A BRIEF HISTORY AND DESCRIPTION OF THE RICHMOND WATER WORKS.

By Charles E. Bolling, Superintendent Water Works, Richmond, Virginia.

Richmond was chartered in 1782, and from that time to 1832 the citizens got water from springs and wells in their midst. At some time, early in the present century, a wooden conduit, of bored pine logs, fastened together by driving the smaller end into the larger, was laid from a bold spring in the eastern part of the city along the principal street for over a mile, the size of the bore was three inches. This pipe furnished several taverns and many citizens. Often now in making excavations in the streets, we uncover this ancient wooden conduit, and find it still sound and undecayed. I mention this, as it may be of interest to those who are now considering the laying of wooden mains.

In the year 1830, the city of Richmond having a population of 16,-060 people, decided, by a vote of the citizens, to construct Water Works. The City Council engaged Mr. Albert Stein, formerly a resident of Philadelphia to prepare plans and supervise the construction. It is necessary to describe the situation of Richmond, in order clearly to understand. Richmond is on James River, at the head of tide water, the topography of its site is exceedingly varying, consisting of a succession of hills and valleys, differing in elevation as much as one hundred and sixty feet. From the head of tide water, the river channel rises rapidly along a rocky bed, and at a distance of a mile and a quarter, it has reached a height of forty feet above mean tide. At this time, a part of the James River and Kanawha Canal had been constructed along the northern shore of the river, and its water surface was eighty-three feet above tide. Here Mr. Stein selected a site for the pumps and recommended that power be taken from the James River and Kanawha Canal under a head of forty feet above the river. This plan, however, was not carried out. The power was obtained from a small forebay, parellel with and below the canal, about 500 ft. long, which was supplied by means of a low wooden dam built upon the rock ledges, and which afforded a head of ten feet. This water power was leased. The wheel and pump were furnished by William Kemble of New York. A low breast wheel, operated a double acting horizontal pump of 400,000 gallons daily capacity. From the pump to the reservoir, situated on a hill 2,500 feet distance and 160 feet above it, an eight-inch cast iron main was laid. The dimensions of the reservoir were 194x104x10 ft. 8 inches, and its capacity one million gallons. The reservoir divided into two equal compartments by a brick wall, the enclosing banks of clay, inner slopes and bottom paved with brick. In one compartment a filter bed 32 1-2 ft.x16 ft. and 3 feet above the bottom of the reservoir, was constructed. The bed consisted of layers of coarse gravel, fine gravel and sand. By means of the pipe arrangement water was forced upward and finally found its way over the division wall into the other compartment of the reservoir. For the purpose of cleaning the bed, water could be admitted from the surface, and wasted through the pump main, by means of a waste branch, into a ravine. Mr. Stein states in his report "that this was the largest filtering bed in the United States, and says also "that he was doubtful

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of its proving a success." The water in the reservoir was 21 1-2 feet higher than the highest point in the city, and was supplied through a 10 inch main 6,175 feet long, estimated to deliver 400,000 gallons daily; and according to Mr. Stein's calculations, furnished 4,000 families, allowing 100 gallons for each family. From the terminus of the main, smaller distributing pipes were laid, and a few fire plugs erected. The cost of the works &c., exclusive of the dam and forebay, was $76,860. The works were accepted by the city February 17, 1832. In 1833, another water wheel and pump of the same design and capacity was erected, and another 8 inch main laid to the reservoir. In 1835 the filter bed was pronounced a failure for clarifying the water, and its use abandoned. In 1835 the city purchased the dam, forebay and water power rights for $25,000, and five years later replaced a portion of the wooden dam, with a stone dam. In 1843 the population then numbering 23,000, the reservoir capacity was increased to seven million gallons, by raising the banks, and a new addition. In 1848, there were 1,212 water takers, and the supply becoming scarce, a new supply main 12 inches in diameter, 6,175 feet long was laid to the city. In 1849 two more pumps of the same design, but slightly greater capacity were erected, and two 8 inch mains laid to the Reservoir. Five years later came the demand for more pumps, and two more wheels and pumps were added, of like design to the others, but larger, having a capacity of 2,264,000 gallons per day, and two mains of 12 inch diameter were laid from the pump house to the reservoir. The water takers at this time numbered 1,882, the pumping capacity was 4,453,107 gallons and the reservoir capacity 7,000,000 gallons.

