CHAPTER VII

Inception and Widespread Adoption of Rapid Filtration in America

While slow sand filtration was gaining a foothold here and abroad, in America rapid filtration appeared as a rival. The new process was soon well in the lead, then forged ahead until adoptions of the older process virtually ceased. Meanwhile old plants of the slow sand type either had their burdens lessened by the addition of rapid or other types of filters or else were abandoned.

The rapid filter was an American product, although its basic principles and the elements of the apparatus used were anticipated abroad both in patents and practice. In America, too, patents anticipating some elements of the rapid filter were granted and in one or two instances put in use in a small way before the American rapid filter began its remarkable career.

For many years the American rapid filter was called "mechanical" because it was cleaned by mechanical means in contrast to manual labor used in cleaning slow sand filters. Then came the contrasting terms, "American" *vs.* "English," then "rapid" *vs.* "slow," with or without the adjectives "American" and "English." The chief mechanical devices employed were jets of water applied on or just below the surface; reverse-flow wash, which operated through the whole depth of the filter; and revolving sand agitators or stirrers, which loosened the media from top to bottom.

Most of the early American rapid filters operated under considerable pressure. Often this was provided by pumping from the source of supply through a closed filter tank into the distributing mains of the water works system.

Direct pumping and negative head were covered in many British and a few French patents long before the advent of the American rapid filter. An English patent issued in 1819 to Henry Tritton claimed "rarefaction or exhaustion of air" by an air pump applied to a chamber receiving filtrate from an open gravity filter. Darcy's French and English patents of 1856 included a negative head of 5 m.

FIG. 35. BIRDSILL HOLLY (1820–1894)
Patented direct pumping system, 1869, and reverse-flow wash filter, 1871. Although no filter of his design is known, in the 1880's and later, the principle of pumping water through rapid filters direct to consumers was applied in many instances
(From portrait in *District Heating*, New York, 1915)

or 16 ft., provided by carrying the filter outlet pipe to the bottom of the clear-water well.

In England, in 1791, James Peacock patented a filter with a false perforated bottom and reverse-flow wash. Robert Thom completed a filter with these elements at Greenock, Scotland, in 1827. In France, in 1835–38, Henry de Fonvielle patented a closed filter which was cleaned by opposing countercurrents of water under pressure. One was installed at a Paris hospital in 1836. Henry Darcy obtained French and English patents in 1856 on a filter similar to those of Peacock and Thom, plus horizontally directed jets of water just above the surface of the filter to prevent or lessen mud deposits and also a revolving broom to help clean the top of the filter.

Three engineers were granted noteworthy American patents in this field before 1880: Henry Flad of St. Louis, in 1867, patented a filter closely resembling Peacock's design of 1791. Several small Flad filters were installed in St. Louis, including one for a hotel. Birdsill Holly, of Lockport, N.Y., well known for his direct pumping engines, was granted a patent in 1871 for a filter provided with perforated underdrains which served also to distribute water for reverse-flow wash. J. D. Cook, of Toledo, Ohio, in 1877 patented a series of filters washed by reverse flow, with pipe connections permitting any filter to be cut out for washing while the others remained in service. This was a modification of a plant he had designed for Toledo but which was not constructed.

Mechanical sand agitators to aid in filter cleaning seem to have made their first appearance in patent claims in 1858, in a communication to the British patent office from William Clark describing a filter working under pump pressure, the filter having within it a vertical revolving shaft with prongs which "operate on the layers of sand." An American patent was granted in 1872 to Andrew J. Robinson, of Troy, N.Y., the single claim of which was for "an agitator arranged within an air-tight water filter to remove the accumulated dirt from the same by agitating the filtering material while the pressure is on." Eight years later, Daniel C. Otis, of New York City, obtained a patent on an apparatus for an upward-flow filter with reverse-flow wash aided by a sand agitator. He did not limit himself to a specific type of agitator, but showed a drawing of one composed of a series of horizontal blades attached to a rotatable central vertical shaft. The Otis patent

FIG. 36. JOHN WESLEY HYATT (1837–1920)
President, Newark Filtering Co. and Hyatt Pure Water Co., 1880–1892; took out scores of patents on filtration procedure and apparatus
(From portrait in *Cyclopedia of National Biography*)

was granted July 6, 1880, just before the advent of mechanical or rapid filtration.

The Hyatt Mechanical Filter

Four men whose names deserve to be linked at this point are Patrick Clark, John Wesley Hyatt, Col. L. H. Gardner and Isaiah Smith Hyatt.

Clark's contribution to the art of mechanical filtration was the application of vertical jets of water to aid in cleaning filter media supported on a false bottom. He built a filter at Rahway, N.J., in or just before 1880. In October 1880, he applied for a patent. In December, he, John W. Hyatt and Albert C. Westervelt incorporated the Newark Filtering Co.

John Hyatt, an inventor and manufacturer of Newark, N.J., applied for a patent February 11, 1881, on what was virtually a stack of Clark's filters, placed in a closed tank and operated each independently of the others by means of common supply, delivery and wash pipes. His application, like Clark's, was granted on June 21, 1881, and assigned to the Newark Filtering Co. On the same day, Hyatt obtained a patent in England.

Col. L. H. Gardner, Superintendent of the New Orleans Water Co., after making small-scale experiments on coagulation at New Orleans, was convinced that it was more efficacious than filtration for the clarification of muddy water (1).

Isaiah Smith Hyatt, older brother of John, while acting as sales agent for the Newark Filtering Co., was baffled in attempts to clarify Mississippi River water for a New Orleans industrial plant. Colonel Gardner suggested using a coagulant. This was a success (1). Isaiah Hyatt obtained on February 19, 1884, a patent on simultaneous coagulation-filtration. Although unsound in principle, it largely dominated mechanical filtration for many years.

The first Clark-Hyatt filters are reported as having been "introduced" to municipal supplies in the latter part of 1881 on a new water supply for Frankfurt am Main, Germany, but they may have been temporary (2). The two earliest, and for about three years the only, Hyatt plants in the United States were installed in 1882 at Somerville, N.J., and Newport, R.I. Priority is given to Somerville because the plant there is the better authenticated of the two and because the Clark-Hyatt filters of 1882 were displaced in 1885 by John Hyatt's

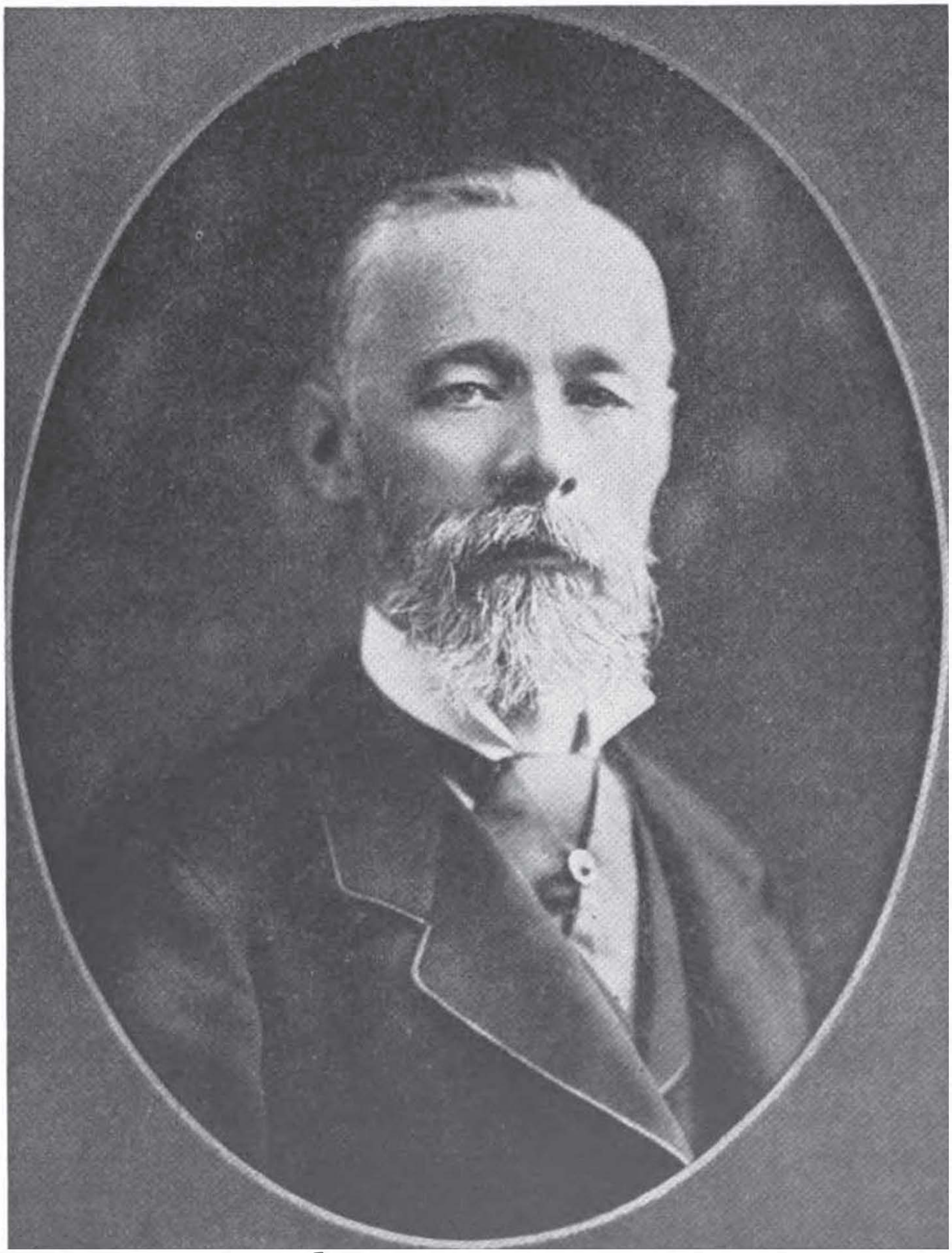

FIG. 37. ISAIAH SMITH HYATT (1835–1885)
Patented simultaneous coagulation and filtration in 1884; method first applied to municipal water supply in 1885 by Somerville & Raritan Water Co., New Jersey
(From photograph supplied by Ralph W. Hyatt, son of John W. Hyatt)

sand-transfer wash filters combined with Isaiah Hyatt's coagulation-filtration system. Before the close of 1882 a Hyatt filter had been installed for an urban water works in France (3).

Thus in 1880–85 did four men join in the evolution of mechanical or rapid filtration. Clark soon faded out of the picture. Gardner entered it only by suggesting to Isaiah Hyatt the use of a coagulant, and Isaiah Hyatt, still a young man, died in March 1885. John Hyatt was then alone. Already he had taken out 20 filter patents while only two were granted to his older brother. By the close of 1889, John had obtained about 50 patents. Scattered grants in the 1890's brought his record above 60. Most notable of all these were three on washing systems, including sectional wash; several on strainers for underdrain systems; and two on aeration, primarily in connection with filtration. The Hyatt aeration patents, like those granted to Professor Albert R. Leeds a little earlier, were of little practical importance, but they marked an era in water purification during which stress was laid on the removal of organic matter.

The advent of the mechanical filter in the field of municipal water supply has long been dated 1885 and placed at Somerville, N.J., both the earliest filters at Somerville and their forerunner at Rahway being ignored. This has been partly due * to regarding coagulation as an element rather than an adjunct of mechanical filtration.

Coagulation and Mechanical Filtration.—No coagulant was used in the various antecedents of the American rapid filter; nor by the Hyatts in their first years; nor at the start by Warren, one of the most important early rivals of the Hyatts; nor in England with many if not most of the early mechanical filters; nor with many of the later ones up to the present day. Here in America, Montreal affords a notable instance of mechanical filtration without coagulation.

Alum was not even named by Isaiah Hyatt in his coagulation-filtration patent. He had "successfully purified the water of the Mississippi River at New Orleans," he said, by using "perchloride of iron," but claimed use of "any other suitable agent which is capable of coagulating the impurities of the liquid and preventing their passage through

* A considerable degree of responsibility for this rests on me. In compiling the various editions of *The Manual of American Water Works* (1888–1897), on which various writers have drawn, I overlooked a brief description of Clark's Rahway filter in a United States Census report (4). I also overlooked a brief contemporary mention of the Somerville filter of 1882 (5).—*M. N. B.*

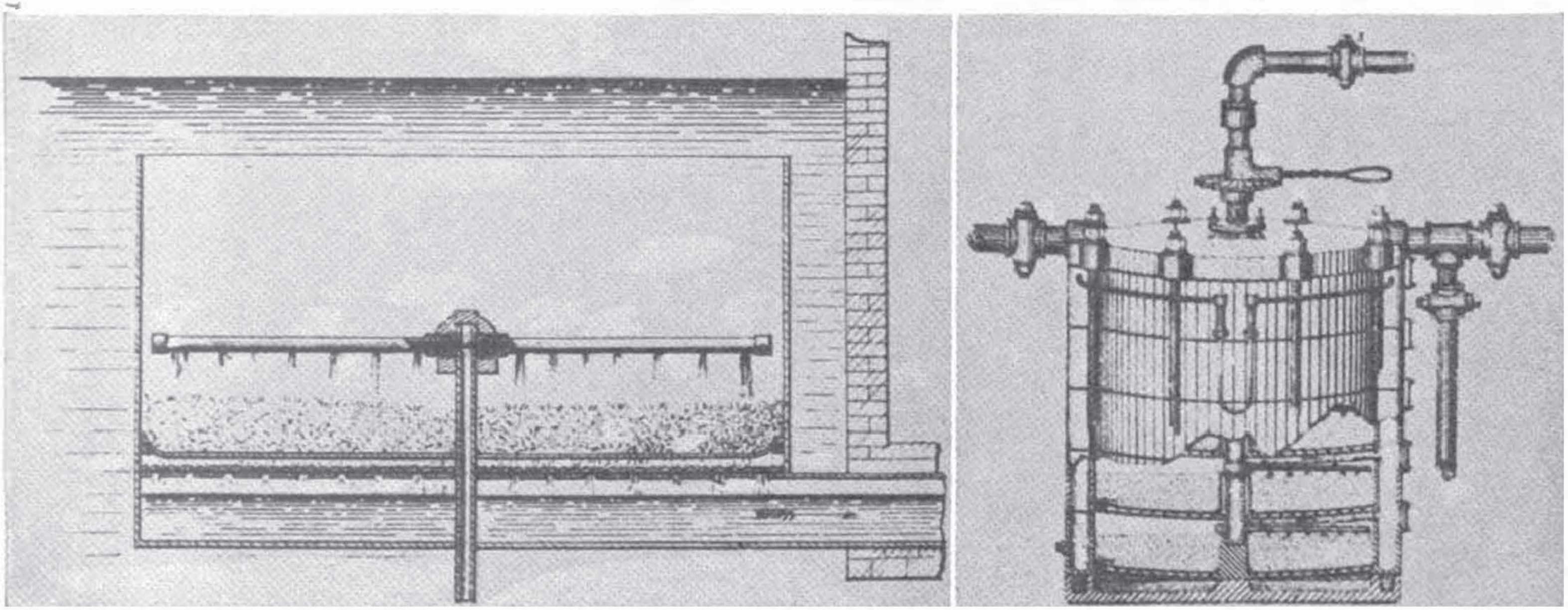

FIG. 38. EVOLUTION OF RAPID FILTER BY CLARK AND HYATT

Patrick Clark suspended shallow filter in river and provided surface-jet wash from perforated revolving arm: loosened dirt was swept downstream; filter installed about 1880 at Rahway, N.J., Water Works
(From U.S. patent drawing, June 21, 1881)

John W. Hyatt superimposed several Clark filters in closed tank and serviced them with common pipe system; method first applied in 1882 by Somerville & Raritan Water Co., New Jersey
(From "The Multifold Water Filter," *Eng. News*, January 1, 1882)

the filter bed." A patent granted to Isaiah Hyatt on the same day as the one under consideration claimed a filter composed of some "inert material and metallic iron in comminuted form thoroughly commingled" and stated that he had "used with good results 1 part to from 15 to 20 parts sand or analogous material." In place of sand either quartz or sulfate of baryta might be used. For liquids con-

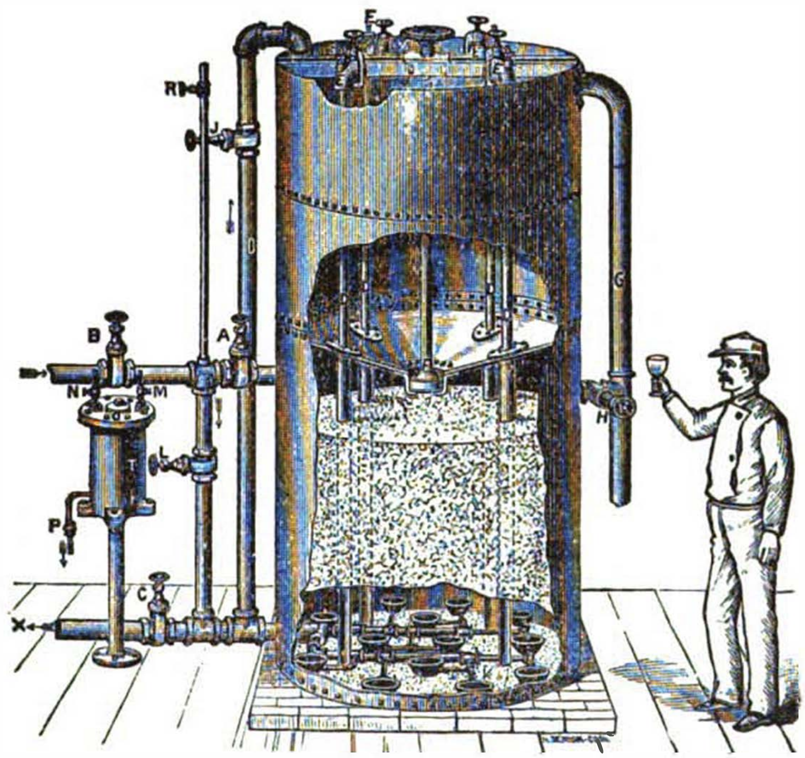

Fig. 39. Hyatt Sand-Transfer Wash Filter

One or more pipes led from near bottom of filter to top of closed upper chamber; by opening valves at upper end of pipes and introducing water under pressure through the underdrains, the sand and its load of dirt were transferred to the top of the upper chamber, from which dirty water was wasted and clean sand returned to the lower chamber

(From Geyelin's "Analysis of Mechanical Filter Actions," *Proc. A.W.W.A.*, 1889)

taining a high percentage of impurities an increased ratio of iron would be necessary. So far as is known, this combination of filtering material was never employed.

Evidence that John Hyatt was not committed to alum in the latter part of 1885 is afforded by his promotion efforts at Albany, N.Y. In an informal proposal August 26, 1885, for installing a 20-mgd. filter plant, the Newark Filtering Co. said its intention was to use "our new method of purification by the use of metallic iron, which method has just been perfected by our Mr. Hyatt, and obviates the necessity of using alum." A demonstration plant at the company's factory in Newark would be ready for inspection "next week." The filters would be 30 ft. in diameter and work under pressure. How the comminuted iron was to be used was not stated (7). Commingling it with filter sand may or may not have been proposed, as it was in a second Isaiah Hyatt patent of February 19, 1884. A little later in the same year, John Hyatt exhibited to the Albany special water commission a system of filtration in which iron and lime were substituted for alum and the water was to be aerated by forced air (8). This he was willing to install at Albany. As to bacteria, the commission had not found in practical operation any system which would "satisfactorily destroy such life in large quantities except at enormous expense." But Hyatt had "shown to the commission plans by which he claims such destruction may be effected at reasonable expense" (7).

