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THE PROPRIETORS OF THE LOCKS AND CANALS ON MERRIMACK RIVER

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THE By-Laws of the Boston Society of Civil Engineers state that at the annual meeting the president shall deliver an address. No bounds are set on the subject matter. This leaves me in a very favorable position, with you, a captive audience, completely at my mercy. I can only hope that you will find something of interest and value in my remarks.

For many years the Proprietors of the Locks and Canals on Merrimack River was closely connected with the Boston Society of Civil Engineers, with hydraulic engineering, and with New England industry. Many of you probably have never heard of the company and may only think of Lowell as a city that used to have a textile industry, but at its zenith it was one of the marvels of the day. It was shown with pride as the epitome of what a industrial city should be, the Venice of America, with its "mile of mills" along the river, its boarding houses for the operatives, and its churches and Public buildings. The Locks and Canals supplied the water for all the power used and was the reason for the development. Almost every engineer of the Locks and Canals has been intimately identified with the Boston Society of Civil Engineers as founder, president, or active member of its Board of Government and Committees. Changing times have broken or changed these relationships and it seemed to me to be fitting to record here some of the history of the Locks and Canals and note the effects wrought by our dynamic economy.

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The charter of the Proprietors of the Locks and Canals on Merrimack River was granted by the Massachusetts Legislature in 1792, which makes it one of the older corporations that is still in operation. The time was before the start of the industrial revolution in New England and the company's name indicated its original purpose, which was to convey lumber and other goods around the rapids in the Merrimack River at Lowell. Much of the lumber for the thriving ship building industry in Newburyport was obtained from New Hampshire and transported in the only possible way at that time, by water down the Merrimack River, and it was Newburyport capital that financed this first canal.

The original works consisted of a low dam across the Merrimack River above the head of the rapids called Pawtucket Falls and a canal, $1\frac{3}{4}$ miles long, excavated from above the dam, across country to the Concord River just above its confluence with the Merrimack. The difference of elevation at that time was a little over 30 feet and there were four sets of locks to pass the boats and rafts from one level to the other. The legislature set the rates of toll and it is interesting to see all the products listed from nails and shingles, through staves and hoops for barrels and hogsheads, to boat loads of manure.

The transportation canal was a moderately successful venture, and made money for its backers, for a limited time only. As the communities further up the river grew and traffic increased, a larger proportion of the business and the travelers wished to make Boston the terminus of their trip. The Middlesex Canal, running from Charlestown to the Merrimack River just above Lowell, was conceived in 1793 to satisfy this demand and eliminate the long trip from Newburyport to Boston around Cape Ann. The Middlesex Canal was completed and started operation in 1804. Over the next few years the traffic through the Pawtucket Canal of the Proprietors of the Locks and Canals decreased and the owners probably began to wish that they had chosen some other form of investment.

In 1813 a cotton mill was built in Waltham. It is interesting to note that this mill was probably the first one in the world that combined all the operations necessary for converting the raw cotton into finished cloth. The earlier mills in this country, Slater's for instance, in Rhode Island, were spinning mills only, and in England, though the power loom had been introduced, it was used in separate mills by people that bought their yarn from the spinners, as had always

been done by the hand weavers. Mr. Francis C. Lowell and his brother-in-law, Patrick Tracy Jackson, were instrumental in establishing the mill in Waltham and as it became successful and expanded to use all the limited capabilities for water power on the Charles River at Waltham, Jackson began looking around for some locality where additional water power was available.

He eventually heard of the falls on the Merrimack River and learned of the rights belonging to the Proprietors of the Locks and Canals. The stock in the Pawtucket Canal was obtained with comparative ease since the Middlesex Canal was offering such strong competition. So the canal company was purchased together with the farms and land in Chelmsford which later became the major portion of the city of Lowell. On February 5, 1882 the Merrimack Manufacturing Company was incorporated and the shares of the Locks and Canals were conveyed to the directors, in trust.

The enlargement of the original Pawtucket Canal, probably only 30 ft. wide and 4 ft. deep, was the first and most important step to be accomplished. It was decided to make it 60 ft. wide and 8 ft. deep which, it was estimated, would furnish 50 mill powers. The work began in the spring of 1882, but could not be completed until the summer of the following year. An additional canal was also dug to the Merrimack River at the site of the mills of the Merrimack Manufacturing Co. where the full 30 ft. fall could be utilized, because Mr. Moody said he had a fancy for large wheels. As all the original installations in the mills used breast wheels, this would mean 60 ft. diameter wheels at this location. The first wheel of the Merrimack Company was set in motion on September 1, 1823 to begin the many changes that took place in subsequent years.