In 1860 a 24 inch water main was laid from the reservoir to the city. In 1873 the supply again becoming scarce, the population amounting to 56,800, more pumps were needed. Under the direction of Emile Geyelin, of Philadelphia, two double acting horizontal pumps, 17 inch cylinders, were put in and were operated by a Jonval Turbine Wheel 9 feet in diameter under a 12 foot head, having a daily capacity of 3,000,000 gallons, during their construction, as a temporary expedient, a Guild and Garrison steam pump, 800,000 gallons capacity, was erected on the Canal. This was subsequently sold. A 24 inch water main was laid from the pump house to the reservoir. The pumping capacity, after the completion of this work, was 7,558,000 the daily consumption 2,518,000 gallons, and the rate per capita 44 gallons. The city was now rapidly growing, and houses being erected in the higher portions, of nearly equal elevation to the water surface in the reservoir, and supplied by mains along streets of widely differing grades. Greater pressure was demanded. Up to this time no plan had been carefully considered or adopted for future needs, but, step by step, as the demand came, pumps and mains had been added, thereby greatly increasing the cost. Col. W. E. Cutshaw, city engineer, was directed by the Council to prepare plans for a new reservoir. After several surveys he recommended a site and plan for a new reservoir, which was adopted and built under his supervision in the years 1874 and 1875. The site chosen was a high and level plateau, about a mile west of the old reservoir, and two-thirds of a mile from the river where there was a good and convenient location for a future pumping station. This reservoir, rectangular in shape is divided into two equal compartments by a division bank. Its capacity is 45,000,000 gallons. The banks are 24 feet high, of good puddle clay spread in thin layers and carefully

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consolidated by rolling with corrugated rollers. The inner slopes are 2 to 1, paved with bricks laid on edge in hydraulic cement. The bottom is covered with 6 inches of concrete. The outer slopes are well turfed. On the top of the banks there is a twenty foot gravel roadway, margined by a granite coping and iron fence. The bottom of the reservoir has a settling space 3 1-2 feet below the flow line to the city. In the division bank are constructed the inlet and outlet chambers, made of brick and stone masonry. Water can be fed to either compartment from the inlet chamber, at the top or bottom. The outlet chamber has three gates at different heights on each side, opening into the compartments through which the water can be supplied to the city. Two 30 inch cast iron mains lead from the outside to the inlet chamber, with gate valves on the outside of the bank, and two (2) 30 inch supply mains pass from the outlet chamber, with gate valves on the outside. A 24-inch cast iron main leads from the old pumping station past the lower reservoir, to the new reservoir. This main is so connected that it can be used as pump main from the old pumping station, or to feed the lower reservoir from the new, or as a supply main to the city. A 30 inch cast iron main from the outlet chamber 7,100 feet long extends from the reservoir to the city. The surface of the water is 37 feet higher than that of the old reservoir. It was completed and put into service January, 1876.

Four years afterwards, owing to increased consumption, came again the demand for more pumping machinery. The daily consumption was then 5,850,000 gallons, and the rate per capita 92 gallons, double what it was ten years before. Surveys for a new pumping station were made by Col. Cutshaw, city engineer, resulting in his recommendation of the erection of a water power plant of 12,000,000 daily capacity, situated two miles above the old station, and taking its power from the old James River and Kanawha Canal, under a head of 20 feet. This location was opposite the new reservoir and about 3,600 feet distant. The construction carried with it the cost of deepening and widening the canal for a distance of 6 1-2 miles westward, and the enlargement of the connecting feeder with James River above Bosher's Dam, a substantial stone dam in the river, built by the Canal Co. This work was commenced in 1880, and completed in 1882. The canal area was enlarged so as to allow for a flow of 705 cubic feet per second, thus providing for future additions to the pumps as the wheels then being put in, required only 300 cubic feet per second. The pumping machinery was designed by Prof. Charles A. Smith, of St. Louis, and was furnished by H. A. Ramsay & Co., of Baltimore. The water wheel—termed a vertical partial turbine—23 1-2 feet in diameter, was keyed directly to the shaft operating three vertical acting plunger pumps, the crank arms on the shaft placed at angles of 120 degrees were three in number. There were three sets of pumps, each having a daily capacity of four million gallons. The water after passing through the wheels is delivered into the Richmond level of the James river and Kanawha Canal, where it is again used by large water power manufactories in the city While these works were being built, Richmond suffered from water famine, and to meet the emergency a Worthington steam pump of six million capacity was quickly erected. This is the same pump used at the Centennial Grounds in Philadelphia in 1876. It is now kept in reserve and not used. Owing to certain constructions made by the R. A. R. R. Co. who succeeded to the property