Hyatt's European Campaign.—German and French sources afford information not found elsewhere regarding not only Hyatt's promotional campaign in Europe but also his earliest American installations, both industrial and municipal. Henry Gill, Director of the Berlin Water Works, published late in 1881 a German description of an American filter that appeared before the Clark-Hyatt filter had been described in any American journal (2).* His report mentioned a notice published November 24, 1881, to the effect that the mayor and council of Berlin had asked a commission charged with building a sand filter at the projected Lake Tegel works to consider whether it "could recommend that the new American filter could advantageously be substituted for the customary wall-inclosed sand filter which is being proposed." The American filter, he said, had been brought to Europe by Amassa Mason. After an unsuccessful attempt to introduce it in England it "was introduced . . . for the first time in Frankfurt am Main" to purify the water of the river when the spring water supply of the city became inadequate. The manufacture of the filter, after a German patent had been obtained, was given over to a

* Simultaneous articles appeared in *Engineering News* and in *The Scientific American* early in January 1882 (9, 10). Each contains little if anything not given in John Hyatt's patent of June 21, 1881, except that the *Scientific American* article credits Patrick Clark, of Rahway, N.J., with the invention of the filter in its "original form," adding that it "has been brought to its present state of perfection by Mr. John W. Hyatt, a prominent inventor of Newark, N.J."

Karlsrühe manufacturer, Herr Ruhl, who formerly lived in Berlin and had his apparatus on exhibit there. The article describes in detail the original Clark-Hyatt multifold filter with surface-jet wash. The Frankfurt am Main wash, however, was modified to force the revolving perforated arms down through the sand—a possibility suggested by Hyatt in one of his early patents.

Gill damns the filter with faint praise by saying that for factory use, where muddy river or sea water must be freed from gross impurities, the American filter had "a not too inconsiderable worth." The chief superiority claimed for the filter was speed. For "a city population," Gill declares, "water cannot be sufficiently freed of suspended particles when it is filtered quickly." He cites the typical English slow sand filter as the model to go by, including its slow rate of filtration, assumes that the American filter in question would have to be operated at the same rate, rules out stacking the filters because that would require extra pumping lift, and concludes that for the proposed capacity of 17.4 mgd. at the projected works, fourteen buildings, each 478 ft. square, all heated in winter, would be required. Because of their design and the necessity for heated housing Gill puts the life of the American filter at ten to fifteen years, against 100 years for "the common walled sand filter." To operate them, he says, 56 men would be required against ten for slow sand filters. The only data presented on actual operating experience tells that to wash the sand, in place, 20 per cent of filtered water was found necessary. Considering all the drawbacks, Gill concludes that the American filter had no advantage in either capital or operating cost. Therefore it was not recommended for the Berlin water works (2).

Professor William Ripley Nichols, in an abstract of a later German version of Gill's report, states his belief that the report was on a Hyatt filter (11). This was confirmed soon afterwards in a letter from the Newark Filtering Co. (12). The letter also states that 20 per cent of wash water was not required, American practice showing that 2 per cent or less was enough and that the depth of sand in the Berlin filter was 10 in. instead of 6 in., as stated by Gill. More significant was the company's statement that it was in receipt of an order for a filter with a capacity of 1.5 mgd. to be delivered at the Berlin water works. It may be added that in 1883 slow sand filters were built for the Lake Tegel supply of Berlin (13).

Early Hyatt Filters in Belgium and France.—An article published October 1, 1882, in *Le Génie Civil* (3) stated that Messrs. Hyatt and Rapp, "American engineers," had taken out a French patent on a filter and confided its construction to M. Rikkers of St. Denis. Clark-Hyatt filters had been established in a distillery at Antwerp, Belgium, and on an urban water works in France. Hyatt, instead of Clark, was credited for the filter placed in a stream for the water supply of Rahway, N.J. Hyatt filters, the article said, had been in use a year on the municipal water supplies of Newport, R.I., and Somerville, N.J., and on industrial supplies for a paper mill at Rochester, N.Y., aniline works at Albany, N.Y., and at the Warmouth Sugar Refinery in New Orleans. By lumping all these separate installations together, the time during which the Newport and Somerville plants had been in use was exaggerated.

Hyatt Filters at Newport, R.I.—Verification of the mention of Hyatt filters at Newport in *Le Génie Civil* of October 1, 1882, has been made through the recollections of Bradford Norman, son of George H. Norman, founder of the Newport water works (14). The younger Norman stated that in 1882 a filter was in use consisting of [rectangular] cast-iron sections bolted together and provided with sight ports. The filtering media were sand and mica. The underdrains were formed by winding wire around Maltese-cross-shaped iron castings. Reverse-flow wash was used, without separate sand agitators. After about six years the filter was abandoned because it was so corroded and clogged that it would not function.

Before the Hyatt filter of 1882 was installed, George H. Norman, then owner of the Newport water works, built in succession filters of his own design, consisting of one size of sand, confined in timber cribwork with brick coping, the latter extending slightly above the ground surface. Difficulty in cleaning led to their abandonment, Harold E. Watson, the present commissioner, believes.

Clark's Rahway Filter.—The only known description of Clark's filter at Rahway reads: "Clark filter, 16 ft. sq.; sand 6 in. deep, on fine wire cloth; cleaned once in 24 hours." The supply was the north branch of the Rahway River. The water was characterized as "generally good; in spring polluted by refuse of felt factory above, also dead vegetable matter" (4). The water works were built in 1871–72 with George H. Bailey of Newark as engineer.

In 1876, Patrick Clark, then city engineer of Rahway, reported to the water board that he visited the pumping station on March 27 under directions to "suggest some remedy for the almost constant turbid condition of the water delivered to the consumers." The original plan of the works, he stated, was unfortunate because "the filtering basin built along the river bank," on the assumption that it would yield spring water, actually supplied, in large part, water from the river, rendered turbid by every rain. He recommended construction of "a large settling basin and filtering apparatus." The following summer, Bailey, engineer for the original works, was about to make a report and estimates on filtration when the board decided to give up the project. On the succeeding May 7, the board ordered on file a communication from H. R. Worthington "relating to J. D. Cook's plan of filtration" (see below). On May 8, 1876, the board appointed Clark as its Chief Engineer. On October 21, the minutes of the board noted his resignation, with permission to let his filter remain at the works. C. W. Ludlow, superintendent in 1938 (15), could not learn when the filter was installed and abandoned but gave as the recollection of an assistant engineer, who was at the pumping station shortly after the filter was built, that "the filter was inadequate, did not serve its purpose and a short time after installation was discontinued."

From the scanty data available, it is assumed that the Clark filter was put in use early in 1880 or late in 1879 and used from 12 to 18 months. As its area was 256 sq.ft. and the water consumption in 1880 was 0.394 mgd. (16), it worked at the rate of about 64 mgd. an acre. Its importance lies in the fact that the Clark and Hyatt patents of June 21, 1881, were the basis of the American mechanical filter.

Hyatt Filters With Coagulating Apparatus for Somerville and Raritan, N.J.—The Somerville Water Co., with George H. Pierson as engineer, built water works in 1881–82 to supply Raritan and Somerville, N.J. The supply was taken from the Rahway River, a stream carrying suspended matter from a red-shale drainage area (5, 6).

Company minutes show tentative acceptance, in August 1881, of an offer from the Newark Filtering Co. to furnish four pressure filters (19). Although the water company began to supply consumers by May 1, it was not until May 8 that it contracted for filter connections. A description of the filters published in August 1882, from data supplied by the designing engineer, stated that there were four filters of

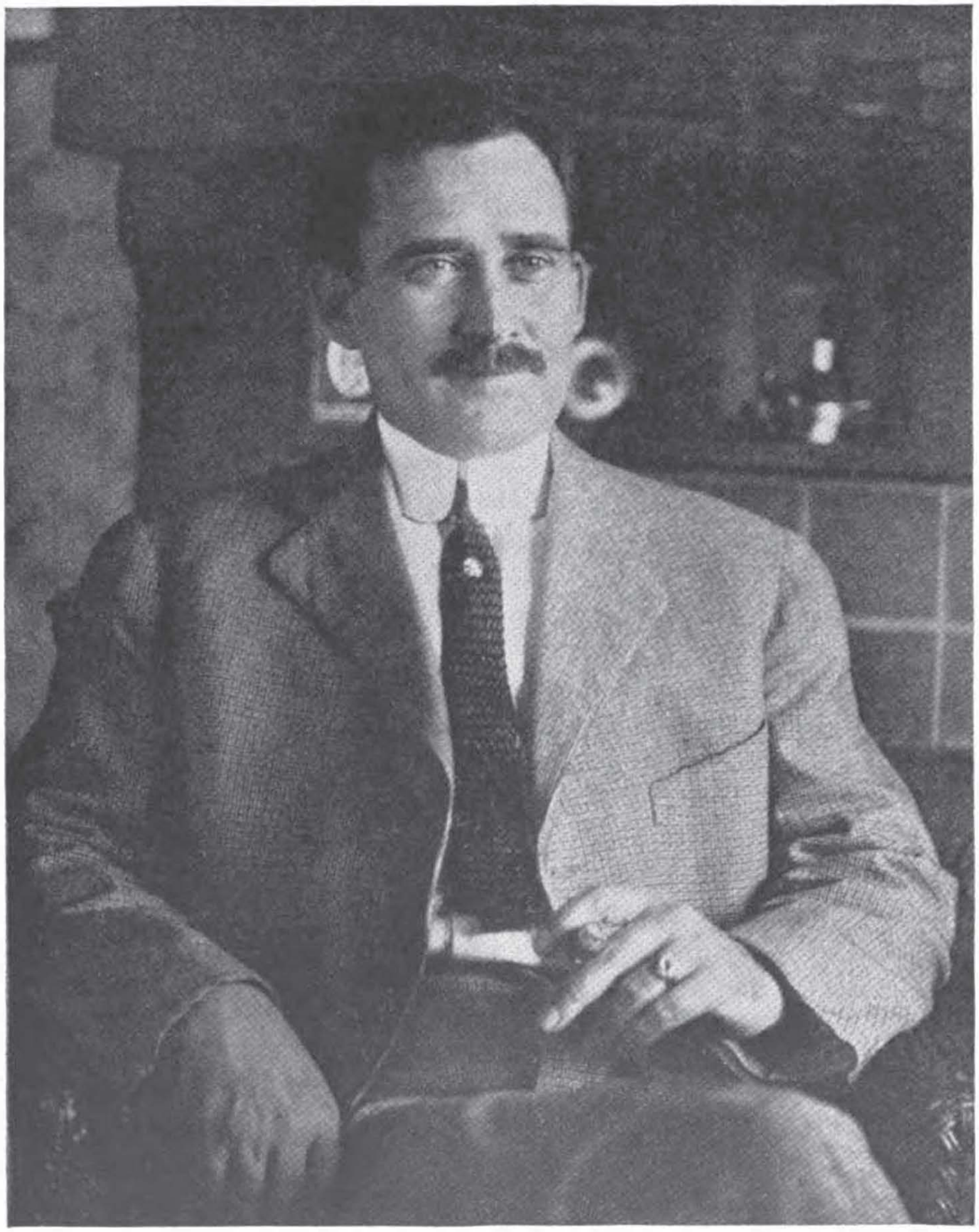

FIG. 40. GEORGE F. HODKINSON (1868–)
With Newark Filtering Co., 1886–88; Secy., Hyatt Pure Water Co., 1888–92; in charge of Chicago office of New York Filter Co., 1892–93; with Western Filter Co., St. Louis, 1893–95; with O. H. Jewell Filter Co., Chicago, 1896–1900; Engr. & Mgr., Roberts Filter Mfg. Co., Philadelphia, 1904–08; Mgr., Filtration Dept., American Water Co., Philadelphia, 1908–34; head of G. F. Hodkinson Co., Philadelphia, 1934–
(From photograph supplied by Hodkinson)

the Hyatt multifold type, each 5 ft. in diameter and 8 ft. high, and that the water consumption was 0.2 mgd. (6). From this and other data it is inferred that each filter tank contained a stack of Clark-Hyatt rectangular filters, washed by surface jets and reverse flow, combined.

On April 7, 1885, the water company minutes state, a communication was received from the Newark Filtering Co., proposing to furnish new filters for $7,000. The executive committee was directed to obtain other proposals. The only one received was from the Crocker Filtering Co., of New York, dated April 29. It offered to put in two of its largest "filtering machines for $5,000." On May 23, 1885, the water company ordered "four Hyatt filters, 6½ ft. in diameter by 15 ft. high, capable of withstanding a pressure of 150 psi. and *accompanied by suitable coagulating apparatus.* [Author's italics.] They must be guaranteed to deliver 0.5 mgd. of bright, clear and wholesome water, if washed once a day." The filters were to be set up by the filter company on foundations provided by the water company. If the filters were satisfactory to the water company on a test made "after the river had been muddy ten days" the water company would pay $6,500 for them, less $2,500 for the old filters, which were to be removed at the expense of the filtering company. The new filters appear to have been put in use in July 1885. The net result of later negotiations was that the water company paid $3,950 for the new filters and retained the old ones (19).

A report made by a representative of the New Jersey State Board of Health after a visit of inspection in 1911 states that there were then in use four Hyatt filters of "a very old type," washed by ejecting the sand by means of a water jet. The process took a half hour per filter. The Hyatt filters were replaced in 1913 by two Jewell filters. Since then three additional Jewell filters have been installed and also one filter has been provided by the American Water Softener Co. of Philadelphia (19).

Subsequent Hyatt Installations.—As far as can be determined over a half century later, the only Hyatt filters put into permanent use on municipal supplies in 1885 were at Somerville, N.J., in May, and a very small one at Tunkhannock, Pa., in August.

An advertisement, dated November 1886, listed five municipal plants as "in operation." Besides the two plants completed in 1885 these were located at Charleston, W.Va., Belleville, Ill., and Rich Hill, Mo.

All have been authenticated. An advertisement probably referring to the close of 1888 stated that Hyatt filters had been "adopted" by 30 cities and towns and thousands of manufacturers and private consumers. This seems to have been the peak year for the Hyatt filters. A compilation from all available sources shows a few plants put in use in 1889–91 and only one in January 1892. The decline after 1888 was apparently due to competition and protracted infringement litigation.

Pre-aeration was used at three of the Hyatt plants: Belleville, Ill., and Greenwich, Conn., put in use in 1887, and Long Branch, N.J., completed in 1888. Scanty data in local newspapers establish this fact for the first two places, indicating that air was sucked into the water flowing through a vertical tube placed above ground. At Long Branch a similar device was sunk deep into the earth. These aerators were in line with patents granted to John Hyatt in 1885 and 1887 (see Chap. XVI).

At Long Branch the filtering media were sand and prepared coke, 3 to 1. Wash water, admitted to the bottom of the filter through a perforated pipe, found its way to the top, from which it ran to waste (20).*

The Atlanta filters had the next to the largest capacity (3 mgd.) of any Hyatt filters installed before consolidation with the New York Filter Co. There were 12 units, 8 ft. in diameter by 13½ ft. high, in two compartments arranged for washing by the sand-transfer system. They were completed in 1887. Originally the filters were 60 in. deep, composed of 3 parts of sharp screened sand and 1 part of ¼-in. screened "coke" from locomotive boxes. In 1893, 30 in. of uniform-sized sand was substituted (when the filters were moved). "Crystal alum," applied in the influent pipes about 30 ft. ahead of the filters, was used until 1903, when a coagulating basin was completed at the new site. The strainers were copper saucers or cones, filled with 0.1-in. copper "shot" and covered with perforated plates. These filters originally treated water from a 52-acre impounding reservoir on South River, a stream draining red clay land. In 1893 they were moved to the Hemphill station on the Chattahoochee River and put alongside a battery

* The Long Branch filters were still in use (summers only) a half century later at the West End Station of the Consolidated Water Co., Long Branch, but they had been changed from pressure to gravity type and new underdrains installed, probably in 1897 when clear-water basins were added (21).

of eight horizontal filters, 8 ft. in diameter and 20 ft. long, just completed. The latter were of the Hyatt "sectional wash type," patented by John Hyatt, August 27, 1889. All these filters worked under a 17-psi. head, given by settling basins.

The first, or sand-transfer wash, filters were put into use about the middle of November 1887. They were shut down in or about 1912 but were not removed until 1933.

The horizontal sectional wash filters of 1893 were added to at intervals until the number reached 36 in 1910 and their combined capacity 18 mgd. These filters were washed by passing water at high velocity up through the filter. Three inlet valves, separately operated, theoretically divided the filter into as many sections (22). About 1935, the practice of opening all the valves at once was adopted. Renovation of this battery of 36 filters was scheduled in 1942, but only to the extent of repairing valves, rustproofing all metal surfaces and cleaning and reclassifying the 28-in. sand and 19-in. gravel strata. The filters were still turning out water of an excellent quality, bacterially and chemically. "Modern" rectangular filters of 36-mgd. capacity were put into use in 1932, giving a total capacity of 54 mgd.

The flow diagram in 1942 showed: storage reservoir giving three days' detention; dosing with sulfate of alumina; around-the-end baffled mixing chamber, 1,800-ft. travel in 45 min.; addition of ammonia and chlorine for disinfection; ten hours' sedimentation; addition of activated carbon for taste-and-odor control; filtration; lime applied to filtrate to control corrosion and red water; clear-water reservoir.

A 6-mgd. plant at Oakland, Calif., was the largest and latest known Hyatt installation before the consolidation. Twelve 0.5-mgd. units went into service in May 1891. They were still used occasionally up to July 29, 1942, wrote J. D. DeCosta, Engineer of Distribution of the Bay Cities Utilities District, but "many years ago new underdrains and egg crates * were installed. The tank shells had been in use about 50 years.

The Warren Filter

John E. Warren, agent of the paper mills of S. D. Warren & Co., Cumberland Mills, Me., planned and constructed a filter plant for the

* Egg crates is the name given to compartments in the gravel layer of the filter, formed by vertical partitions extending from the filter floor to the base of the sand. Their object is to prevent the wash water from taking lateral paths through the gravel, disrupting it and turning it over (26).

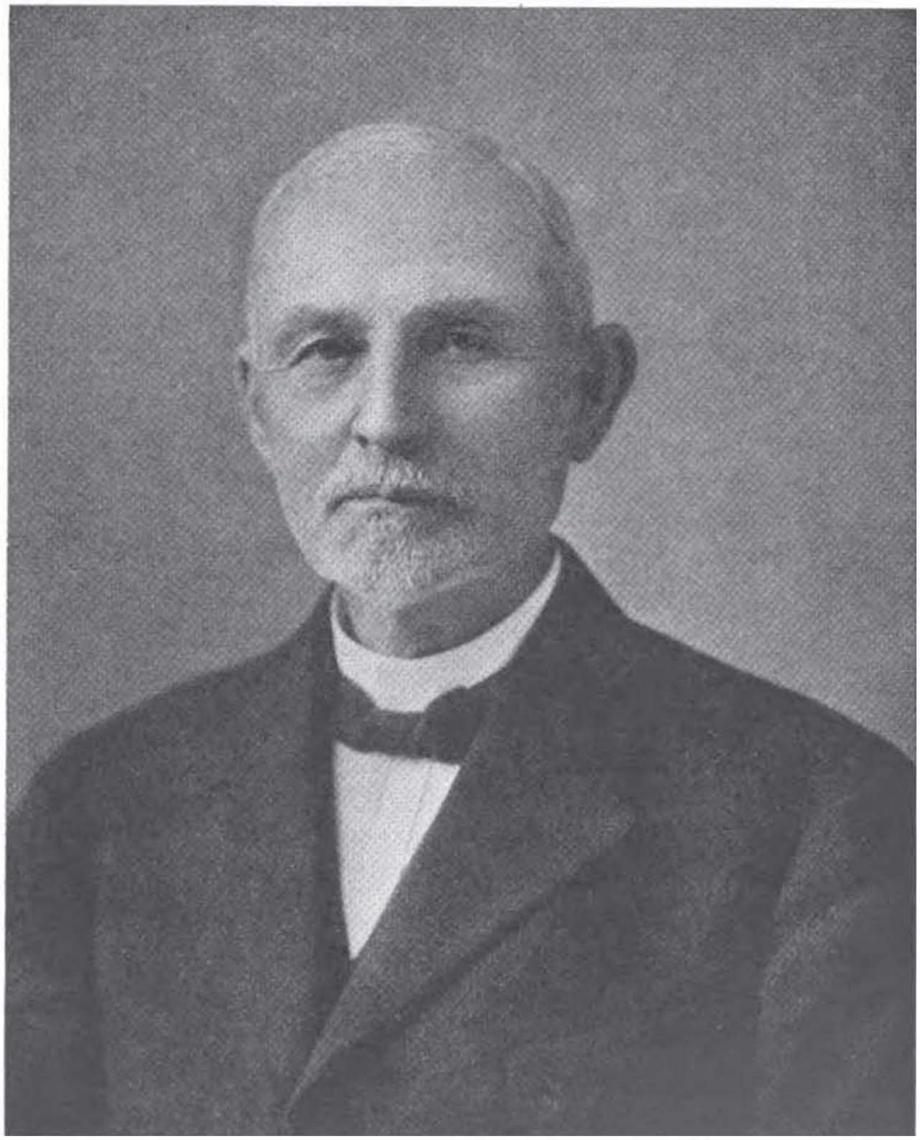

FIG. 41. JOHN E. WARREN (1840–1915)
Designed and installed twelve large rapid filters for paper mill of Cumberland Manufacturing Co. in Maine
(From portrait supplied by Joseph A. Warren, son of the inventor)

mills in 1884. It was for some years the largest mechanical filter plant in existence, with a rated capacity of 12 mgd. It was put in use after the Clark filter at Rahway and the first Hyatt filter for the Somerville Water Co., but before the second Hyatt plant for that company. A diary (27) kept by Warren notes the inception and completion of the filters in 1884 but no other mention of them appears until 1889:

May 12, 1884: We are making no additions to the mills this summer except to provide a general water supply and filtering arrangement which the fouling of the water by the Saccarappa manufacturers renders necessary. This will be accomplished by a device of my own which I am confident will be most effective.