In 1825 the Proprietors of the Locks and Canals was reorganized by selling them all the land and water power not required by the Merrimack Manufacturing Co. The Locks and Canals proceeded to construct the necessary new canals to develop the water power and sell the land to various new manufacturing companies which were formed to take advantage of the power available. The development was made on two levels with the fall between the upper and lower levels being indentured at 13 ft. and that between the lower level and the river at 17 ft. Between 1822 and 1848 the length of canals was increased from $1\frac{3}{4}$ miles to 5 miles and the use changed from transportation to power.

The water was sold to the mills by the Locks and Canals by the mill power. According to Nathan Appleton this standard came from Waltham. He says in his "Introduction of the Power Loom and Origin of Lowell," "The second mill built at Waltham contained 3,584 spindles, spinning No. 14 yarn, with all the apparatus necessary to convert cotton into cloth. This was taken as the standard for what was called a mill power, or the right to draw 25 cubic feet per second, on a fall of thirty feet, equal, according to Mr. Francis, to about 60 horse powers." This form of measurement is still used by the Locks and Canals, the only change being a division into Permanent and Surplus mill powers in 1853. The mills own the water wheels and convert the water bought from the Locks into power. Their investment in generating equipment may have contributed to the status quo in later years, as any redevelopment would have made such equipment obsolete. Such a division also sets the Locks apart from most power companies as it has never generated any power itself. According to Mr. Safford they have served merely as a "water boy for the mills."

The first engineer of the Locks and Canals was Major George W. Whistler. There is very little information about when he started in Lowell, but we know that he resigned to go to Russia and build railroads in 1837, and died over there. His son, the artist, is, of course, more famous for the well-known portrait of his mother. An old memoir of Patrick Tracy Jackson by John A. Lowell states that in 1830 Mr. Jackson began to think about constructing a Boston & Lowell Railroad, which was finally opened in 1835. There is no direct mention of Major Whistler, but reading between the lines, it seems probable that he was brought to Lowell in connection with the building of the railroad since his experience had been in that field rather than in connection with the water power.

Major Whistler had an assistant, from 1834 to 1837, a man who later became one of the best known early hydraulic engineers, James B. Francis. At the age of 22, Francis was appointed chief engineer of the Proprietors of the Locks and Canals, after the resignation of Major Whistler. He held this position for 48 years. One of his great works was the Northern Canal, which provided additional capacity for supplying water and power for the mills. He not only designed and built the canal, with its great granite river wall, but he designed the machinery for lifting the ten headgates and the water wheel which

was used to operate them. The water wheel is probably the only surviving example of an early Francis Type turbine in existence. It has been used for operating the head gates until about two years ago when electric motors were installed for remote control.

Francis also built the guard gate at the head of the original Pawtucket Canal. At the time, it was believed by most people to be entirely unnecessary and was nicknamed Francis' Folly. But in April 1852, only two years after it was hung, a freshet occurred which required the gate to be dropped to prevent the Merrimack River from flowing through the city of Lowell. The gate was dropped again to save the city in 1936. Even in this great flood, the water overtopped Francis' gate by only about a foot, and sandbags were able to increase the effective height by this small amount.

An important part of Francis' duty at Lowell was to distribute the water among the various mills in accordance with their respective rights. In order to be certain that the division was equitable, he performed many original experiments on hydraulic motors and the flow of water over weirs and in short canals. These and later experiments, which included diverging tubes, were published as "Lowell Hydraulic Experiments" and formed one of the earliest works on hydraulics.

James B. Francis was one of the founders of the Boston Society of Civil Engineers and its president in 1874. He was later elected an honorary member.

Uriah A. Boyden was Francis' assistant in Lowell. His name is usually associated with the outward flow turbine which bears his name. While the turbine itself was not new, his diffuser which applied the principles of the expanding tube to slow down the velocity of the water leaving the turbine and thus increase the power produced, was a very important development. It was the forerunner of the modern draft tube which is an essential part of all reaction turbine installations. Boyden wheels gradually replaced the original breast wheels in the Lowell mills.

Uriah A. Boyden was also a founder and member of the Boston Society of Civil Engineers.