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of the canal, and abandoned its use for navigation, the efficiency of the new water wheels was much reduced, so much so that in 1891, I recommended their removal, and the substitution of Special Lefel Wheels, connecting them with the present shafts of the pumps by means of spur and pinion gears. This was carried out, and these have now been in successful operation for nine years, the water is lifted by these pumps through a 30 inch main to the new reservoir, 165 ft. above the pumps. In 1898 two of the old low breast wheels at the old station were completely broken down and useless, they were removed. These wheels were 18 feetx16 feet. In place of these a McCormick turbine wheel, 45 inches in diameter was put in, and connected by spur and pinion gearing to the pumps. The pump cylinders were enlarged slightly, and the speed increased. By this change the capacity of these two pumps was increased seventy per cent., though operated under the same head of water.

As a general summary, Richmond has two pumping stations and a steam auxiliary pump, with a total daily capacity of 24 million gallons; two reservoirs, one of ten million, the other of forty-five million capacity, either pumping plant can be used to supply either or both reservoirs. From the old reservoir, which furnishes the low service, there are three separate supply mains. From the new or upper reservoir, two separate supply mains, and water can also be fed to the lower reservoir. Should the Canal, furnishing power to the new pumps, be injured or cut off, the old pumps and steam pump will fill the higher reservoir, or if the old station was injured or thrown out of service, the upper station will supply the whole city. In other words we are doubly protected. The distribution is divided into three services, a high, low and intermediate. There are 28,700 feet of pump mains, 10,-972 feet of supply mains, 486,846 feet of distribution mains, 590 fire hydrants, 14,554 taps (of which about 12,000 are in use), and 4,296 water meters. Our daily consumption is ten million gallons and the present rate per capita 99.

Meters, though mentioned last, I regard as the greatest improvement made to the Water Department, during my fifteen years administration.

After many years of persuasion, the City Council three years ago adopted the meter system, since then 2,500 meters have been set, and due to them, our daily consumption has been reduced over 40 per cent., the pressure at the high points has been nearly trebled and by an outlay of $23,000 for meters the city has saved the expenditure of $270,-000 for more pumps and mains.

The members of this Association, who visit our pumping stations, will find at work the wheels and pumps erected in 1830, along with those erected in 1898, and it will be interesting to see the advancement, step by step in water wheels and pumps. Nowhere else to be found in the United States, extending over so long a period as seventy years.

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President Clayton:—Gentlemen you have heard this interesting paper of Mr. Bolling. What action will you take in regard to it?

Mr. Maignen:—I would ask Mr. Bolling what is the actual consumption?

Mr. Bolling:—The consumption averages 10 million gallons a day. An average is an uncertain thing when carried through a period ot 365 days. Our worst conditions are in extremely cold weather, when we suffer more, from anchor ice which clogs our pumps and wheels, than from anything else, and prior to putting in the meters,—when we had no meters,—we suffered much at the high points from great waste at the low points. We have pumped continuously for over thirty days seventeen millions gallons a day, under the most adverse circumstances, with steam and water power.

Mr. Maignen:—If you had to locate a filter plant, where would you locate it?