Sept. 9, 1884: My scheme for filtering which has been the principal job of outside work is complete and bids fair to be a complete success although we have hardly given it a fair test as yet.

Jan. 2, 1889: In my record of 1884 I mentioned a system of filters which I had then constructed here and which proved an eminent success, so much so that patents were secured and plants have been constructed by us elsewhere. . . . the Cumberland Manufacturing Co. has been organized. . . . , a Mr. Nye as general manager (27).*

The filters of 1884 at the Cumberland paper mills were of the gravity open wooden tank type, in contrast with the more commonly used closed metal tanks. They were 20 in number, each 8 ft. in diameter. In a description published in 1887 (29) their capacity was given as 12 mgd., but some years later measurements showed 7 to 8 mgd. was being treated. These filters, wrote Joseph A. Warren in 1942, were used until about 1896 when enlargements of the mill required their removal. They were succeeded by 30 filters, 10½ ft. in diameter, which were still being used in July 1942. They are of the early type, with revolving rakes driven by a shaft and raised and lowered by a vertical shaft having a screw cut on an extension, with a nut that can be run

* Joseph A. Warren (28), of the Research Laboratory, S. D. Warren & Co., and son of John E., states that his father was connected with the paper mill from 1868 to his death in 1915. John Warren was the nephew of S. D. Warren, who began manufacturing paper in 1854 at Cumberland Mills, Me. The "Saccarappa manufacturers," mentioned in the diary, owned a cotton mill located on the Presumpscot River, about a mile above the paper mill. The fouling of the water was partly caused by fiber waste from the cotton mill. Joseph A. Warren was 14 years old when his father built the filters. He recalls seeing a pressure sand filter, probably supplied by Hyatt, at the paper mill, and thinks that Hyatt filters were tried on special water services in the mill and may have suggested to his father the building of gravity filters. Walter B. Nye was manager of the Cumberland Manufacturing Co., builder of Warren filters, until the company sold out to the New York Filter Manufacturing Co. in 1898.

in either direction. A 0.35-mil.gal. precoagulation tank with Carmichael dosing apparatus was provided for these filters. "Alum" was used for only a short time as the improvement it effected in the filter effluent was not sufficient to warrant its cost. The Warren filters have been supplemented by rectangular Norwood filters (28).

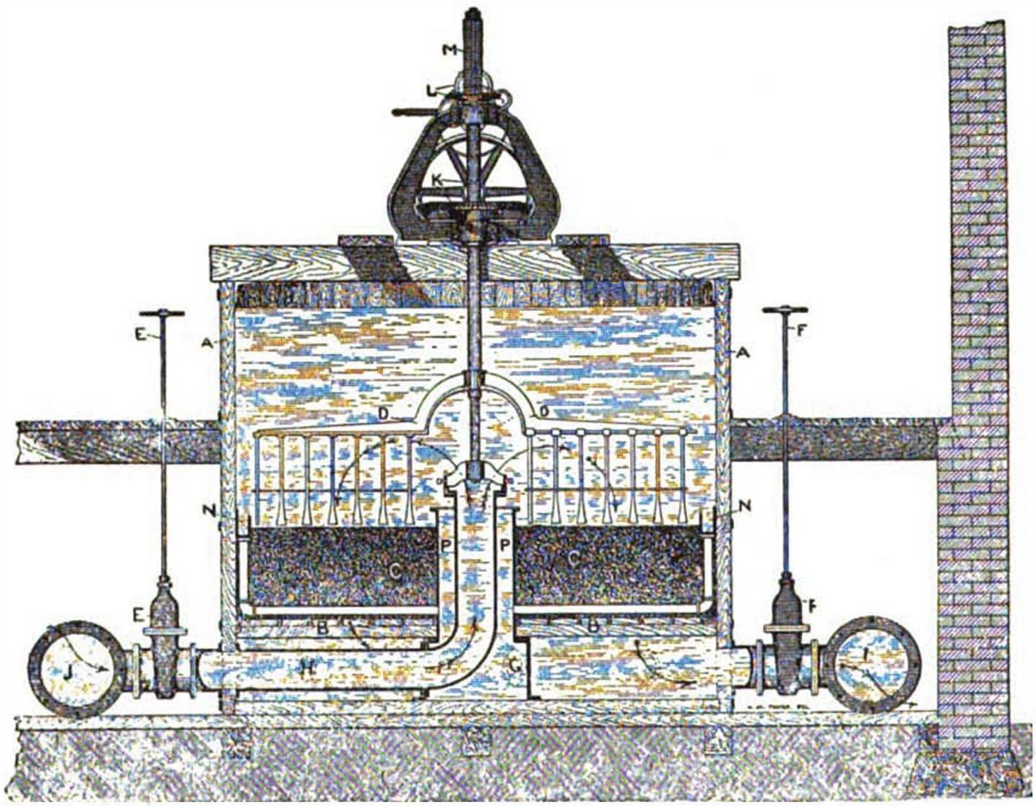

FIG. 42. SECTION OF WARREN GRAVITY FILTER
Revolving rakes forced down into filter media to aid reverse-flow wash
(From Geyelin's "Analysis of Mechanical Filter Actions," *Proc. A.W.W.A.*, 1889)

John E. Warren's first filter patent, dated December 22, 1885, was for the combination of a filter with a false bottom, a toothed sand agitator, vertically adjustable, and a plunger for rotating and lowering the agitator. A second patent was granted on March 12, 1888, and a third on May 28, 1889, both covering details of the typical Warren filter. The third patent claimed the combination of a filter, a central well extending up through and also below the filter, the filter being closed at the bottom to receive sediment and provided with a discharge outlet and an inlet extending into the well. There were a peripheral gutter connected with the well and a revolving rake agitator. A later adjunct to the Warren filter was an alum dosing apparatus, patented in July 1890, by the inventor Professor Henry Carmichael, of Malden, Mass., who assigned it to the company. It consisted of a six-arm pump made up of curved tubes attached to a hollow hub, driven by a propeller located in the raw-water supply main. The speed of the pump varied with the velocity and therefore the volume of the raw water. The dosing could be further regulated by varying the level of the alum solution in the dosing tank, so that the pump would pick up more or less alum as desired.

Little publicity was given to the Warren filter until 1887 (29). Early in 1894, descriptions of nine Warren plants built for municipal service were published (30). The first two of these were put into use at Augusta and Brunswick, Me., in 1887, the third in 1890, at Oshkosh, Wis. Not until the fourth plant was installed in December 1892, at Macon, Ga., was a coagulant used. It was employed on the four latest plants described in the article. Four of the five plants using a coagulant, and possibly the fifth, included small precoagulation tanks. A 12-mgd. settling reservoir was placed ahead of the coagulation tank at Athens, Ga. The rights in the Warren filter were acquired by the New York Filter Manufacturing Co. on or about April 1, 1898.

The National Filter

The National Water Purifying Co. of New York City was incorporated August 20, 1886, to promote a filter patented by William M. Deutsch, who had been a salesman for the Newark Filtering Co., builder of Hyatt filters. Albert R. Leeds, Professor of Chemistry, Stevens Institute of Technology, Hoboken, N.J., transferred rights in his water aeration patents to the company, became its professional adviser, and invested and lost more and more of his professional earnings in the stock of the company (31).

All told, Deutsch was granted ten American patents in 1886–90 and was assignee of two by Claude Deutsch. British patents of December 28, 1886, and October 25, 1892, were virtually duplicates of American patents of the same dates.

Deutsch obtained his first patent (No. 355,004, December 28, 1886) very soon after quitting as salesman of Hyatt filters. Its most significant claims were for horizontal perforated wash pipes at two levels, one just beneath the surface and another at the bottom of the filter.

the latter serving also as underdrains; and for sectional wash made possible by diametrical partitions carried from the bottom to the surface of the filter. The underdrains consisted of two eccentric perforated pipes, the space between which was filled by coarse granular material. As far as is known, such underdrains were never used.

A patent application on September 4, 1886, was held up nearly six years (granted June 7, 1892; No. 476,737). Its only claim was for a filter divided into a number of compartments, with a separate discharge pipe for each, to provide for separate or sectional washing.*

Deutsch's patent of March 29, 1892 (applied for October 8, 1887) was for "a method of and apparatus for cleaning and purifying filter

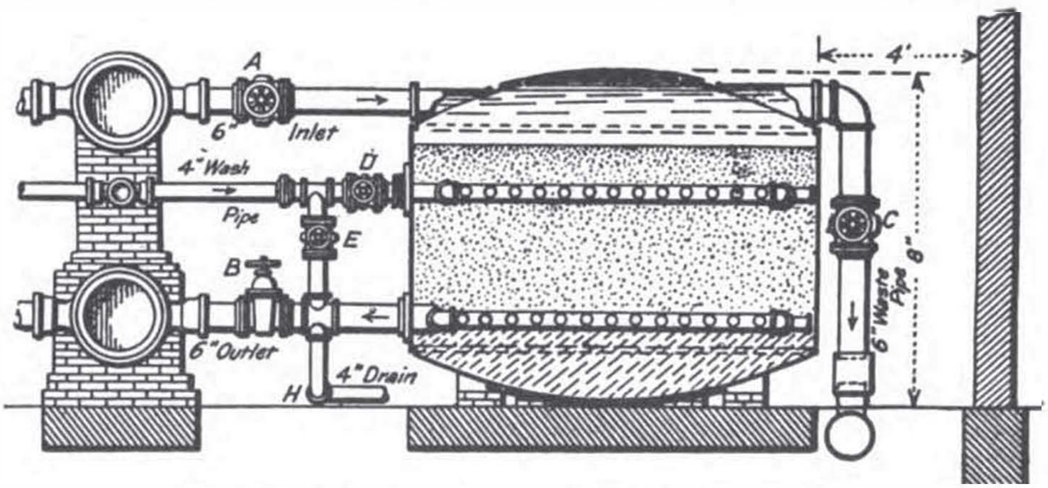

FIG. 43. NATIONAL FILTER AT TERRE HAUTE, IND.
Double reverse-flow wash: *A*, for top layer; *B*, for entire filter through underdrains
(From *Eng. News*, February 7, 1891)

beds" by aeration. The preferable method was to admit air to the underdrains from an air chamber placed above the filter tank, thus filling with air the space above the filter. Then, by turning on water above the filter the air would be compressed and forced down through the filter. A part of the air would "remain in the interstices, aerating

* On November 30, 1888, an examiner in the U.S. Patent Office reporting on the interference claim by Deutsch, ruled that John W. Hyatt was first in the field with sectional wash (32). The examiner stated that while Deutsch was a salesman for the Hyatt filter he had access to Hyatt's drawings for a sectional wash filter. Hyatt filed an application for a sectional wash filter patent September 7, 1885. His application was renewed May 15, 1886, but the patent was not granted until August 27, 1889 (No. 409,970).

and purifying the bed." As an alternative, air might be supplied from a "source independent of the bed, as from a compressor." No evidence that this scheme was ever used has been found.

Air-and-water wash for cleaning filters was the subject of an apparatus patent granted to Deutsch January 26, 1896 (No. 553,641; application October 21, 1891). The claims were for cleaning a filter by compressing air within the filter and strainer by the pressure of a body of water, then allowing the compressed air and water to escape suddenly. An apparatus patent dated May 29, 1900, covered the combination of a large number of water pipes, a superimposed filtering bed and a multiplicity of air-supply pipes having air-distributing nozzles.

Sedimentation, coagulation and filtration were the subject of three Deutsch patents, all dated June 19, 1900. Application for the third of these was filed by W. M. Deutsch on October 27, 1897, soon after Fuller completed his Louisville experiments, demonstrating, as experience had shown, the necessity of clarifying highly turbid water before filtration. The patent was for a combination of settling basins, filters, means for forcing a coagulant into settled water before its admission to the bottom of the filters, connections for washing the filters, in sections, by reverse flow. The other two patents were granted to Claude Deutsch. One was similar to the W. M. Deutsch patent; the other was on a process for passing water to be filtered and a coagulant into a settling tank, introducing carbonate of lime and allowing the water to settle.

The earliest publicity for the National filter that has been found is a small advertisement in Croes' *Statistical Tables of American Water Works* for 1887. It claimed surface washing as "a new principle in filtration." Its declaration, "No Infection From Cholera and Typhoid," seems to have been the first such claim for the American mechanical filter.

A short article published early in 1887 stated that both the National filter and Professor Albert R. Leeds' system of aeration were controlled by the National Water Purifying Co. (33). Charles B. Brush, of Hoboken, N.J., in a paper read before the New England Water Works Association on June 16, 1887, said: "Mr. Deutsch and Dr. Leeds are the inventors of the National System." Brush mentioned litigation between the Newark Filtering Co. (Hyatt) and the National Water Purifying Co. This and other infringement litigation, apparently on coagulation, was also noted in an advertisement of the Hyatt Pure Water Co. appearing in *The Manual of American Water Works* for 1888 thus:

> *A decree has been obtained against* John E. Johnson, representing the Continental Filter Co. manufacturing the Roeske filter. We are now in the United States Courts prosecuting 'The National Co.' of New York, Wm. M. Deutsch, Albert R. Leeds, the 'Jewell Pure Water Co.' of Chicago, Ill., and others.

More spicy was the following:

> We are the pioneers in rapid and perfect chemico-mechanical water purification and maintain supremacy in spite of illicit *imitators* who brazenly pirate our property, copying *our processes and mechanical devices,* attempting to evade our patents, adopting and advertising as advantageous, features which we have superseded by improvements—surface washing in particular.

Thus began the litigation between the early filter companies that contributed toward the various consolidations.

Four National filter plants were put in use in 1887: Chattanooga, Tenn., and Champaign, Ill., in June; Exeter, N. H., in August; and Winnipeg, Manitoba, in December.

Champaign, Ill.—At Champaign no record or tradition of a National filter plant could be found although inquiries were sent in 1940–41 to the water companies, University of Illinois professors and Champaign and Urbana libraries. Evidence that such a plant was in use is found though, in a trade catalog of the New York Filter Co., published in 1893. The catalog contains a testimonial from S. L. Nelson, Superintendent, Union Water Co., dated January 14, 1888. It states that a National filter was put in operation in June 1887, and had been working satisfactorily for six months. It combined aeration, lime precipitation and filtration. Besides rendering the water "clear and bright, free from odor and vegetable matter" it also "removes hardness." The source of supply was an abandoned coal prospecting shaft, but it was soon given up for deep wells.

Chattanooga, Tenn.—At Chattanooga, ten vertical pressure filters were completed in June 1887. Two smaller ones were added late in the year, presumably to meet the original contract guarantee of 3 mgd. Additions in 1887–91 brought the total to 20, with a nominal capacity of 5 mgd. Twenty-four Jewell pressure filters were added in 1892 and two in 1894, with a combined capacity of about 3 mgd. Water from the Tennessee River, highly turbid at times, was pumped through the filters into the distribution system. In 1897 a settling basin and a clear-water basin were constructed after which the National and Jewell filters, although still in closed tanks, were operated under gravity head. Twenty 1-mgd. open concrete gravity filters were built in 1914, 1917, 1925, and 1930. In 1911 a second and in 1925 a third settling basin were added. In 1940 the old National and Jewell filters were replaced, after a service of 50 years, by six open gravity filters with a capacity of 2 mgd. each, bringing to 32 mgd. the capacity of the existing filters. A steel mixing tank, supplying basins No. 1 and 2, was erected early in 1940.*

Terre Haute, Ind.—At Terre Haute, an early installation of National pressure filters is notable because of the high head under which it worked for 24 years and because the filter tanks were still in use after over 50 years of service. The Terre Haute Water Works Co. completed works in 1873 under a charter or franchise requiring "filtration." The supply was taken from the Wabash River. A filter crib was provided but was submerged a large part of the year, sometimes to a depth of 25 ft., and in general was unsatisfactory. In September 1889, after a change in ownership, a contract was let for 12 National high-pressure filters, 10 ft. in diameter and 7 ft. high, including the slightly dished heads. They were put into use in July 1890, but because they did not come up to the contract requirement of 3 mgd., a thirteenth filter was added in 1891. It was horizontal, 8 ft. in diameter and 20 ft. long.

Fortunately, a detailed description of the earliest filters, written just after they were put in use, is available (35). Some of the tanks, the superintendent, L. L. Williamson, wrote (36), had "withstood a test pressure as high as 208 psi., without leakage . . . borne entirely by the flange of the heads." The plates, wrote the manager, W. H. Durbin, in 1940 (37), were $\frac{11}{16}$ in. thick for the heads and $\frac{1}{2}$ in. for the sides, all of open-hearth steel. Because under fire pressure "several of the dished heads were ruptured at various times," the new settling basins were changed to a few feet of gravity head in 1924. W. E. Taylor, Chief Engineer of the works, 1908–40, states (38) that the working pressure ranged from 60 psi. domestic to 120 psi. fire. Major and minor ruptures combined probably numbered several a year. Bracings were added at unknown dates, but did not prevent ruptures,

* Chattanooga data are based on a contemporary description of the earliest filters (33) and on slightly later descriptions (34), supplemented and brought up to 1940 by A. F. Pozelius, Manager, City Water Co. of Chattanooga, and L. E. Wickersham, Sanitary Engineer, American Water Works & Electric Co., New York City.

which usually occurred under fire pressure. Deformation by "breathing" about $\frac{1}{4}$ in. at the center of the heads probably started incipient cracks at the inner part of the flanging radius. This also applied, Taylor adds, to the earlier of the horizontal 8 x 20-ft. Jewell filters installed in 1900. The same type and size of Jewell filters installed later in 1900, but having "a much easier and longer flanging radius," did not rupture. The thickness of the plates of the Jewell tanks, states Durbin, was $\frac{3}{4}$ in. for the heads and $\frac{5}{8}$ in. for the sides.

A double upward-flow washing system with water under pump pressure, wrote Williamson, was used for the National filters: (a) from perforated pipes located 6 in. below the surface of the filters, "thus breaking up the surface layer of the bed where most of the sediment accumulated"; (b) from the underdrains, "lifting the whole mass of sand and washing out the finer particles of sediment which have lodged in the lower part of the bed." The time required for washing was in the first case 3 to 5 min. and in the latter 5 to 7 min. Dirty wash water was discharged from above the filter through a single pipe. The amount of water filtered averaged 2.75 mgd., against a rated capacity of 4 mgd. Loss of head in the filters ranged from 10 to 30 psi. The filters were washed from one to six times a day using filtered water for the pressure filters and unfiltered water for the gravity filters, the total wash water required amounting to 3 to 30 per cent of the pumpage. The filtering material was sea sand and coke. "Alum" was used as a coagulant.

