate Percentage Composition of Coagulating Chemicals.

Constituent.	Pure potash alum	Sulphate of aluminum	Alumino-ferric	Sulphate of Iron
Matter insoluble in water..		0.30	0.06	0.50
Alumina (Al_2O_3)	10.77	17.00	14.26	.....
Iron oxides (Fe_2O_3 and FeO)		.25	.60	57.50
Potash (K_2O)	9.93	.....	.....	.....
Sulphur trioxide (SO_3) ...	33.76	38.70	35.81	28.80
Water (H_2O)	45.54	43.75	49.27	13.20

When potash alum, sulphate of aluminum, or alumino-ferric are applied to a turbid water the chemical is rapidly decomposed. The strong sulphate radicle of the chemical displaces the weak carbonate or bicarbonate radicle in the water, and an equivalent amount of carbon dioxide is liberated. The white, insoluble, and gelatinous aluminum hydrate that is formed absorbs the dissolved color and envelops and brings together into comparatively large aggregates the mud and the bacteria in the water. These flocks of coagulated matter are removed with comparative speed by subsidence.

Generally speaking, the application of these coagulating chemicals to a water will bring about a slight increase in the amount of incrustants in the water and a decrease in temporary hardness. The total hardness of the water—that is, the sum of the temporary hardness and the incrustants expressed in terms chemically equivalent—will remain unchanged. The increase in incrustants has some significance as regards corrosion of uncoated iron and incrustation in boilers; but, practically speaking, these are factors of comparatively little importance in view of the relatively small amounts of the coagulating chemical ordinarily employed.

Most surface waters naturally contain more than sufficient carbonate and bicarbonate radicles to make possible complete decomposition of the chemical which is applied for coagulation. In some waters, however, the natural alkalinity is so low, particularly at times of floods, that this is not true, and for such waters it is necessary to make up the deficiency by applying soda ash or lime water before the coagulant is added.

Sulphate of iron, known commercially as copperas, is obtained in two grades, namely, the ordinary commercial by-product from iron and steel manufacturing, and the higher-grade sugar copperas manufactured by a vacuum crystallizing process.

The use of copperas in water purification introduces more complicated features than alum compounds, chiefly for the reason that lime is required for the precipitation of the iron. When added to a natural water the copperas is decomposed somewhat like alum except that the formation of the hydrate of iron takes place very slowly. By adding lime in the form of limewater or milk of lime rapid formation of insoluble iron hydrates is induced. In general terms it may be stated that to obtain satisfactory results from the use of lime and iron as coagulants it is necessary to make use of sufficient lime to neutralize and precipitate the iron. The use of too little lime results in poor coagulation, caused by the incomplete precipitation of the iron, some of which is usually left in solution and appears in the effluent of the filters. The use of too much lime results in the formation of lime incrustants, which deposit in the air and strainer systems and cause much trouble through clogging.

Water treated with lime and iron will show an increase in permanent hardness, as compared with the effect of the use of compounds of aluminum. In general the aluminum salts are considered more satisfactory as coagulants; they remove color from water more rapidly and completely and make it possible to obtain by filtration a more brilliant water than do iron rails.

Devices for Application of Coagulants.—No department in a filtration plant is more important than that wherein the coagulating chemicals are applied to the water. To obtain satisfactory results from the plant as a whole and the filters in particular, it is necessary that the application of the coagulating chemicals be at all times under strict and accurate control and be adapted to the quality of the water to be filtered. Material variation in the dose of the chemical applied to the water or in the quality of the water means overdosing or underdosing. The former results in a waste of the chemical and sometimes in undecomposed coagulant in the filtered water, and the latter results in incomplete coagulation and impaired efficiency. Owing to the high rates of filtration used in rapid filters undercoagulated water will