Mr. Bolling:—Our river starting at tide, in a distance of nine miles rises 113 feet. Our power is taken from the old James River Canal into which empties several streams, draining a large area. The falls of the river are such that we can lead water by gravity from the river to a large sedimentary basin, and the canal, which furnishes the power will intercept and receive the surface water, and these streams. With about 20 day's sedimentation of our water, we get rid of 80 per cent. of the muddy deposit, and there is a great improvement in the water from a bacteriological standpoint, although there are very few bacteria in the water, as Dr. Levy remarked yesterday. I believe the water carried through a period of 20 day's sedimentary storage would meet the ordinary conditions of clear water. Secondary treatment, if necessary, could be carried on by means of lower basins where a coagulant couid be admitted and the decanted water passed to the pumps and filter plants at a point very near the pumps. could be easily constructed when necessary and the water flow by gravity to the pumps. The water sediments in the present reservoir to some extent, but not so much as if in an actual state of quiescence, as the passage from its inlet to its outlet takes about five days and that does not remove as much of the muddy deposit as we could desire.

Mr. Maignen:—What would you think of using the new reservoirs for sedimentation purposes, employing centrifugal pumps actuated by an electric motor fed from the river water power, to raise the sedimented water into the filters placed near by and from which the filtered water would flow direct to the city, supplying the higher part with filtered water, and what water was not consumed would overflow into the old reservoir which would supply the lower part of the city with filtered water, as now is the case, with this difference, that all the city would have filtered water from both elevations?

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Mr. Bolling:—The only change necessary would be the construction of a pumping station to lift the water from the present basin, pass it through the filter beds, and then pump it from the filter to the city. I think that would be the only change needed?

Mr. Maignen:—I think that is so.

Mr. Bolling:—That practice would be more expensive than the construction of sedimentation basins. We have gone into that, and considering the additional cost of the coagulant and the small amount of sedimentation obtained in our present reservoirs has led us to give up that idea. The water sediments in the reservoir, to some extent, as it slowly passes through the reservoir, but it is only in the reservoir five days, and in that time there is not enough of the mud in solution removed from the water as is necessary.

Mr. Trautwine:—In regard to Mr. Bolling's mention of his difficulty with anchor ice, I would say that in Philadelphia, at the steam pumping stations, that difficulty is overcome by discharging the outboard delivery from the steam pumps just above the intakes. The hot water from that delivery keeps the intakes free from anchor ice.

Mr. Bolling:—In regard to the anchor ice, I would say that all of our steam pumps are constructed in the method suggested by Mr. Trautwine—the condensed water is discharged from the pumps into the canal just above the intake. We have no trouble from anchor ice with the steam pumps. It is only with the water power pumps where we have suffered, and we propose making some experiments by injecting steam into the water wheels where the guides get into trouble.

President Clayton:—The next paper on the programme is by Mr. F. A. W. Davis, Vice-President and Treasurer of the Water Works, Indianapolis, Ind. The title of the paper, "He who runs may read" is a review of a paper read last year on clauses in certain franchises.

Mr. Davis:—Mr. President and Gentlemen of the Association—Preliminary to reading my paper I would like to say that heretofore I have brought you such information as I could regarding the physical property of our works. The paper which I shall read is a review of a paper upon franchises, or rather certain clauses of franchises. Before reading the paper I wish to call your attention to a photograph which I will leave here so that you can see it, and with the photograph are some slips giving details of an experiment made with a ten inch well. You will find that the slips will give you a good deal of information as to the use of air, the quantity of water lifted by the air, the quantity of air used, and some little idea of the expansive force and temperature of the air. The temperature of the water and the temperature of the atmosphere is included on these slips. I bring these slips to your notice because so many inquiries have been received asking for information; I believe the only inquiry, so far as I can recall now, that I have not answered is

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as to the cost of the air lift system. I have not felt that I was justified in presenting to you a statement of the cost of lifting water by air without having a boiler set aside for this special use, and having the coal used in the boiler weighed and also having everything that pertained to the operation added to the cost. You will find one interesting statement here, and that is to the effect that you will have to exercise judgment in the use of air. You will find a very great difference in the percentage. Properly used, it is a good power, but it can be wasted, as you will learn by an examination of the slips.

I have also brought you some statements which have come from St. Louis on electrolysis, and a few samples of the action of electrolysis; an action which is entirely new in all my experience with electricity upon a comparatively new eight inch wrought iron main. The pipe is entirely destroyed. These samples were black when taken out, but it was a little damp the day they were taken from the ground, and they begin to show some rust.

Mr. Davis read the paper, as follows:

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