The underdrainage system of the National filters at Terre Haute consisted of semicircular pipe, embedded in the concrete bottom of the filters, with strainers tapped in the pipe. After six or seven years these were replaced by a center manifold and $1\frac{1}{2}$-in. laterals, with Jewell strainers tapped in every 6 in. In 1924, mushroom strainers were substituted. The wash-water outlet at the side of each tank, originally used, has been replaced by a central funnel. The filtering media of sand and coke, mixed, have been replaced by 30 in. of sand on 9 in. of gravel.

Two Jewell open gravity filters with a capacity of 0.5 mgd. each were installed in 1891, delivering their filtrate to a 0.775-mil.gal. clear-water basin for fire use. In 1900, nine high-pressure horizontal Jewell filters were added. Each was 8 x 20 ft. in plan. Until 1902, there was no presedimentation. Even then, only a 0.72-mil.gal. settling basin was provided.

The thirteen National and nine Jewell pressure filters and the small settling basin served until 1924, when they were supplemented by four concrete open gravity filters with a total rated capacity of 4 mgd. and a 2.5-mil.gal. settling reservoir. At that time all the old pressure filters were changed to operate under the low head of the new settling reservoir, thus becoming gravity filters, although the tanks remained closed. The rated capacity of the plant in 1942 was 12 mgd. The population of Terre Haute increased from 30,217 when the earliest filters were installed in 1890, to 62,693 in 1940.

Chlorination with hypochlorite of lime was introduced in 1911. In 1916 [should be 1913?], says Taylor (38), an "electrolytic chlorine double cell was installed by the Chloride Process Co., under the supervision of Omar H. Jewell of Chicago. Difficulty of control and dosage led to the abandonment of the apparatus after a few years." In 1916 liquid chlorine was introduced.

New Orleans.—New Orleans undertook, a half century ago, one of the boldest and most disastrous attempts ever made to filter the water supply of a city. Cocksure of the efficiency of its filters, disregarding a pending lawsuit for infringement of Isaiah Smith Hyatt's patent on simultaneous coagulation and filtration without presedimentation, and despite the advice of its noted chemist and heavy stockholder, Albert R. Leeds (31), the National Water Purifying Co. contracted to build a larger mechanical filtration plant than had yet been constructed. It went so far as to guarantee a constant supply of clear water at a stipulated cost for coagulant.*

The contract was signed in 1891. The plant was put in operation in March 1893. After tests the New Orleans Water Works Co. refused to accept the plant on the ground of non-fulfillment of guarantee. Its refusal was upheld by the state courts. This left the company with a 14-mgd. filter plant to dispose of piecemeal elsewhere if and when it could, together with a heavy loss of money and prestige.

Due very likely to their dismal failure, data on these filters are scanty. The plant was featured in the first trade catalog of the New York Filter Co., issued in 1893, a few months after the consolidation of the National, Hyatt and American filter companies. The cata-

* The officials of the water company, stated General Superintendent George G. Earl, in a report to the New Orleans Sewerage and Water Board, dated July 6, 1900, "advised the filter people to put up one filter instead of thirty and find out first what could be accomplished" (39).

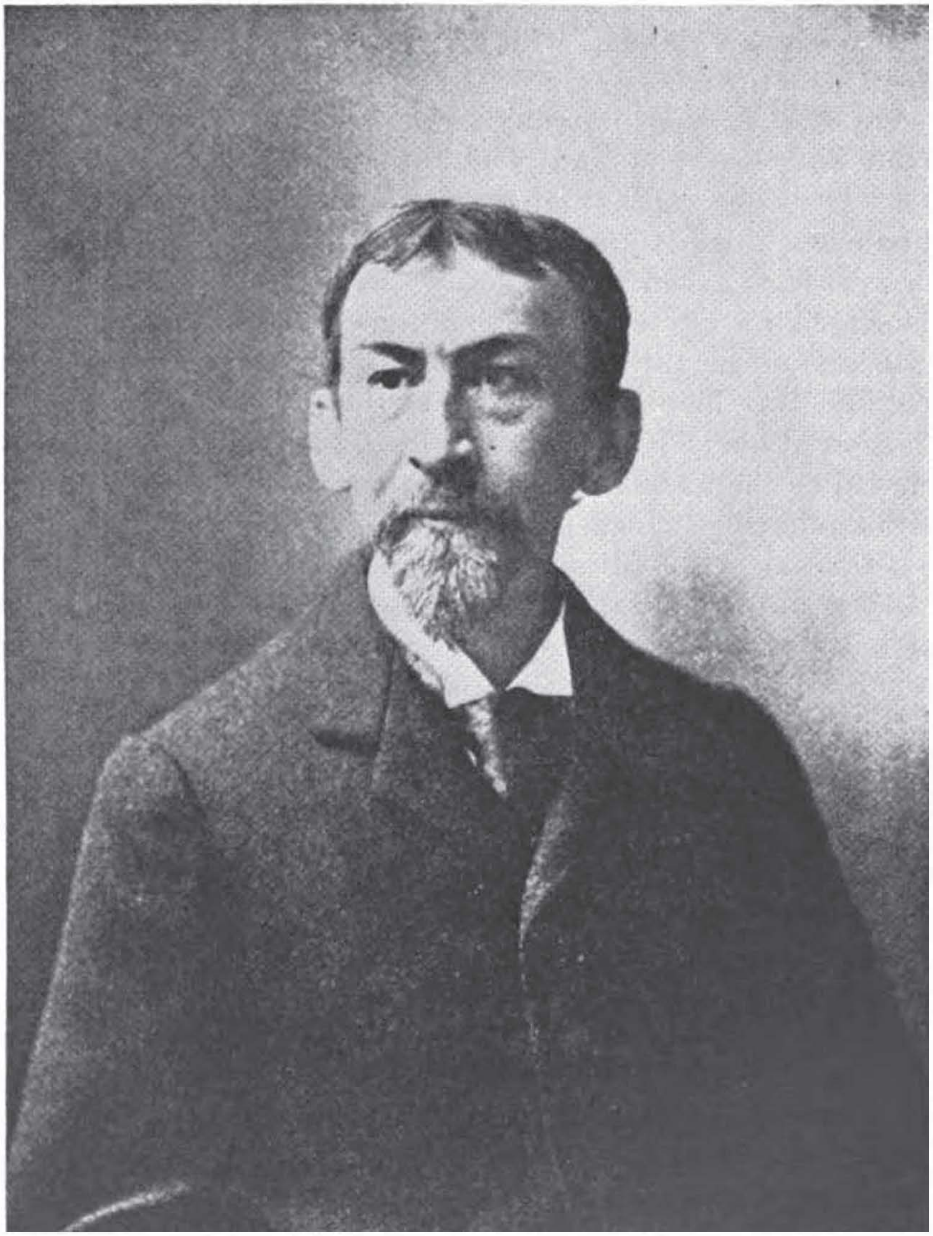

Fig. 44. Albert R. Leeds (1843–1902)
Chemist and stockholder, National Water Purifying Co.; patentee of apparatus for treating water by electrolysis and by forced aeration
(From portrait in Leeds obituary, *Stevens Indicator,* April 1902)

log contained an imposing view of the 30 filters at New Orleans, each 8 ft. in diameter and 30 ft. long, beneath which appeared: "Filters the Entire Supply of the City." In the technical press the first mention of these filters was a brief notice that the company had been defeated in its suit to collect $134,500 claimed under the contract, followed by a statement that the decision had been appealed (40).*

When George G. Earl became Chief Engineer of the Sewerage and Water Board in 1892, the water company

> . . . had its pressure filter plant under contract, with guarantees as to performance which proved utterly impossible to meet. . . . The water as delivered was not fit for any use except lawn sprinkling. The water mains were so clogged with mud that the water delivered was often muddier than the river itself. The average turbidity of the river water was around 625 ppm. and the attempt to purify this water without preliminary sedimentation, by the use of pressure filters, in line between the pumps and the distribution system, was predoomed to failure (42).

F. W. Capellen, City Engineer of Minneapolis, has reported filter operating conditions found by him on a visit to New Orleans in 1894 (43). The filter contract called for the delivery of 14 mgd. of "crystal clear water, free from opalescent hue. Loss of head in the filters was not to exceed 15 lb. when the water was dirty nor 6 lb. when clean; and the filter company was permitted to use not to exceed $8 worth of coagulant per million gallons per 24 hours." During his stay in New Orleans, "the filters had to be washed every four hours, due to a large amount of fibrous sediment in the river water." Summing up, Capellen said: "The filter company has . . . undertaken a task that has no parallel anywhere, either here or in Europe, and it would appear that the water should be settled . . . and then filtered. I understand that the plant has been put in at a loss."

Professor Albert R. Leeds, in his now-it-can-be-told confession before the American Water Works Association in 1896, soon after the filter contract was voided by the Louisiana courts, drew a picture of the New Orleans tragedy (31). After reviewing events leading up to the forma-

* Nothing further regarding this lawsuit has been found in the technical press. G. A. Llambias, Special Counsel, Sewerage and Water Board of New Orleans, at the request of A. B. Wood, General Superintendent, states that the suit was brought to obtain payment for the amount claimed under a contract to furnish a filter plant. The defense was that two tests proved the plant to be entirely insufficient and unfit for delivering the guaranteed quantity and quality of water. A plea for a part of the contract price was denied (41).

tion of the National Water Purifying Co., including the taking over by it of his aeration patents and his professional savings, and saying that he was the "largest holder" of its $1,500,000 stock, he continued:

> . . . the company, against professional advice, against everything I could say, undertook to purify the waters of the Mississippi at New Orleans. . . . That company put in a very great plant there, that cost $130,000. It undertook by mechanical filtration to take the water directly from the Mississippi River at all seasons of the year, at all times of flood; with the Red River and the Arkansas River pouring different sorts of constituents into it; it undertook to . . . [pump water through the filters to the water mains under a varying domestic and fire demand] and to supply—what do you suppose?
>
> I think you will say that they ought to have been satisfied if they could have supplied wholesome water. But, gentlemen, the contract signed by the filter company against the professional protest of a person who had repeatedly analyzed the Mississippi water, was, under all these extravagant engineering conditions, to supply at all times, clear and wholesome water, free from opalescence; in other words, the water of the Mississippi river, containing sometimes 2,000 parts [per million] of solid matter and full of filth at all times, . . . was to be made as pure as the most crystal spring water, the penalty for failure to do which was the loss of their money.
>
> . . . an engineer spent a year there testing [the plant] under these conditions . . . finally, the filter company brought the water company into court. The case was carried to the Court of Appeals and decided against the filter company, for the reason that, singularly enough, [although] a great deal of filtered water was clear and free from opalescence, there was also some that was not. That adverse decision came during a financial and commercial crisis, and the company was broken to pieces, . . . (31).

Stunned by the failure of the filter plant, the water company made no further attempt to filter its water supply. In 1891 the number of service connections not in use exceeded those in service. In 1896 there were only 4,800 connections on 118 miles of pipe. Meters could not be used. For decades rainwater cisterns were depended on for domestic supply. The population of the city was 242,000 in 1890 and 287,000 in 1900.

After the city took over the water works from the company, an experimental water purification plant was installed and operated under the immediate charge of Robert Spurr Weston. In 1909 a coagulation, sedimentation and filtration plant, with a normal capacity of 40 mgd., was put in operation. The filters were of the Jewell type, using perforated plates between ridge blocks. Equipment was supplied by the Roberts Filter Manufacturing Co., of Philadelphia. The chemicals used were lime and sulfate of iron, thus clarifying and softening the water as well as removing bacteria. Chlorination with hypochlorite of lime was used from May 1915 to July 1916, when it was supplanted by liquid chlorine. Enlargements in the plant completed in 1932 brought its normal capacity to 112 mgd., which it still was in 1942. Until 1936, the lime and sulfate of iron were applied simultaneously. Since then split treatment has been practiced. Recarbonation was used during most of the year 1941–42.*

The American Filter Company

The American Filter Co. of Chicago was the third, chronologically, of the concerns that united to form the New York Filter Manufacturing Co. early in 1892. A former Hyatt representative was a patentee of the American company's filter and a stockholder in the company. This was Ernest H. Riddell, once of Riddell & Kerrick, agents of the Newark Filtering Co., at Chicago and Cincinnati.† The other patentee, also a stockholder, was Chester B. Davis, of Chicago.

In early advertisements, the American Filter Co. offered to supply filter plants for any purpose and to furnish plans and specifications and to undertake construction of the whole or any part of water works systems. From other sources of information it appears that of ten water works for which Chester B. Davis was engineer up to 1889 the only three having filters had American Filter Co. installations. These were at Elgin and Rogers Park, Ill., and Mount Clemens, Mich. When the Elgin filters were under criticism in 1900, the mayor stated that the engineer for the original water works was financially interested in the filters then installed.

* The information in this paragraph was brought up to September 28, 1942, by A. B. Wood, General Superintendent, New Orleans Sewerage and Water Board. For details of changes completed in 1936, see article by Carl C. Friedrichs Jr., in the April 1936 *Journal American Water Works Association* (44).

† G. F. Hodkinson, of Philadelphia, who joined the Hyatt staff in 1886 and was secretary of the Hyatt Pure Water Co. in 1892 when the New York Filter Co. merger occurred, says the American Filter Co. was organized January 25, 1888, with a capital stock of $100,000, of which Riddell and Chester B. Davis received $25,000 each for their patent rights in the United States and Canada. Riddell went to England about 1894 to promote the sale of the patent rights there and became associated with Leonard H. Bristowe (53). Testimony to Riddell's success in England was supplied by C. L. Simpson, grandson of James Simpson of London, who stated in 1909 that "about 20 years ago he used an American rapid filter called the Riddell . . . a pressure or pump-through filter"; and by Managing Director Spence, of Peter Spence & Sons, Chemical Manufacturers, Manchester, England, who wrote in 1937 that in 1895–96 "Messrs. Bell Bros. installed a number of Riddell filters."

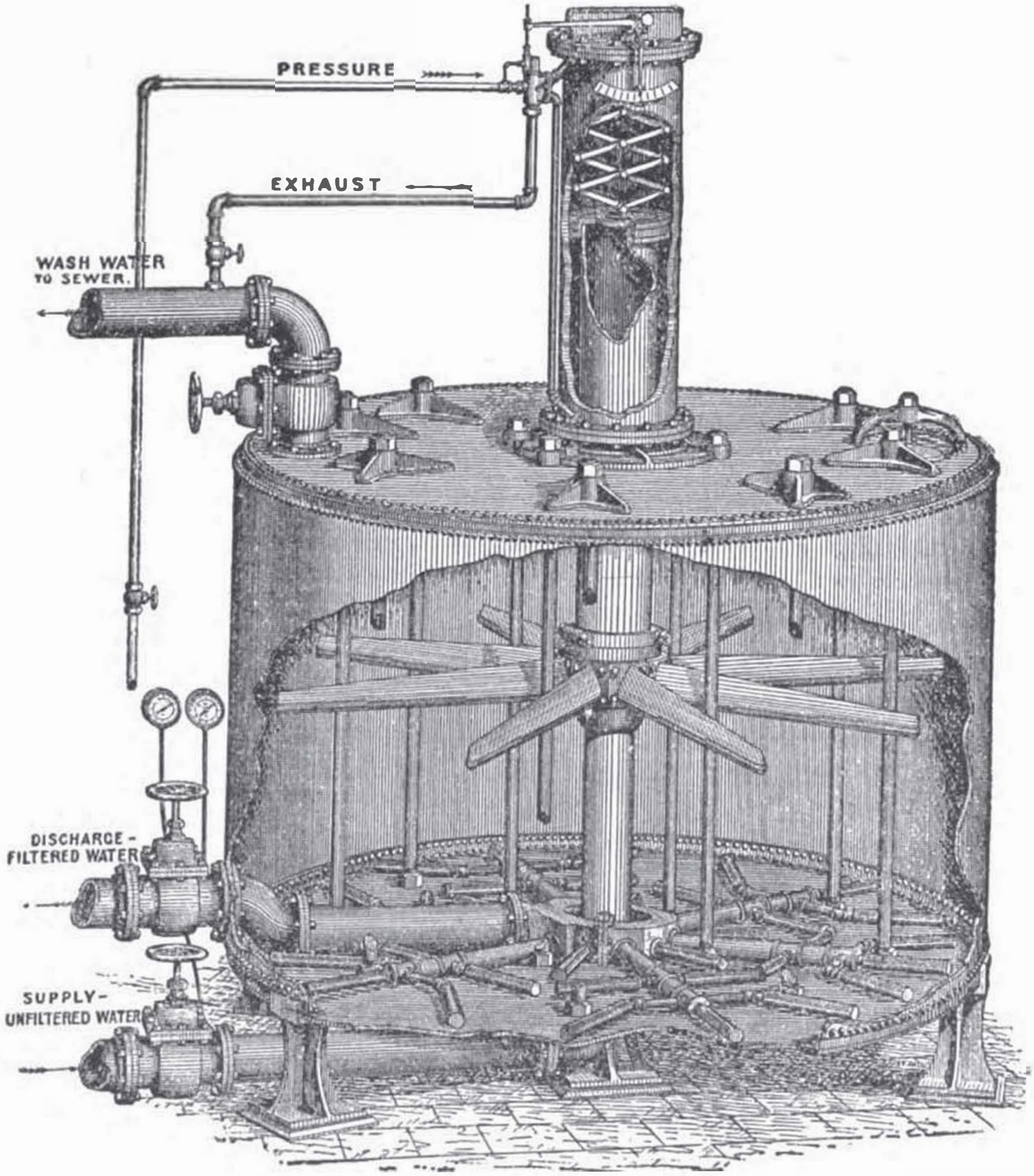

FIG. 45. THE AMERICAN FILTER

Raw water admitted above filter through central vertical pipe to and through radial perforated arm; washed by reversing flow through filtered-water discharge pipe, vertical feed pipe and radial arms, latter being forced into media by hydraulic piston and then oscillated; when long horizontally placed cylindrical tanks used, two or more sets of washing arms employed

(From Geyelin's "Analysis of Mechanical Filter Actions," *Proc. A.W.W.A.*, 1889)

Three United States patents were granted to Davis and Riddell. Application for the first was filed December 12, 1887. The patent was granted June 11, 1889. It covered a filter in a closed vertical tank, underdrains of perforated pipe having wire closely wound around them, and a washing system composed of horizontal oscillating perforated radial arms moving up and down through the filter by means of a hydraulically operated piston working in a central vertical cylinder. Wash water was distributed through the perforated arms. A British patent, also dated June 11, 1889, was similar to the first American patent. Two United States patents dated April 14, 1891, were much the same as the first one. The washing system was the same, in principle, as one described in an early Hyatt patent.

Nine installations by the American Filter Co. have been authenticated. By dates put in use, these were: Elgin, Ill., June 1888; Sidney, Ohio, September 1888; Greenville, Texas, November 1888; Mount Clemens, Mich., and Rogers Park, Ill., March 1889; Cairo, Ill., June 1889; Streator, Ill., August 1889; Davenport, Iowa, and Little Rock, Ark., June 1891.

Elgin, Ill.—At Elgin, the first six filters were 10 ft. in diameter and height, had a total rated capacity of 1.5 mgd., were supplied by the Chicago Steam Boiler & Engine Works for about $17,000, and treated water from the Fox River. In 1893, the New York Filter Co., successor to the American Filter Co., added two 8 x 10-ft. filters, bringing the capacity to 2 mgd. The earliest bills for a coagulant, dated June 1888, were for alum. Peculiar tastes and odors in the filtrate in 1893 led to the removal of all the filter material in one of the original filters. The wooden supports of the underdrains were found to be "slightly soured." To this the tastes and odors were attributed. One by one in each filter a concrete bed was placed to support the underdrains and the depth of sand was increased. Thereafter the quality of the filtrate was satisfactory and the coagulant was cut in half. The filters were shut down in 1903 on the introduction of artesian well water. Twenty years later their use was resumed to supplement the artesian supply but shortly afterward the river suction pipe was broken by order of the State Board of Health. In 1938 a softening plant was installed.

Rogers Park, Ill.—The Rogers Park filters are of interest because they supplied water for 25 years, 1889–1914, to an area annexed to Chicago in 1893. The city took over the property of the Rogers

Park Water Co. in 1907 and operated the filters until 1914 for the benefit of such consumers as wished filtered water instead of water from the city's Lake View intake which extended 6,000 ft. into Lake Michigan, compared with 3,200 ft. for the company intake.

Streator, Ill.—At Streator, four American filters were still in use in 1940, after over a half century of service. The shells were 10 ft. in diameter and 7 ft. high, of $\frac{5}{8}$-in. plates. Twelve $2\frac{1}{2}$-in. stay rods tied the top and bottom together. Six Western pressure filters were also in use in 1940. These were horizontal, 8 ft. in diameter and 21 ft. long, with "bumped" ends and center walls dividing each filter into two compartments. Three of these were installed in about 1896 and have $\frac{1}{2}$-in. shells. Until about 1907 the American and the three earlier Western filters operated on the discharge end of the high-pressure pump and considerable sand was carried into the distribution system. Settling and clear-water basins were then installed. Since then all nine filters have worked under an 11-ft. head, but as closed low-pressure filters.

The underdrain system of both makes of filters consisted of Cook well strainers. During the last two years, wrote H. J. Adams, Superintendent of the Northern Illinois Water Corporation, on September 16, 1940, the underdrainage system in the American and three earlier Western filters has been removed, owing to corrosion and wear. It has been replaced by 1 x $\frac{3}{16}$-in. steel grating, supported on 4-in. channel irons. The 2 ft. of concrete below the filter has been removed, so the channel irons rest on the steel bottoms of the tanks. On the grating was placed 18 in. of 2-in. gravel and above that 26 in. of standard filter sand. These changes give, in effect, a false bottom to the filters and provide a chamber which equalizes the distribution of wash water and reduces friction loss, and increases the yield of the filters. All the American and Western filters at Streator were still in use in 1940 but it was hoped that within a few years they could be replaced by open-type gravity filters.

Davenport, Iowa.—American filters at Davenport, put in use in June 1891, were still being operated in November 1941, but only the shells and piping remained. As originally installed, there were ten horizontal cylindrical units, $7\frac{1}{2}$ x 30 ft. in dimension, divided by a vertical bulkhead into two compartments, each with a sand area of 100 sq.ft. The nominal capacity of the plant, with one unit out of service for cleaning, was 5 mgd.

Notes taken by Alvord, Burdick & Howson during a valuation of the property in 1902 showed that the filters then contained 4½ ft. of sand, but no gravel. The strainer system was a cast-iron manifold into which 2-in. brass pipe with No. 7 slots was screwed. The filters were backwashed in the "usual way," but "each 30-ft. shell," says Mr. Burdick, "was equipped with four plunger cylinders on top, 12 in. in diameter, 3½ ft. long, with a piston and a plunger and a hollow eight-legged spider inside the filter which normally was above the sand line, but when the filter was being washed could be forced down nearly to the bottom of the sand. This device did not work well mechanically. . . . The filters were being backwashed without agitation in 1902." In a paper read before the Illinois Society of Engineers in 1936, Mr. Burdick said, "Good success was only attained after the addition of sedimentation basins about 1900."

In 1908, the filters were equipped with Jewell strainers and air-and-water wash. Subsequently air agitation was given up, not only for the American filters but also for Jewell filters installed in 1908. About 1920, the inside surfaces of the filter tanks were cleaned by air blast and lined with cement brushed on. The dished heads of some of the early filters gave way before the practice of subjecting them to 80–100 psi. fire pressure was stopped. Repairs were made by machine flanging, hand flanging having been used in the original fabrication.

For many years Charles B. Henderson was in charge of the Davenport water works. He was succeeded in the late 1930's by J. H. Wells as manager. Wells wrote November 14, 1940, "These filters are still in use and in good condition . . . [but] we expect this winter to change them from pressure to gravity."

The Blessing Filter

James H. Blessing, of the Albany (N.Y.) Steam Trap Co., entered the field of mechanical filtration a few years after the Hyatts. He applied for four pressure filter patents in 1886. By 1895 he had been granted seven patents in the United States and two in England. His strainer system was unique, his sand agitators less so but interesting. He supplied only two municipal water works with filters but installed many for houses, offices and industrial plants. His business was absorbed by the New York Filter Manufacturing Co. in 1896 for which he received only $2,400 of the $600,000 stock of the company. He

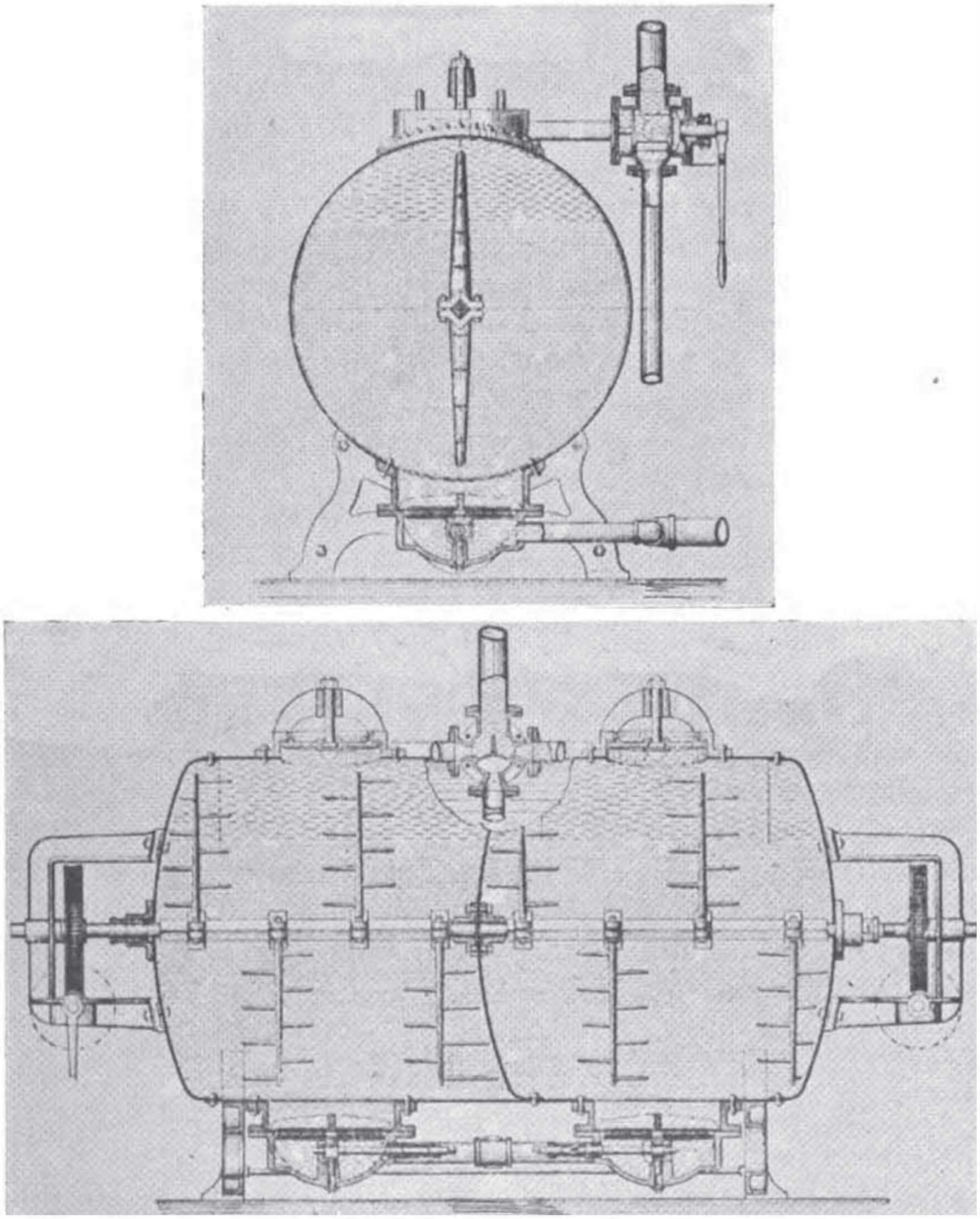

FIG. 46. BLESSING HORIZONTAL DUPLEX FILTER

First permanent rapid filter in municipal supply in New England put in use at Athol, Mass., 1889; lower section contains sand screens; agitation by horizontal revolving arms

(From undated trade catalog of Albany Steam Trap Co.)

seems to have been equalled by none of his rivals in studying the art of water purification—as disclosed by patents.*

A "sand screen" of gravel in a chamber below the bottom of a filter and a revolving agitator to clean the gravel were covered in Blessing's first patent (March 20, 1886). In his second (November 23, 1886) a new sand screen was substituted. This was a perforated plate in the bottom of the filter tank into the holes of which pins or plungers mounted on a reciprocating head were inserted from below. A slight difference in the diameters of the holes and pins allowed the filtrate but not the filter sand to pass through. Reciprocation of the pins, effected by a cam mounted on a horizontal revolving shaft, removed any sand lodged in the holes. This patent also covers a filter-sand agitator, consisting of a revolving central shaft combined with which were either "chain sheaves" or three revolving horizontal arms provided with vertical teeth on their upper and lower sides.

A duplex filter patent, also of November 23, 1886, covered two filters similar to those of the second patent. British patents essentially like the second and third American, also dated November 23, 1886, were granted to Blessing. All the filters thus far described were placed in vertical or cylindrical tanks.

A "charcoal purifier," to receive effluent from the duplex filters, was included in Blessing's fourth patent (April 20, 1889). In a Blessing trade catalog of 1890 it was stated that "Mr. Blessing has devised a Purifier" which may be attached "to the filter of his invention," and used or not used as desired, "the animal charcoal in the Purifier being finally relied upon to reduce to a minimum the micro-organisms which may possibly remain in the water passing through the filter." Testimonials in the catalog show that the purifier had been supplied with filters for house use.

A "chemical chamber," for use in treating effluent from a duplex filter, was the subject of an application filed by Blessing August 25, 1887, but held up until September 13, 1892, then assigned to the New York Filter Co., which had recently acquired the Hyatt coagulation patent.

* Evidence of this is afforded by a bound volume of American and British patents dated from 1812 into the 1880's. This volume was given by Blessing to Wallace Greenalch, one-time Water Commissioner of Albany, who presented it to the author, together with a Blessing trade catalog, in 1937. Both are in the author's collection of source material deposited in the Library of the United Engineering Societies, New York City.—*M. N. B.*

In a trade circular regarding the duplex filter in 1887, Blessing boldly declared:

> As to the matter of treating water chemically, we will say we are prepared to so treat water by any of the well-known methods, such as practiced by the Messrs. Clark, Graham, Darcet, Miller, Hofman, Le Tellier, Holden, Demalley, Maingay, Jaminet, Frost, Spence and many others, depending entirely on the circumstances and the requirements of the water to be treated.

A number of these processes were covered by patents, copies of which are in the bound volume already mentioned. All differed from the claims of the Hyatt patent on coagulation.

Horizontal filters with sand agitators differing somewhat from those already noted were the subject of two patents granted to Blessing on December 9, 1890.

Athol, Mass.—At Athol, Mass., Blessing's filters were installed by the Athol Water Co. in 1887 and added to in 1890.* Algae growths in an impounding reservoir seem to have led to the installation of the Blessing filter. It was 8 ft. in diameter, 16 ft. long, divided by a vertical diaphragm into equal and independent units, each provided with a "sand screen" in its bottom and sand agitators revolving on a horizontal arm. The filter medium was sand.

Percy M. Blake, of Hyde Park, Mass., reported on the Athol filters in May 1896 (45). A solution of crude sulfate of alumina was added to the water at the gate house, 4,781 ft. above the filter plant, which was on the 10-in. gravity supply main. During the summer of 1895 it was "necessary to wash and scour each filter twice daily." The effluent after washing was not "thoroughly freed from sediment and products of decay, although the process is probably as effective for water of the kind obtained from any mechanical process."

Robert Spurr Weston saw the Athol filters in 1903. He says they were then used as strainers only, treating water badly infected with algae. His firm made plans for a coagulation basin in or about 1905. The town bought the works from the company in 1906. Slow sand filters were built in 1912, after plans by James L. Tighe of Holyoke, but they treated water from another reservoir.

* The Athol plant has been called the earliest mechanical filter installation on a New England municipal water supply, but hitherto unpublished data show that a Hyatt aeration and filter plant was put into use in 1887 or early in 1888 on the works of the Greenwich Water Co., supplying Greenwich, Conn., Rye and Port Chester, N.Y. The first Athol filter was used for half a century.

A central rapid filtration plant superseded both the rapid and slow filters June 7, 1937. On November 27, 1937, Frank Hall, Superintendent, wrote that the Blessing filters were being scrapped. During the last three years of their use a coagulant was employed the year around. Latterly, the sand in the Blessing filters had been taken out and washed once a year. Black and lumpy sand in the ends of the filters where there was no agitation by the revolving arms, was replaced by new sand.

Thus came to an end the earliest mechanical filters in Massachusetts and the earliest permanent installation in New England, after a half century of service.

Ottumwa, Iowa.—At Ottumwa, Iowa, a thousand miles west of Athol, the only other known Blessing filter on a municipal supply was installed late in 1890 or early in 1891. It was preceded by one of the largest known American sets of charcoal filters and followed in 1895 by Jewell gravity filters (34).

Three Jewells and Their Filters

As the Hyatt, National and American filter companies were about to merge and the Warren filter was coming to the front, the Jewell filter entered the municipal field. It had been under promotion for several years, both at home and abroad, but chiefly in the industrial field. Once established in the municipal field it attained prominence. The three Jewells—Omar H., and his sons, Ira H. and William M.—took out about 50 patents in 1888–1900. The earliest were granted to Omar H. Jewell; later ones to him and one or both sons, or to one son alone.

Omar H. Jewell was born at Wheaton, Ill., June 1, 1842. As master mechanic for grain elevators he became interested in improving the quality of boiler feed water from the notoriously foul Chicago River. The first of his filters seen by his son William was located in Elevator L, of Armour, Dole & Co., on the South Branch of the Chicago River. Probably it was built in or about 1885. The Jewell Pure Water Co. was organized and largely financed by James B. Clow & Sons, well known Chicago dealers in water works supplies. W. E. Clow, chairman of the Clow concern, stated in 1937 that in the earlier years he had charge of sales and sold filters in England, France, Germany and Italy. The elder Jewell devoted himself to manufacturing the filters.

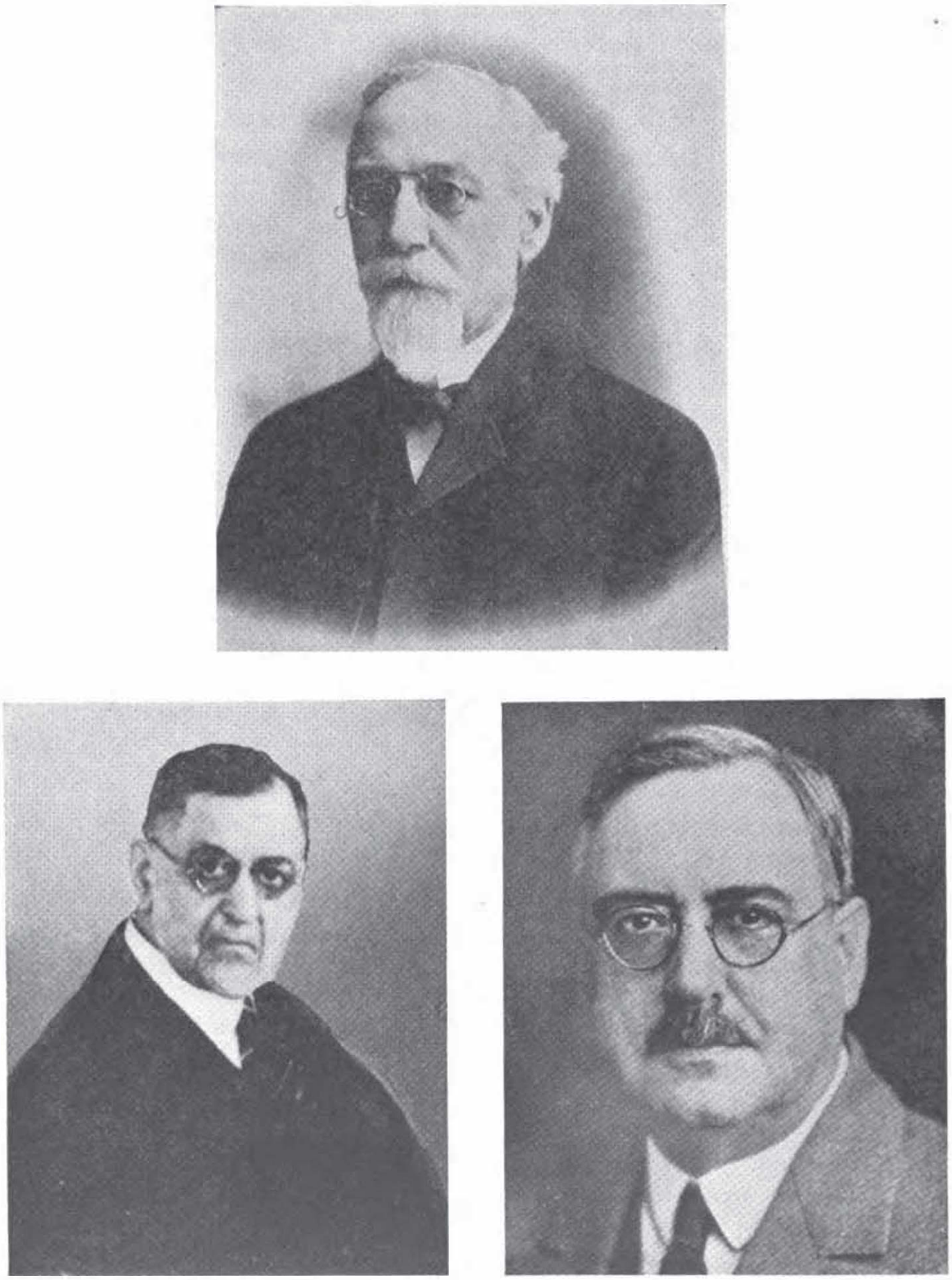

FIG. 47. THE THREE JEWELLS—FATHER AND SONS
Top: OMAR H. JEWELL (1842–1920)
Left: IRA H. JEWELL (1869–1940) *Right:* WILLIAM M. JEWELL (1870–1940)
(From photographs supplied by Ira and William Jewell)

William M. Jewell became chemist of the Jewell Pure Water Co. in 1887, following graduation from the College of Pharmacy, University of Illinois, at the early age of 17. With his father and brother the firm of O. H. Jewell & Sons was formed in 1890. It was soon incorporated as the O. H. Jewell Filter Co., which continued in business until it merged with two other companies in 1900. William Jewell was in Europe from October 1888 to December 1889, assisting Jewell agents in erecting "steel tank pressure filters," made in Chicago and shipped abroad complete. These seem to have been for industrial use. In the late 1890's while George F. Hodkinson was manager of the O. H. Jewell Filter Co. at Chicago, Ira and Ariel * Jewell were sent to Moscow to supervise the operation of an experimental filter plant for a few months. Nicholas Simin had previously visited the United States and arranged for the installation. The Morison-Allen Co. and then the Morison-Jewell Filtration Co. represented the O. H. Jewell Co. in New York and Philadelphia from about 1888 to 1898. William B. Bull of Quincy, Ill., was Vice-President of the O. H. Jewell Filter Co. in the late 1890's.

The first Jewell filter patent was granted to Omar H. Jewell February 7, 1888, and nine more followed. Five of the ten were for a feed-water purifying apparatus.

Electrodes placed in a dome located on the top of a filter tank were an element of one of Omar H. Jewell's early applications for a patent filed December 17, 1887, and granted July 10, 1888 (No. 386,073). The electrodes were connected with a battery or other source of electricity. This was one of the earliest patents on the use of electrolysis in water treatment. Among the many other patents granted to Omar H. Jewell were several on strainers or screens for underdrain washing systems; revolving sand agitators; a settling chamber below the filter; and means for maintaining a partial vacuum in filters (negative head), both process and apparatus.

Ira H. Jewell's earlier patents included one on apparatus for continuous cleaning of filters of large area by lifting, successively, portions of the sand and supernatant water by a pump on a truck on a movable platform, above which was a screen to separate the water and its load of impurities from the filtering material as the water went to waste.

* Ariel Clyde Jewell, wrote Ira H. Jewell on Aug. 8, 1936 (46), "built up a large business in water distilling, operating under the trade name 'Polarstill.' . . . He died several years ago."

Perforated pipes were placed beneath the screen to convey steam or other sterilizing agents. The sand thus cleaned and sterilized was returned to place. (Patent dated August 10, 1897; filed November 7, 1892.) A later patent granted to Ira H. Jewell (May 8, 1900) covered a traveling filter washer similar to the one just described, combined with a horizontal-flow surface-jet wash, revolving sand stirrer arms and a multiplicity of air pipes adapted to discharge air under pressure upward through the filter.

An electrolytic process for producing hydrate of iron for use as a coagulant to be applied to a filter was patented by William M. Jewell July 17, 1900. Two other patents of the same date were on a method and apparatus for producing "a purifying reagent" (coagulant) by "subjecting water to the action of sulfurous-acid gas, passing the solution so formed over iron and converting the resulting solution into ferric sulfate by oxidation." A filter rate-of-flow controller was patented by William Jewell February 23, 1897. A similar device was used on the Jewell filter during the Louisville filtration experiments, 1895–96. William Jewell believed this to have been the first use of such a controller on a mechanical filter.

Brockton, Mass.—The first known attempt to introduce Jewell filters into an American municipal supply was made at Brockton, Mass., in 1888. The report of the Brockton Water Board for that year states that the Morison-Allen Co., New York City, petitioned the mayor, council and water board to allow a demonstration of one of its small filters on the Brockton works. Apparently Brockton would have installed Jewell filters had it not been for the strong objections of the Massachusetts State Board of Health.

Rock Island, Ill.—The first Jewell filter for a municipal supply was put into use at Rock Island, Ill. Installed in 1891, its object was "to clarify the water." Because it was too small it was shut down in two months, but after enlargement, operation was resumed. In 1899, settling basins and slow sand filters were built. In 1911 a return was made to rapid filtration, using open rectangular filters.

Subsequent Plants.—Five other Jewell plants for city water supply were put in use in 1891. By May 1896, a total of 21 plants had been completed and one was under construction. The largest of these was a 10-mgd. plant for the Wilkes-Barre, Pa., Water Co., put in use in 1895. Next in size was a 4.5-mgd. plant completed by the Niagara Water Works Co. in March 1896. Gravity filters were used in eighteen of the 21 plants. Of the three pressure plants, the one at Chattanooga was installed to work with existing filters of the pressure type and those at Terre Haute and Lake Forest were put in on direct pumping systems. Steam for cleaning and sterilizing filters was used at all the plants (34).

A multiplicity of strainers appears to have been the rule in the early Jewell filters. The strainer described and illustrated for the Wilkes-Barre filters, and apparently the type generally used, was a perforated aluminum-bronze plate, placed across a cup screwed into the underdrain and wash pipe. Between the plate and the bottom of the cup was a deflector to spread the wash water and steam. The filters were washed by reverse flow, aided, in the typical gravity filters, by revolving-rake sand agitators. These consisted of horizontal arms from which numerous rods extended to the bottom of the filter. Subsidence or coagulation chambers were provided in most of the plants described in the article of 1896. These were small compared to the rated daily capacity of the filters, except at Creston, Iowa, where the chamber capacity was 0.5 mil.gal. compared with a filter capacity of 0.7 mgd. This was really a presettling reservoir.

After protracted litigation brought by holders of the Hyatt coagulation-filtration patent of February 19, 1884, against users of Jewell filters employing a coagulant, the U.S. Circuit Court of Appeals upheld preliminary injunctions against the Elmira Water Works Co. and the Niagara Falls Water Works Co. in 1897 (47). The settling chambers below the filters, it was held, were too small to avoid infringement of the patent.* Nor did they provide the independent settling reservoirs for coagulation which Hyatt claimed his process made unnecessary.

Early in 1898, the O. H. Jewell Filter Co. settled with the New York Filter Manufacturing Co., holder of the Hyatt coagulation patent, for infringement, and took out a license for the use of the Hyatt patent in the central area, including Tennessee and Kentucky, and west of the Mississippi River. The New York Filter Manufacturing Co. agreed to confine itself to the eastern area, within which it was to supply the Jewell filter. The Morison-Jewell Filtration Co. of New York and Philadelphia settled for infringements and retired from business,

* Coagulation basins with a holding capacity of 2.5 mil.gal., or nearly half the daily capacity of the filters, were constructed at Elmira in 1937. The old chambers beneath each Jewell filter had a detention period of about 20 min. (48, 49).

but its Vice-President and General Manager, Samuel L. Morison, of New York, became general manager of the New York Filter Manufacturing Co. (50). In 1900, the New York Filter Manufacturing Co., the O. H. Jewell Filter Co. and the Continental Filter Co. consolidated as the New York Continental Jewell Filtration Co. Omar and William Jewell made a five-year contract with the consolidated company. Subsequently, William Jewell began private practice, largely as a consultant. Ira Jewell continued to operate independently, as he had been doing for some time past. He was engaged in much litigation, notably an unsuccessful suit against the city of Minneapolis for alleged infringement of down-draft or negative-head and central operating-control patents.

A subsurface filtering and washing system introduced by Ira H. Jewell about 1935 has been applied to a number of plants (51). Wire mesh screens set in large castings near the top of the filter are supplied from below with water for filtration or for washing. The main portion of the filter is washed by the usual reverse-flow method from the bottom. In principle, this was similar to the subsurface washing system of the National filter, forty years earlier.

Omar Jewell died in 1930 at the ripe old age of 88. Ira and William died in 1940.

The Jewell Export Filter Co. was organized about 1900 to exploit filters overseas. In a catalog published in 1903 it was stated that the company had offices at York, England; Berlin, Germany; Trieste, Austria; Moscow, Russia; Alexandria, Egypt; and Arnheim, Holland. In 1912 it had representatives also in Johannesburg, South Africa; Japan; and China. It then reported fifteen installations in Russia and ten in India, besides plants in many other countries. It had only three plants in England in 1912. On the Continent it had few installations in 1912, outside Russia, but some years later Jewell filters were installed at Warsaw, Poland, and the plant was said to be the largest in Europe up to that time. It was reported to have been destroyed or at least badly damaged during the Nazi blitzkrieg of 1939.

In 1903, S. L. Morison of New York, who had been connected with various companies promoting Jewell filters for many years, was Vice-President and General Manager of the Jewell Export Filter Co., and R. W. Lawton was Engineer of Construction. Edmund B. Weston, who as Assistant City Engineer in charge of water works at Providence, R.I., conducted the Providence filtration experiments in 1893–94, was

President and General Manager of the company for many years before his death late in 1916. His headquarters were at Providence, but he traveled widely, going abroad annually for many years before the outbreak of World War I.*

The Continental Filter Company

The Continental Filter Co. came to the front in the early 1890's and obtained enough importance by 1900 to have its name included in the third great consolidation of filter companies, the New York Continental Jewell Filtration Co. It was incorporated in West Virginia, November 20, 1891, with offices in New York. At the time of its consolidation it had built filter plants for six municipal supplies. It was not dissolved until June 1927.

Three Williamsons—David, David Charles and James E.—were Continental filter patentees and engineers. David was the pioneer. He was the Chief Engineer of the Continental Filter Co. during the nineties. David C. was successively draftsman, erecting engineer and assistant engineer of the company from 1897 until it entered the consolidation of 1900. After being with the new company six years he became chief engineer of its filter department, which position he held at least until the close of 1912. Charles L. Parmelee was Chief Engineer of the Continental Filter Co. from March 1899 until the consolidation in 1900. Apparently he was the engineer for the New York Continental Jewell Filtration Co. for a short time in 1900 and held the position until a few years before the company was sold by receivers to the American Water Softener Co. in 1925. He was in private practice at the time of his sudden death in March 1937.†

Nine American patents were granted to the Williamsons between 1892 and 1900, and one to James E. Williamson in 1908.‡ The first patent was for a centrifugal filter. It was issued to David Williamson February 16, 1892. David Williamson's second patent (June 28, 1892)

* The Jewell Export Filter Co. still had offices at Providence in September 1942, but the nature and extent of its recent operations could not be ascertained.

† These notes on the Williamsons and Parmelee have been drawn from testimony by the latter and by David C. Williamson in Defendant's Record, Ira H. Jewell *vs.* City of Minneapolis, December 1912; from correspondence with George F. Hodkinson, of Philadelphia; and from records of the American Water Works Association.

‡ One of the earliest of the nine patents was assigned to the Continental Filter Co. Several of the others were assigned to H. B. Anderson, New York City, who, in 1900, was one of the incorporators of the New York Continental Jewell Filtration Co.

covered double filtration, under pressure, in a horizontal cylindrical tank, divided by a vertical partition into two compartments, which had downward filtration in the first and upward in the second. The filtering material in each unit was supported on a series of perforated plates, forming a false bottom, with a chamber below extending the whole length of the tank. Perforations in the bottom of this chamber afforded passage into a mud drum, also extending the whole length of the cylindrical tank. Raw water under pressure was admitted to the top of the first filter through holes in a curved plate attached to the top of the tank shell. It passed down through the unit and false bottom, then into a chamber beneath the second chamber, then upward through the second unit and into filtrate collecting pipes. Wash water took the same course as the water that had been filtered, except that it was admitted through a single perforated pipe above the first filter and withdrawn through perforated pipes above the second filter. Downward filtration through one or more filters or compartments under either pump or gravity pressure was covered by David Williamson's third and fourth patents, granted early in 1894. The object stated in the first of these was to concentrate the supply and delivery pipes and points of control and facilitate cleaning.

A patent granted to David C. and James E. Williamson late in 1894 claimed concentration in action of wash water to cause the mass of filtering material to be effectually "stirred, ground and thereby cleaned." This was to be effected by discharging wash water into the filter from a central pipe, having an enlarged bottom, with slitted outlets.

Of three patents granted to J. E. Williamson, one issued November 22, 1894, was for aerating the filter material while being washed. Air under pressure was applied from a chamber a little above the filter. The second patent (July 3, 1900) was on an apparatus for cleansing filtering material by water-and-air wash, applied through a single set of nozzles at the bottom of the unit. After reverse-flow wash, the water was shut off, pipes partly drained but with enough water left to form a water seal, and air supplied. The third patent was on a multiplicity of automatically controlled settling tanks and means of supplying a coagulant thereto (September 4, 1900).

D. C. Williamson was granted a patent on December 29, 1908, on a traveling suction pipe and pump for removing sludge from sedimentation basins and reservoirs. The pump could be moved horizontally in either direction along the bottom of the basin; could be provided with an agitator; and could be operated intermittently or continuously.

Six Continental filter plants were installed on municipal supplies: Two of an early type in 1893 and 1895 at Atlantic Highlands and Asbury Park, N.J.; and four of a late type in 1899, at Middletown and Stamford, N.Y., Vincennes, Ind., and Louisiana, Mo.

The New Jersey plants used double filtration, under pressure, for removing iron from deep-well water. They were cleaned by reverse-flow wash and compressed air, used alternately. Each of the two filter tanks used at Atlantic Highlands was 6 ft. in diameter and 11 ft. long. The four tanks at Asbury Park were 6 x 28 ft. The media were coarse sand in the primary and animal charcoal in the secondary filter. No chemicals were used.*

Middletown, N.Y.—Of the four plants of 1899, the one at Middletown, N.Y., included two wooden settling tanks, four gravity filters in wooden tanks and four steel horizontal pressure filters (53). No description of filters at Stamford, N. Y., has been obtained but Superintendent Charles R. Mattice wrote on March 31, 1941, that two Continental filters were "in service and functioning perfectly." The "grids" were changed in 1927 and remodeled in 1937.

Louisiana, Mo.—At Louisiana, Mo., two coagulation-sedimentation tanks and a single gravity filter were put into use in 1899. The settling tanks were used alternately on the fill-and-draw plan. They gave a nominal subsidence period of 108 min. The tank effluent was applied to the filter through 6-in. overhead pipes, perforated with 1-in. holes, 6 in. apart. Air-and-water wash was used, with air applied first. Sulfate of alumina was used as a coagulant. The supply was from the Mississippi River. A week's test of the plant in late September 1899 showed an average bacterial reduction of 97.3 per cent, ranging from 99.9 to 96.5 per cent. The raw-water count was 57,000 to 400 per ml. (54).

Vincennes, Ind.—At Vincennes, Ind., a 2-mgd. plant was put in use late in October 1899, to treat water from the Wabash River which carried considerable loam. It included coagulation tanks and six

* Data on both plants were gathered by me on inspection trips in December 1905. General data were supplied by David Williamson, Chief Engineer, Continental Filter Co. (52). Unfortunately my article of 1896 (34) did not describe the piping connections and flow sequence for the New Jersey plants. Presumably the filters were in general accordance with David Williamson's patent of June 28, 1892.—*M. N. B.*

open gravity filters, all built of wooden staves. The settling tanks were operated in pairs, on the fill-and-draw system, with 21 min. of quiescence. The filtering material was 36 in. of sand on 6 in. of gravel. Water from the settling tank flowed over circumferential weirs onto the filters and was collected by brass strainers. Cleaning was by reverse-flow wash and compressed air. An account of the operation of the coagulation-sedimentation basins by Charles L. Parmelee, then Chief Engineer of the Continental Filter Co., was given in a contemporary article (55). A special feature of the Vincennes filters was central control of hydraulically operated valves, designed by David C. Williamson (56).

New York Continental Jewell Filtration Company

In the twenty years after Patrick Clark and John W. Hyatt joined forces and incorporated the Newark Filtering Co. late in 1880, many filter companies sprang up, competition and patent litigation were rampant, consolidation after consolidation occurred until July 25, 1900, when the New York Continental Jewell Filtration Co. stood almost alone in the field. It was heir to scores of patents, including those granted to Leeds, Deutsch, Warren, Blessing, the Hyatts, two of the three Jewells and the three Williamsons. Some of these had run out; others were about to expire. The Hyatt coagulation-filtration patent, upheld by the highest court after costly and bitter litigation, had about a year of life. Moreover, both practical experience and the Louisville experiments had shown that it was based on a fundamental misconception and that as a rule precoagulation was desirable if not essential. In addition to all this, the underlying principles of water purification had been or were being established on a firm basis of engineering, chemistry and sanitary biology, so that filter design was open to any engineer and filter construction to any contractor. The new company held some unexpired patents on equipment, but so did other companies.

Following its organization in 1900 the New York Continental Jewell Filtration Co. built filter plants after either its own plans and controlled patents or, more and more frequently, the plans of independent engineers. A notable early contract was the equipment for the large filter plant of the East Jersey Water Co., at Little Falls, N.J., completed in 1902 (57). In advertisements in the *Journal of the American Water Works Association* the company announced that the number of its plants had reached 220 in 1906 and 360 in 1909. The New York Continental Jewell Filtration Co. was sold at a receiver's sale held at Nutley, N.J., March 26, 1925. The purchaser was the American Water Softener Co., of Philadelphia, through George F. Hodkinson, who for many years was manager of the latter company's filtration department.

Little Falls Marks New Era *

The Little Falls filters of the East Jersey Water Co. inaugurated a new era in the design of rapid filters. In shape they were rectangular instead of round; in structure they were of reinforced concrete rather than of wood or iron. In them, application of the coagulant had been transferred from the point where the raw water flowed to the filters to the point where the treated water entered a detention basin in which it was held for a period to permit chemical reaction and flocculation. And as an aid in cleansing the filter sand it was agitated by means of compressed air introduced underneath the filter before reverse-flow wash rather than by the old method of stirring with revolving rakes operated from above.

Except for the shape of the filter tanks, these new features were merely adoptions and enlargements of designs already in use at the Continental plants mentioned above. Reverse-flow wash had been patented in England by Peacock in 1791 and had been put to use by Thom at Greenock in 1827. Thom's filters there and at other localities in Scotland had been placed in rectangular masonry tanks larger than those at Little Falls.†

The nominal capacity of the Little Falls filters when placed in service early in September 1902 was 34 mgd. Main elements of the plant were chemical mixing tanks, a coagulation basin, 32 filters—each 15 x 24 ft. in plan and 8 ft. deep—and a clear-water basin beneath the filters. To protect the strainers, which were of the Continental type,

* Although in the design of the Little Falls filters, Fuller and his associates made use of what he had learned in the Louisville and Cincinnati experiments of the late 1890's, described below, the filters for those cities were not placed in service until a few years after those at Little Falls. For that reason, and because, chronologically, they belong after the several installations of Continental filters, the Little Falls installation is described before the experiments and plants at Louisville and Cincinnati.

† See above for a brief review of British and American anticipations of elements of the design of the Little Falls filters and see Chapter V for a resume of Peacock's patents and theories and for descriptions of Thom's installations.

2 in. of broken quartz and then 5 in. of coarse quartz were placed above them. The filtering medium was 30 in. of sand.

In the design of the plant, George W. Fuller was in full charge on behalf of the East Jersey Water Co. and Charles L. Parmelee represented the New York Continental Jewell Filtration Co. J. Waldo Smith, Chief Engineer of the East Jersey Water Co., had general direction over the design and construction. A detailed description of the design of the plant and its early operation was presented before the American Society of Civil Engineers by Fuller in 1903 (57).

Louisville Rapid Filtration Experiments

Many know of the Louisville experiments on water purification in 1895–97 and their contribution to the art and science of rapid filtration. Few ever heard that for several years in the eighties experiments with slow sand filtration showed that it could not cope with the highly turbid water of the Ohio at Louisville. This turbidity had been a source of concern to the directors of the water company and to Chief Engineer Charles A. Hermany since the water works were completed.

Although the later experiments under Hermany, in direct charge of George W. Fuller, were completed in 1897 and described in Fuller's classic report of that year, it was not until July 1909, that the Louisville rapid filters were put into successful operation. Changes in the plant were completed in 1909 and others were made which extended through several years. Finally, the original plant was reconstructed. New features of design and operation were adopted. Some of these were merely in keeping with the ordinary progress of the time; others were innovations. Valuable records have been kept which show, year by year, the work accomplished, classified under sedimentation, coagulation, filtration and chlorination (58).

When the Louisville Water Co., nominal owner of the water works, incorporated October 6, 1854, was unable to sell its stock, the city bought a majority of it in 1856 and all of it later, but the works have always been operated as a company. Conditions before the Civil War delayed construction so that the works were not put into use until October 16, 1860. Consumers were few until the war was over.

The source of supply chosen was the Ohio River, above "town drainage." Theodore R. Scowden was chief engineer during construction. In his report of November 1, 1859 (58), he said that the quality of the water "was attested" by Dr. Locke of Cincinnati and other eminent chemists but he stated their findings in general terms only. "Frequent freshets discolor [!] the water but do not vitiate its . . . qualities." Suspended matters "can be easily removed by filtration or subsidence"—which did not prove to be so easy.

Apprehension that the citizens would be loath to change from the clear water of wells to the turbid water of the Ohio was expressed by Scowden. This he sought to quiet by stating that those accustomed to the use of the Ohio River where works had been established "appear to pay little attention" to turbidity "as the taste is agreeable and its qualities are healthful."

Charles A. Hermany, who had become chief engineer of the works on their completion late in 1860, noted in his annual report of 1864 a lack of "reservoir capacity to obtain a clear water at all times by subsidence."

On March 29, 1876, a committee on water works extension, of which Hermany was a member, reported that surveys had been made for settling basins and filters on the river bottom near the pumping station. It recommended experiments to determine the proper ratio between capacity of settling basins and area of filters and to ascertain "the composition of the filtering media, for the reason that there is no experience in our country by which the problem has been solved." The experimental basins and filters should be of small area but of full working depth (59).

No experiments were made. A contract was let in 1876 for a 100-mil.gal. reservoir, in two compartments, located on Crescent Hill. Water was piped to it on December 15, 1879. It was still in use in 1942.

For 20 years the president of the company, Charles R. Long, led a campaign for filters, during which time two sets of filtration experiments were made: one on slow sand, which was found impracticable; and the other on rapid filtration, which was found efficient *if* changes were made in the design of the commercial filters tested and if adequate precoagulation and presedimentation, also lacking in the filters tested, were provided.

Few data on the slow sand filtration tests are available. President Long noted them in five successive annual reports: 1880, proposed; 1881, plan ready; 1882, under way, good results hoped for; 1883, "working with a reasonable degree of satisfaction"; 1884, "an unsettled problem as to practical feasibility and reasonable cost of maintenance, however desirable and necessary of accomplishment for the comfort, health and welfare of our citizens." Here Long's remarks on the slow sand filtration tests end.

Chief Engineer Hermany's reports contain nothing on the tests except expense items, running from 1882 to 1887 and totaling only $1,941, including labor and material. The largest annual totals were $795 in 1882, for two 12-ft. tanks, including masonry foundation, and $889 in 1883, for "labor in setting tanks" and numerous sundries. Later items may have been for dismantling the plant.

Fortunately, Fuller, in his Louisville report on the rapid filtration experiments of 1895–97 gives more specific information, doubtless obtained, in part, directly from Hermany. Fuller says the tests were conducted under Hermany's direction for eight months in the fall of 1884 and spring of 1885. There were two filter tanks 12 ft. in diameter, "after the English plan described and recommended [for St. Louis] by Mr. Kirkwood. The sand had an effective size of 0.36 mm., agreeing very closely with the size employed in the best English filters in Europe." Summarizing, Fuller said:

> As a result of the tests of 1884–85 it was learned that the clay could be removed and an effluent free from turbidity secured by the English filters at a net rate of about 1.5 mil.gal. per acre daily. But the principal point of practical significance was the marked indication of the clay passing into the sand layer, and the necessity for cleaning and reconditioning the sand layer at periods of comparatively short duration (60).

Soon after President Long gave up hope of clarifying the water by slow sand filtration his attention was directed to rapid filtration where it remained centered until the process was adopted. In his report for 1887 he expressed the hope of being "able to test in a practical way some of the new methods of filtering and purifying water . . . notably the Hyatt Pure Water System, which is now in use in twenty odd cities and towns and . . . appears to meet all essential requirements necessary to a pure and healthful water supply." Less optimistic in 1889, he said no system of filtration "has been practically tested, used or adopted for filtering successfully the water supply of any city of the magnitude of Louisville, to say nothing of the peculiar characteristics of the Ohio River water" that would justify the company in building "a filtering plant of any of the systems attracting attention." In 1891 and again in 1893 he declared that the problem was still unsolved. In 1894 Long said that Lawrence, Mass., was trying a system in a small way somewhat similar to slow sand filtration, but it would not be practicable for Louisville. Mechanical filtration was in use in a number of small cities but none approximating the size of Louisville, except in New Orleans, where the plant had failed to meet the requirements and was not accepted. Satisfactory results in smaller cities and many recent improvements led the Louisville Water Co. to hope that it could find a way for testing "some one or more methods in a practical manner."

Meanwhile, for a year in 1893–94 the company employed a chemist and bacteriologist who made tests and monthly reports. The tests showed the water to be "reasonably free from every species of zymotic or disease-producing germs"—marvelous to relate!

After years of investigating, said President Long in his report for 1895, the company finally adopted a plan for "a series of experimental tests of filtration, embracing agreements with four companies." In 1896, Long reported that these tests were about closed. They had been made under the direction of George W. Fuller, Chief Chemist and Bacteriologist. With pardonable pride, Long characterized the tests as "the first practical step taken towards solving the vexing question of filtration and purification of water supplies for large cities upon modern scientific principles. . . . We have reason to hope that the plans, specifications, and contract for such a system can be made, and the work gotten well under way, [in] the ensuing year."

Instead of such speedy action, further experiments were made. The cost of the tests to the end of 1896 was $26,776. During 1897 the water company continued, "on its own hook," further tests at an additional cost of $15,418. These tests were concluded in January 1898.

The Jewell Filter Co. of Chicago, the Cumberland Manufacturing Co. (Warren filter) of Boston, the Western Filter Co. of St. Louis, and the Harris Magneto-Electric Filter Co. of New York entered competing bids under which each supplied, installed and operated at its own expense a 0.25-mgd. unit, except that there were both a gravity and a pressure Western filter.

Besides Charles Hermany as Chief Engineer and George W. Fuller as Chief Chemist and Bacteriologist, the Louisville Water Co. was staffed as follows: Charles L. Parmelee, Assistant Engineer; Robert Spurr Weston, Assistant Chemist; Dr. Hibbert Hill, Assistant Bacteriologist; Joseph W. Ellms, Assistant Chemist; George A. Johnson, Clerk and Assistant Bacteriologist; Reuben E. Bakenhus and Harold

C. Stevens, assistants. Mechanical analyses of the filter sands used were made by Harry Clark of the Lawrence Experiment Station.

The Jewell filter was represented by the two brothers, William M. and Ira H. Jewell. The Warren filter was in charge of George A. Soper, who made a special report on its operation for its proprietor (61). Charles T. Whittier was in charge of the two Western filters.

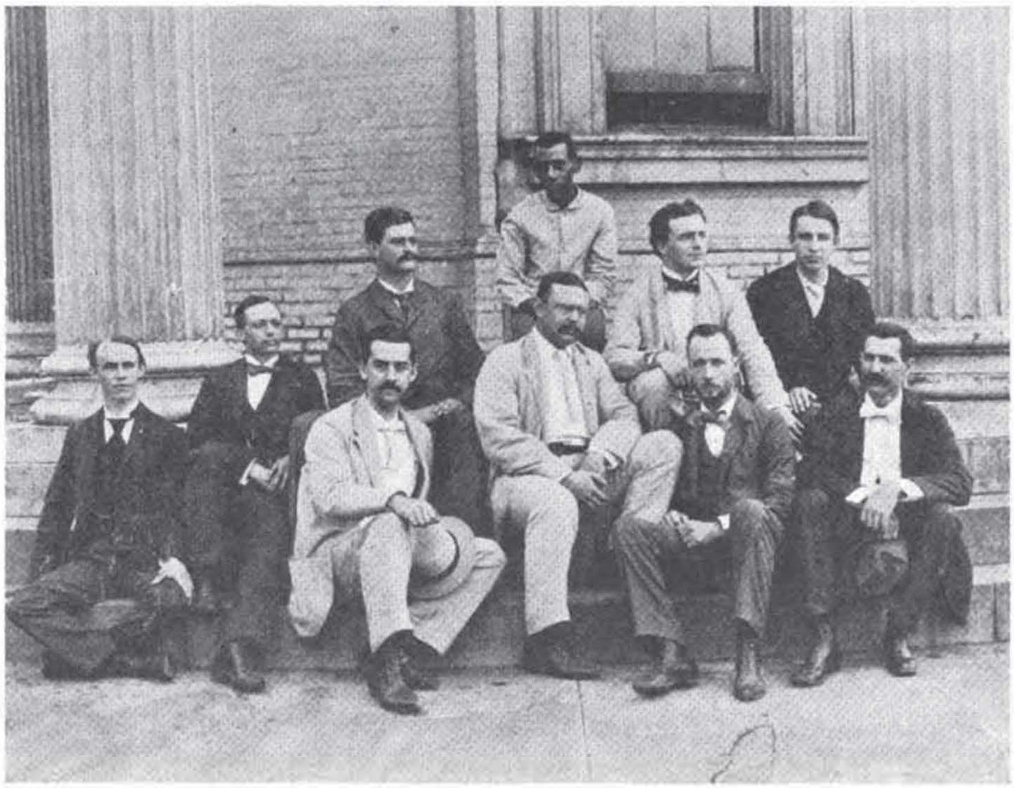

FIG. 48. THE STAFF AT THE LOUISVILLE EXPERIMENT STATION IN 1896

Back row: Robert Spurr Weston, Asst. Chemist; William, the Janitor; George A. Johnson, Clerk & Asst. Bacteriologist; Harold C. Stevens, Asst.
Front row: Reuben E. Bakenhus, Asst.; Joseph W. Ellms, Asst. Chemist; Charles L. Parmelee, Asst. Engr.; George W. Fuller, Chief Chemist & Bacteriologist; Hibbert Hill, Asst. Bacteriologist; [?] Benton, Asst. Bacteriologist
(From A.W.W.A. *Manual of Water Quality and Treatment,* 1940)

Fuller began his duties October 1, 1895; completed his main report on the apparatus of the four contestants at the end of November 1896. Studies were then made of the corrosive action of filtered water on pipes and boilers and on boiler incrustation. The water company also tested electrolytic apparatus, devised by Palmer and Brownell of the Louisville Manual Training School, and "the MacDougal Polarite System" (settling tank, clay extractor and polarite filter). Finally "devices of the company" were tested. Fuller's final report was signed October 7, 1897. Fittingly it was brought out in a thick volume (60) in a style conforming with Kirkwood's classic St. Louis report on *Filtration of River Waters in Europe* and by the same publisher.

The water experimented with at Louisville was taken from the Ohio River at the pumping station. The turbidity ranged from 1 to 5,311 ppm. The population above the pumping station was estimated at 4,500,000, of which 1,575,000 lived in 220 cities and towns. The nearest city discharging sewage into the river above the pumping station was Madison, Ind., 50 miles above Louisville, with a population of about 12,000. Although attention was given to the reduction of bacteria, interest centered in clarification—so much so that bacterial efficiency is not mentioned in the final summary and conclusions.

The apparatus and processes other than the three makes of rapid filters are dismissed briefly in the conclusions. Of two of these the report says: "The Harris Magneto-Electric System was a complete failure. The MacDougal Polarite System, as it was tested by this Company, was not applicable to the purification of the Ohio river water." Bare mention is made, in the final conclusions, of the application to the Jewell filter for a brief period of electrolytically produced chlorine.

The tests of all three makes of filters showed that the combination of sedimentation, coagulation and filtration was "correct in principle," but as used at Louisville had "several weaknesses," the most important being "the totally inadequate facilities, in all cases, for the employment of subsidence to its proper economical limits." Fuller also states:

> In addition to plain subsidence and to coagulation prior to filtration, there are times when coagulation in conjunction with subsidence can be employed to advantage in keeping clay and other suspended matter from passing on to the sand layer.

This seems to imply coagulation-aided subsidence prior to the coagulation and sedimentation practiced with the rapid filters of 1896–97. Further emphasis on the necessity for lightening the burden on the filters and for giving time for coagulation is thus stated:

> The evidence is very decisive that so far as practicable the suspended matter should be removed before reaching the sand layer, and that, at that point, the water should be thoroughly coagulated. Further, it is clear that subsidence

should be employed with waters of this character to a degree where the amount of coagulant to be applied *just before the entrance to the filter* [author's italics] should not frequently exceed 2 grains per gallon.

The full significance of this emphasis on what is now understood as presedimentation and precoagulation cannot be grasped without knowing the state of the art of rapid filtration when the Louisville experiments were being made. The Hyatt process patent of 1884 was based on the combination of coagulation and filtration, without sedimentation. In the next dozen years this was modified to give a short time for the coagulant to act and a little opportunity for sedimentation. (This appeared in some of the rival filters, partly to avoid infringement of the Hyatt patent.) In the filters tested at Louisville, there was no presedimentation and practically no time for the coagulant to act before the water passed to the filters—this, too, notwithstanding the high turbidity at times, and the fact that only a few years earlier a filter company had been brought to ruin by guaranteeing to clarify Mississippi River water by rapid filtration alone.

Three coagulants were tried at Louisville: alum, or basic sulfate of alumina; potash alum; and lime. Of these, alum was found most suitable. Independently of the filter tests, the water company made laboratory studies, the report states, of "the Anderson process" for preparing "iron hydrate directly from metallic iron"—scrap iron in a revolving horizontally placed cylinder through which water is passed. The tests indicated that the process "is not applicable for the economic and efficient purification of Ohio River water."

In addition to the inadequacy of the Jewell, Warren and Western experimental plants for presedimentation and precoagulation, Fuller describes another weakness as follows:

> The several filters represent the prevailing size in practice [sand surfaces 9.5 to 12.15 ft. in diameter], but for economy in operation the individual filters should be much larger, the limit to be determined by the successful operation of mechanical appliances to stir the sand layer effectively while it is being washed by a reverse flow of water.

Unfortunately, when the filters were built, some years later, their area was so great and the sand-stirring apparatus so cumbersome that, combined with an unsatisfactory strainer system, the filters had to be reconstructed. It should be said that in their original design, Fuller took no part. He embodied the lessons of the Louisville tests in the Little Falls plant of the East Jersey Water Co., completed in 1902.

The final conclusion of the report follows:

The general method of subsidence, coagulation and filtration is applicable to the satisfactory purification of the Ohio water at Louisville; but, as practiced by the Warren, Jewell, and Western systems during these tests, its practicality is very questionable if not inadmissable. By removing the bulk of the suspended matters from the water, large reductions could be made in the size of the filter plant, amount of coagulant, and cost of operation. On the basis of 25 mgd., these reductions when capitalized at 5 per cent would represent about $700,000. There is no room for doubt but that for a less sum than this satisfactory provisions for subsidence as outlined herein could be provided, which would not only aid in furnishing a filtered water of better quality, but would also give the water consumers a better service in other regards (60).

Convinced of the practicability of rapid filtration the directors of the company determined, August 23, 1897, "to construct a system of filtration and water purification . . . plans for which are being prepared." The estimated cost of a 25-mgd. plant, including pumping station and water tower, was $500,000. Postponements covering two years occurred. At the close of 1900, said the annual report, $254,000 had been paid on clear-water basin and filter house construction.

The directors of the water company had given Hermany a free hand to plan "such a system of filtration as he thinks will fully meet the requirements and the best interests of the company." To protect his novel features he filed a blanket caveat in the patent office "upon all designs, members, devices, combinations, arrangements and mechanisms, with their functions pertaining to the art of water filtration and purification."

Four functions of the plant designed by Hermany were removal of turbidity, color, organic matter and bacteria. Water for the existing 100-mil.gal. Crescent Hill subsiding, storage and distribution reservoir was to go to 12-mil.gal. coagulation chambers and thence to filters with a capacity of 37.5 mgd.

The chief distinguishing features of his scheme for mechanical filters, according to Hermany, were:

. . . the relatively large size and the rectangular shape of the filter tanks, each one having an area of 0.1 acre; the sand support and strainer system, composed of layers of wire netting and wire cloth; and the sand agitator system, by means of which a set of 72 agitators can be used to stir the sand in one whole bed at a time and moved bodily to any other bed, either transversely or longitudinally. In addition to these important features of the filters proper there are some new ideas in the coagulating section of the plant, which include an immense steel coagulating tank, with three concentric tanks above for preparing the coagulant; and a new coagulant feed pump, which is designed to be more exact and reliable than anything heretofore developed. [Eventually] there will be nine filters in groups of three, but only one group is to be bid upon now. Each tank is 146 ft. 11⅜ in. long, 30 ft. 3 in. wide and 8 ft. deep in the clear, giving a sand surface of 0.1 acre for each, or a unit capacity of 12½ mgd. when working at the rate of 125 mgd. an acre (62).

Construction progress was slow for several years. Whatever the cause, on March 26, 1906, the water works was put into the hands of a board of works (Trustees of the Louisville Water Co.), which included the mayor. The only director of the company on the new board was Charles R. Long, who as president of the company for many years had worked persistently for filtration. Before the end of the year he retired. The new board stated in its report for 1907 that it had found the water works in bad condition, except for the filter plant, then under construction.

Charles Hermany's death, January 18, 1908, terminated his 51 years of service on the Louisville water works, during 47 of which he had been Chief Engineer and Superintendent. The post was filled by S. Bent Russell who for many years had been on the engineering staff of the St. Louis water works, during which time he had made important studies of filtration.

Conditions encountered by Russell at Louisville and reasons for his early resignation were thus related by him 26 years later:

> When I became chief engineer of the Louisville Water Co., with which I had had no previous connection, one of the most pressing problems was to give the city clear water without further delay. The new filter plant was presumably complete. It had some new features meant for cleaning the filter tanks which proved inadequate as built although previous experiments on a small scale were reported to have given promise of success.
>
> After a while a change in the small group controlling the company forced me into a false position. I knew that radical changes would have to be made in plant and methods and also that I would not be allowed to make them. I would have great responsibility without proportionate authority. I decided I ought to resign. I made a public statement to the effect that I thought the chief engineer should have more authority. After I left, the filter plant was altered and made useful (63).

Theodore A. Leisen became chief engineer of the Louisville Water Co. August 1, 1908. He left a similar position at Wilmington, Del., where he had found an upward-flow filter plant in a useless condition and had promptly shut it down. His 1908 Louisville report stated:

In February the Crescent Hill filters, as then constructed, were completed, and arrangements made to start them in operation. It was demonstrated in the trial operation that the filtering process was satisfactory, but the devices for cleaning proved defective for the reason that a uniform distribution of the wash water could not be obtained, and in consequence continuous operation was temporarily discontinued. Investigations were started with a view to remedying the defects and after careful study and submission of the designs for the proposed operations to eminent authorities, it was decided to reconstruct the strainer system to provide means for securing an adequate and uniform supply of wash water, without otherwise materially altering the original design of the filters. Plans for the contemplated changes were immediately commenced, and the work of reconstruction carried out as rapidly as circumstances would permit. The inevitable delays consequent to such work have retarded its progress beyond expectations, but . . . it is confidently hoped that the filters will be in successful operation in May 1909.

In addition . . . plans are being prepared for a 12-mgd. coagulation basin, which will be built the coming season [1909], and, pending the completion of this, Crescent Hill Reservoir will be utilized as a coagulating basin . . . (58).

The "eminent authorities" mentioned by Leisen as approving his proposed changes were Rudolph Hering and George W. Fuller. Their report (64) indicated that, owing to imperfect working of the filters, the sand layers became clogged by the accumulation of mud removed from the water. They advised that each of the three 0.1-acre filter units be divided into two; that the sand agitating machine be abandoned; that the strainer system be remodeled in general accordance with the one designed for the Cincinnati filter plant, to give a vertical rise of wash water of 20 to 24 in. per minute; that better means be provided to remove the wash water; that in place of taking wash water from the elevated tank and distribution system a separate wash-water tank be provided; and that a 12-mgd. coagulation basin be constructed. The estimated cost of these improvements was $150,000.

The filter plant was put into "successful operation" July 13, 1909, the board of works stated, but important additional changes were to follow. Outlay to the end of 1909 had totaled $1,960,000. Leisen, in his report for that year, noted that, in addition to the changes already outlined, lateral wash-water waste troughs had been installed and means provided to supply the coagulant directly to one compartment of the Crescent Hill reservoir.

All elements aiding in the work of purification were working together in 1912, wrote Leisen in his report for that year. Until then the "full benefits from both the sedimentation reservoirs and the coagulation basins were never attainable at the same time."

Chief Engineer Leisen was succeeded in 1914 by James B. Wilson. In his report for that year Wilson states that a supplementary plant of 36-mgd. capacity, built by the Pittsburgh Manufacturing Co., was put in use on November 1. In his report for 1915 Wilson noted that the new filters required an "abnormal amount of wash water." Experiments showed that rather than change a part of the filter material it would be better to lower the wash-water troughs. This had been done for three of twelve filters and had decreased the wash 20 per cent. The same thing was done for the other nine filters in 1916, saving 30 per cent of wash water. Use of the new filters, except for emergencies, was temporarily discontinued.

Reconstruction of the new filters was carried out early in 1924. Reasons for their almost complete abandonment for many years were stated by Superintendent of Filtration W. H. Lovejoy in 1925:

> In 1914 a second battery of twelve 3-mgd. units was built in the north half of the filter house, which had been left for that purpose in the original construction. Soon after starting these latter beds certain weaknesses began to show up that were due to features overlooked in both the design and the equipment. After running these units for two or three years under the constant burden of frequent breakdowns and repairs, we finally were forced to let them lie idle and keep only a part of the units ready for service to help out the old filters in case of peak loads. This was the situation up to about a year ago, when our normal peak loads had increased to such a point that we were forced to start preparations to put these north filters in shape for dependable use (65).

Summarized, the troubles with the filters in question were: (1) filter gallery crowded; (2) operating floor too narrow; (3) troughs too high above sand; (4) all valves too light, and operating motors also too light; (5) effluent controllers stuck and so located that they couldn't be taken apart for repairs.

Lovejoy credited the Hermany filters of 1909 (which were soon revamped, as already described) with having been in continuous and successful operation up to 1925. By 1927, the 72-mgd. combined capacity of the old and new filters was sometimes exceeded due to "operating troubles from algae." Moreover, there was "some doubt as to the condition of the steel filter shells and steel false bottoms in the Hermany filters." Accordingly, Alvord, Burdick & Howson were instructed to plan a 48-mgd. addition to the plant, thus permitting an entire rebuilding of the Hermany filters if this should prove necessary" (58). The third set of filters, combined with the second, gave a capacity of

84 mgd. Removal of the Hermany filters by company forces was begun October 28, 1930. Six new 6-mgd. filters built by contract were put into use in June 1931. They occupied the same space and had the same capacity as the old Hermany filters and restored the capacity of the plant to 120 mgd.

Another important addition to the physical equipment of the plant was made in 1933 when Dorr flocculators were installed in the coagulation basins.

Algae troubles were encountered immediately after the original plant was put into use and again the next year. The three sieges of 1909–10 were described by Lovejoy, who was serving as chemist and bacteriologist of the plant (66). About August 1, the growths cut the filter runs from twelve hours to five. From August 5 to 21, the runs were about six hours; then the filters slowly recovered.

A worse siege of algae occurred from September 1 to October 1, with filter runs reduced to an average of two and one-half hours. The turbidity averaged 50 as against 150 during the August siege. The third siege was worse than the first two. It began August 12, 1910. In those days average length of filter runs was cut from fourteen to one and one-half hours. Use of copper sulfate was decided on but it took a week to get it. On August 20, application of the agent was begun. In three days the filter runs were increased to thirteen hours.

In 1913, Stover, then chemist and bacteriologist of the plant, noted that it would naturally be supposed that the operation of a filter plant would be easiest when bacteria and suspended matters in the water were lowest but many filter superintendents had found "that warm weather and clean water bring troubles peculiarly their own." When the Ohio River has a turbidity below 30 ppm., he said, the length of runs almost invariably decreases, and "if such turbidities are accompanied by micro-organisms, still greater decreases follow. Copper sulfate increased the length of the runs during the recent algae troubles but hypochlorite did not (67).

Returning to the subject of his earlier paper, Lovejoy wrote in 1928: "After experiencing recurring sieges of algae regularly for about eighteen years with their serious and sometimes disastrous effects on plant operation a new scheme of treatment was adopted" (68).

A double-purpose dredge boat was built, tried experimentally in 1927 and put into use in 1928. It was 20 x 40 ft. and 4 ft. deep. On it was mounted an 8-in. electric-driven dredge pump. To this was attached a flexible hose with a suction hood at its lower end. An 8-in. pipeline, on pontoons, was provided to carry the sucked-up mud to a drain when the apparatus was used to clean the basin. But when used to create artificial turbidity the mud was discharged into the raw water at the inlet end of the settling basin. Some of the suspended matter is re-deposited in the settling basin. Some is carried forward to the coagulating basin. "The residual turbidity of 100 ppm. entering the basin," says Lovejoy, "is sufficient to provide a nucleus for an excellent floc which carries down an additional quantity of organisms . . . before the water goes to the filters." He knew artificial turbidity was used for laboratory work but not "on a large scale" (68).

Lovejoy's article prompted Lewis V. Carpenter to report two earlier instances of this method of algae control—one in 1925 at Evanston, Ill., and the other in 1924 at Huntington, W.Va. (69).

In his report for 1928, Chief Engineer Chambers said that the dredge was used for mud diffusion 110 hours in August–September. Besides removing "practically all the mud" remaining in the north basin, it held the filter runs "up to an average well above 20 hours." In 1929, the dredge was operated 28 days for a total of 143 hours in the south basin solely to create artificial turbidity for algae control. This also cleaned the basin.

Comparative tests of copper sulfate, prechlorination and artificial turbidity for algae removal in August–September 1929, indicated that the latter is the most effective and cheapest of the three. The two basins had not been emptied for cleaning since 1924. Under the old methods they would have been due for cleaning in 1927 and 1929. Dredging had kept them "virtually cleaned without interruption in the service" (58).

The worst drought in a hundred years, with only 8.47 in. of rainfall in April–November against a normal of 23.47, occurred in 1930. Suspended matter in the raw water averaged only 60 ppm. This produced the worst algae trouble in 22 years, said the 1930 report, but

. . . by the use of artificial turbidity and a high washing rate in the filters we were able to hold up filter runs better than ever before. . . . Difficulties from high algae content, high hardness and bad tastes and odors complicated our operation very seriously. Phenol taste developed late in December, and this was handled fairly successfully with pre-ammoniation. However, following this a mouldy organic taste appeared which has so far withstood all the varied treatments which we have tried. This was prevalent all along the Ohio River from Pittsburgh to Cairo and apparently none of the plants on the river were able to remove it or combat it perceptibly.

Besides this calamity and a spring cleaning, a fall cleaning was necessitated by the "accumulation of a heavy mat of organisms and organic matter which caused septic action to take place in the basins . . . the first time this has happened in the history of the plant operation. [It] was caused by the long period of drought *and clear water in the reservoir* [Author's italics]."

Prechlorination by hypochlorite of lime was mentioned as under consideration in Leisen's report of 1911 (70) but was not put in use until May 1, 1914. Liquid chlorine was substituted in 1915 and became fixed practice. Postchlorination was added in 1924. Hydrated lime for pH or acidity control has been used continuously since August 1931. Copper sulfate to keep down algae has been used from time to time since August 20, 1909, only 38 days after the plant was put into operation, but from 1927 onward chief reliance has been put on artificial turbidity when the river water has been relatively clear. Pre-ammoniation to prevent the formation of phenolic tastes and activated carbon to control tastes and odors due to micro-organisms and organic matter were adopted in 1930 and 1931 respectively. Since 1936, wrote Filtration Superintendent Lovejoy on August 26, 1942 (71), "pre- and superchlorination have supplanted artificial turbidity for combating algae and for the lengthening of filter runs. Prechlorination at rates of 20–30 lb. per million gallons has been highly successful in solving this problem."

In common with southern cities generally, typhoid was high in Louisville until the twentieth century and persisted at a higher rate than in many other parts of the country until quite recently. For the years 1906–10 the typhoid death rate was 52.7 per 100,000. It fell to 19.7 for 1911–15, to 9.7 for 1916–20, 4.9 for 1921–25 and on down to 0.9 for 1936–40 (72). The filters had gone into use in 1910 but not until 1912 was there complete functioning together of all three purification elements—filtration, sedimentation and coagulation. In 1914–15 prechlorination was begun and in 1924 postchlorination was added. Doubtless these improvements in the water treatment contributed to the decline of typhoid, following the law of diminishing returns and supplemented by other causes for typhoid reduction.

A memorial gateway to Hermany was dedicated in 1930. On a bronze tablet stating that he served as Chief Engineer of the Louisville Water Co. from 1861 to 1908, these words appear: A PIONEER IN WATER FILTRATION.

A pioneer Hermany was. He conducted experiments with slow sand filters for several years in the 1880's. Finding that such filters could not clarify the muddy water of the Ohio he watched the early use of rapid or mechanical filters. Conflicting claims of rival filter companies led Hermany and the directors of the Louisville Water Co. to give the filter companies a free hand for each to show what his make of filter could do with standard working units. Each company was to operate its own filter, with its own staff, at its own expense, but subject to the technical supervision of Hermany and an able laboratory staff headed by George W. Fuller.

To Fuller belongs the credit for drawing revolutionary conclusions from the Louisville experiments, but he had no chance to apply them at Louisville. Hermany designed the plant. Although Fuller understood that he would be consulted, he was not.

The greatest lesson of the Louisville experiments was the important role of presedimentation and precoagulation in the operation of mechanical filters treating highly turbid waters. Fuller's own words on this subject, written to the author nearly forty years after the Louisville experiments and only a few months before Fuller's death, follow:

> [The work at Louisville] was genuine pioneering in dealing with coagulation and preparation of turbid waters for application to rapid filters comparable to practice of that date [with filters] operated for the most part under guidance of filter companies without technical advice (73).

How little work filters perform at Louisville compared with the previous treatment of the water is amazing. Figures supplied in 1934 by Lovejoy show that for the years 1910–33 the average percentage of reductions by the three original elements of the plant were:

Turbidity: Filters, 10 per cent, with yearly range from 16.5 in 1923 to 5.5 in 1912.

Bacteria: Filters, 9.6 per cent, with two years showing increases due to aftergrowths caused by prechlorination. For the three years the bacterial removal was reported for filtration and chlorination in combination. For the other years the range was high—0.02 in 1919 to 30.9 for 1930. Chlorination alone during the 19 years it was practiced removed an average of 0.9 per cent of the bacteria in the raw water, with a range from 1.8 to 11.4 per cent.

As will be understood by most readers, the percentage distribution of work done by the main elements of the process depends largely upon the turbidities and bacterial counts of the raw water. This is illustrated by the year of the great drought, 1930, when with a raw-water turbidity of only 60 ppm. sedimentation did only 20 per cent of the work. Coagulation came to the rescue with 67 per cent (both unprecedented figures). Filtration did 13 per cent. In this same drought year the bacteria in the raw water averaged 3,492 and were reduced 14.7 per cent by sedimentation. Here also coagulation did a good job (47 per cent reduction) but not so good as in other years nor as good as sedimentation the same year. The 30.9 reduction by filtration in 1930 was three times the average for the whole period and was approached no nearer than 13.4 per cent. In this dry year chlorination did valiant work with 7.4 per cent of the bacterial reduction to its credit.

Cincinnati's Rapid Filters

Shortly after George W. Fuller completed his Louisville experiments he became Chief Chemist and Bacteriologist for a filter testing station at Cincinnati. The object of the test, wrote George H. Benzenburg, who succeeded George F. Bauscaren as Chief Engineer of the filter plant finally built, was to obtain "reliable data as to the relative merits of the so-called English and [the] mechanical filtering systems in the purification of the Ohio River water" (74). The main tests extended from March 28, 1898, to January 25, 1899. The final conclusion of Fuller's report was that either modified English slow sand filters or American rapid filters would purify the Ohio River but that the latter would be preferable (75). After many delays a 112-mgd. plant, using lime and sulfate of iron as coagulants, was put into use October 22, 1907.

The crude beginnings of a public water supply through private enterprise at Cincinnati date from 1797, when water from wells was hauled through the streets and sold from door to door. Competitors soon began to sell Ohio River water, delivered first by sled, then by cart. Running water was first distributed through pipes in 1821. In 1824 there began a movement for municipal ownership that persisted despite three defeats until the city bought the works in 1839. From that time until the rapid filtration plant was completed in 1907 there was an almost continuous movement for more and better water than the Ohio River in its natural state afforded. Settling reservoirs were recommended in 1861; both these and filters by James P. Kirkwood in 1865; settling reservoirs again in 1871; these and filters in 1880 or 1881. In 1888 sedimentation experiments were made. In 1896 settling reservoirs and filters were recommended for the third time but in 1897 the commission to which the matter was referred advised that further investigations be made before deciding on any method of treatment. These resulted in the testing station and then in the large plant already mentioned.

Major changes in the Cincinnati plant since it was put in use are typical of the problems and progress in the art of water purification during the past thirty-five years. These changes were summarized for use here by Clarence Bahlman (76), Superintendent of Filtration:

Chlorination of the filtrate was begun in 1911; first, occasionally with hypochlorite of lime; then intermittently with liquid chlorine (1915–17); and continuously with liquid chlorine from 1918.

The brass screen which originally separated the 8-in. layer of gravel from the 30-in. sand bed having failed, it was removed in 1915; the depth of the gravel was increased to 14 in. and the sand placed directly on the gravel.

Alum as a coagulant, applied in the presedimentation reservoirs at times of low runoff in the river, was introduced in 1926. It was used from 5 to 20 per cent of the time up to 1934. Iron sulfate and lime are applied constantly to the coagulation basins.

Growth of sand from incrustations caused removal of the excess in 1929 and the placing of 12 in. of new sand above the old sand left in the filter. This was the only renewal of sand from the opening of the plant in 1907 to late in 1934.

Algal growths in the river, following the completion of additional dams in the Ohio River, have often resulted in very short filter runs. The wash-water reservoir of 182,000 gal. was increased to 843,000 gal in 1930.

Intense phenolic tastes which first appeared in 1918, but sometimes do not occur for several years, were completely eliminated between 1927 and 1931 by suspending chlorination and resorting to double coagulation and high lime treatment, up to 1 to 3 parts of caustic alkalinity in the effluent.

Ammonia-chlorine treatment to combat occasional phenolic and algal tastes was provided in 1931. It has been very successful but in one case of a heavy "slug" of phenol did not completely prevent taste formation.

Activated carbon treatment at the entrance to the coagulation basins was provided for in 1931 but not used until 1933 and 1934 when intense algal tastes occurred. Although not always completely successful, it was sufficiently so to stop all complaints.

Bloodworms or Chironomous in the larval state have caused growths which have broken loose from the side walls and slopes of the 19-mil.gal. open clear-well. Contrary to experience elsewhere, the higher residual chlorine made possible by ammoniation has not eliminated these growths.

The drought of 1934 resulted in maximum capacity rates of filtration on several days and led to a study for probable enlargement of the plant.

Enlargement of the plant to a capacity of 160 mgd. was made in 1936–38. Since then it has sometimes been run at a rate of 200 mgd. New features introduced were pneumatic unloading of chemicals, dry chemical feed, mixing by hydraulic jump, flocculators, sludge collectors and continuous removal of sludge.

In the earlier years of my quarter-century experiences at this plant, it seemed to us that a sparkling clear water of uniform bacterial quality was all that we were striving for. In the last decade or so, however, we note an ever increasing consumers' demand for a water free from all objectionable and unnatural tastes, and an increasing interest on the part of industry as to the chemical constitution of water. Although the average annual total hardness is only 100 ppm., the hardness during summer months often approaches 170 ppm., of which 75 per cent is calcium sulfate. Softening the water is, therefore, receiving some attention.

Typhoid was high at Cincinnati until the filtration plant was put in operation. The epidemic of 1887 caused a typhoid death rate of 142 per 100,000, according to Johnson's "Typhoid Toll" (77), compared with a range of 42 to 56 for the five preceding years, and 40 to 71 after that, the 71 being for the year immediately following the epidemic. Filtered water came into use late in November 1907, thus having little effect on typhoid that year. The rate for the years 1902–06 was 59 and for 1908–13 only 11 per 100,000 (77). For 1916–20 the rate was 3.4, for 1936–40 was 1.1; for 1941, 0.2 and for 1942 it was 0.4 per 100,000 (72).

Cincinnati's quest for pure water through a century and a half centered almost wholly on quantity until 1860. Then it became a quest for purer and ever purer water, culminating in rapid sand filtration to which have been added such accessories as chlorine disinfection and taste and odor control by ammonia and activated carbon.

St. Louis's Rapid Filters

Need for removing the heavy burden of sediment from the water supply of St. Louis was recognized at the inception of the first water works in 1829, but the little that was attempted by sedimentation during the next thirty years was nullified by deposits in the small reservoirs provided. In 1865, James P. Kirkwood made plans for settling basins and filters (78). They were approved by the special water commission and he was sent to Europe to get data on practice there. Strong opposition to filtration resulted in the recall of Kirkwood before his report (79) was completed and to building new works with settling basins only.

It is now obvious that the slow sand filter proposed by Kirkwood in 1865 would have been a sad failure at St. Louis, even with more presedimentation than he proposed. Coagulation was necessary. L. H. Gardner showed its possibilities in 1884 by his large-scale demonstration in a St. Louis reservoir, but that seems to have made little or no impression on the city officials (1). Tests of upward-flow filters with reverse-flow wash soon followed (78). Pioneer studies of sedimentation were made by James A. Seddons in 1888–89, preparatory to an extension of the settling reservoir (80). Tests of the "Anderson process" of precoagulation and slow sand filtration, the coagulant being comminuted metallic iron produced in revolving cylinders, were made in the early nineties (78) (see Chap. XVIII). In view of the scientific direction given to these tests it seems a pity that they were not concerned with rapid filters, then widely used but on a small scale. The coming World's Fair at St. Louis led or drove the city to adopt coagulation as an aid to sedimentation and prepared the way for rapid filtration, achieved in 1915, fifty years after the water commission had been forced to resign for its approval of Kirkwood's plan for sedimentation and filtration. The plant of 1915 was the largest installation of rapid filters yet made, with a capacity of 120 mgd. It was located at Chain of Rocks, on the Mississippi River, some miles above the old settling reservoirs and pumping station. In 1929, an 80-mgd. plant was completed at Howard Bend, on the Missouri River, 13 miles west of the city limits, thus providing two independent sources of supply.

Operating methods at both plants, as described February 28, 1934, for use here, by Chief Chemist August V. Graf, were: At both plants, double coagulation, first with milk of lime and sulfate of iron, then with sulfate of alumina, is practiced. Secondary coagulation is necessary to provide floc for successful filtration. Occasionally more sulfate of alumina than is necessary for flocculation is provided to aid in reducing the normal carbonate alkalinity below 30 ppm. The average amount of lime used at Chain of Rocks in the ten years 1924–33 was 5.2 gpg., resulting in a reduction in hardness of 74 ppm. (81).

At the Howard Bend plant, in the language of Mr. Graf, the flow pattern is as follows:

The water enters a shore intake, is pumped into a rising well from whence it flows through a number of presedimentation basins, thence through a rapid mixing conduit where milk of lime and ferrous sulfate are added to the water, through five tangential conditioning basins, through the primary coagulation basins, thence through two large sedimentation basins operated in parallel, through another rapid mixing conduit where aluminum sulfate is added, through a third large basin and thence to the carbonation chamber where carbon dioxide is added, through a conditioning basin and thence to the filters.

Sludge removal at the two plants is a large undertaking, as the following data from Mr. Graf's notes of 1934 show:

At the Chain of Rocks the amount of mud removed averaged 350,000 tons a year for the past 10 years. About half of this was removed by opening the sewer gates for one-half hour at varying intervals and the remainder by labor and teams. The teams were used to draw scrapers which cut off portions of the mass of mud and dragged them to a central gutter, through which water was flowing. The men were provided with scrapers which were used as such and also as braces to keep small A-shaped boxes in place as the mud drawn by the horses and the water used to aid in removing the mud were carried along by the boxes. Since 1928, small tractors, equipped with bulldozers, have been used to push the mud to the central gutter. A few men, provided with scrapers, are used to remove the mud from the sloping sides and to clean up after the tractors.

At Howard Bend the sewer gates on the presedimentation basins are opened as often as necessary to keep the sludge depth below a certain height. When enough solid material, which is not removed by opening the sewer gates, has accumulated, the basins are taken out of service and are cleaned by means of streams from fire hoses. The basins are comparatively small and the bottoms have decided slopes to the sewer outlets. The primary coagulation basins are equipped with mechanical sludge removers which makes draining and cleaning of these basins unnecessary. The sludge is pumped from these basins, a small part being added to the raw water on its way to the presedimentation basins and the greater part being used to fill the low places around the plant. Sludge disposal is not a problem at either plant (81).

In epitome, St. Louis depended on water from wells or the Missouri, hauled to customers from about 1800 to 1829; then, for decades, on water pumped from the river to settling reservoirs of inadequate capacity. After a century of such service, sedimentation was aided by coagulation. Rapid filtration was provided in 1915 and has been supplemented in later years by various accessory innovations, as already outlined.

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