The mills in Lowell were now growing rapidly. More buildings were being built, more machinery installed and more power consumed. Mr. Francis found that many, if not all, of the mills were using more water than they were entitled to under their water power

rights. In 1853, after detailed study by Mr. Francis, all the agreements with the mills were renegotiated. It was at this time that the water was divided into Permanent and Surplus Mill Powers. The Permanent Mill Powers, in the same number as the original mill powers, were redeeded to the mills for \$300 per mill power per year "forever." Any available water in the river above what was needed to satisfy the Permanent Mill Power use, was to belong to the Locks and Canals to be used by them for their needs, or distributed equitably between the mills for a fair price. The annual payment for the Permanent water was fixed at a point which would cover the operating expenses of the Locks and Canals, and amounts received from the sale of Surplus Water were to be used for extension and improvement of the facilities for utilizing the water power.

In 1885 when Mr. Francis retired, Hiram F. Mills, a member of the Boston Society of Civil Engineers, who was chief engineer of the Essex Company in Lawrence, was appointed engineer of the Locks and Canals also. During his tenure a great deal of work was done to improve the hydraulics of the canals in Lowell to increase their capacities. Before his retirement in 1916, a start was made toward electrifying the Lowell mills.

Arthur T. Safford was appointed chief engineer of the Locks and Canals in 1916 and held that position until 1940. He was also a member of the Boston Society of Civil Engineers and president in 1934-35. He was elected an honorary member in 1944.

During Mr. Safford's time at the Locks and Canals, the remaining mills were electrified and some of them installed new vertical water wheel units after World War I. The first part of this period was still one of expansion and growth, although probably at a slower rate than in the early years, because by this time the Merrimack River at Lowell was pretty fully developed. But by 1927 the cotton mills were beginning to feel the effects of southern competition and soon began to go out of business. The depression of the 1930's was very serious to Lowell and many more mills closed their doors or moved south.

The Locks and Canals, in spite of fixed permanent power rentals, had operated very satisfactorily with 1853 rates until the depression. While the "Mill Day" had originally been twelve hours, later reduced to ten and then eight hours, it was not until the mid-thirties that more than one shift was operated. To the Locks and

Canals, this meant two and three shifts of operating personnel, because the method of operating the canals had not changed since they were first used for power.

Sales of "surplus water" had been the means, for a good many years, of financing the Locks and Canals operations and it was only the low wage rates through the thirtys that offset the declining sales of surplus as mills closed down or curtailed production. When World War II started, a great impetus was given to manufacturing. The remaining textile mills, now including wool and synthetics, received large government orders and many new small industries started operations in the vacant mill buildings.

It was in 1940 that S. Stanley Kent, a member and vice-president of the Boston Society of Civil Engineers, was made chief engineer. He had been assistant engineer under Mr. Safford for 21 years and had contributed much in those years without receiving any credit. He was a member of the 1927 and 1936 flood committees of the Boston Society and practically the entire credit for the concept of the unit hydrograph is due to his work. Unfortunately, Mr. Kent died in 1943 before having an opportunity to receive full acknowledgment of his abilities.

The writer was appointed chief engineer in 1943, after serving two years as Mr. Kent's assistant, and continued in that position until 1956.

During the remaining war years, and post-war years when industry had a large pent-up demand, the Locks and Canals continued to be able, on the average, to make both ends meet. But it was evident, as the spiral of increasing wages and material costs set in, that it would be impossible to continue operating without taking steps to counteract the fact that a large proportion of income was based on a dollar that was nearly a hundred years old. Rates for "surplus water" could be raised, but by this time other forms of power were available and the local public utility furnished very effective competition to prevent unduly high costs for any portion of power used by the mills. It was this situation which resulted in our study and application of remote control of gates and automatic control of canal level by syphon spillways, which was first described in my paper "New Controls for Old Canals" published in the July 1950 Journal. Additional remote control installations allowed the Locks and Canals to reduce their operating personnel for the canal system from fifteen in 1946 to five in 1956.

The past three or four years, however, have seen textiles in New England experiencing poor business again and three of the remaining mills in Lowell moved or liquidated. To a certain extent new enterprises have taken the place of the cotton business and supplied many new jobs in place of the old ones. From the point of view of the Locks and Canals, however, the new industries which have moved into the city are of little value because they are light manufacturing and do not raise the load high enough to require the use of "surplus water."

As an example, one mill which used to have a load of about 4,500 kw. runs a maximum of about 1,500 kw., even though its space is filled and there are very likely more employees working in the buildings. Another which ran as high as 3,000 kw. during the war, had a 400 kw. load last year, with only part of the buildings being used.

Over a period of a good many years, studies have been made for the redevelopment of the water power of the Locks and Canals in a single modern station. Nothing has ever come of these plans for a number of reasons. First, the cost would be very large with too little savings to make it appear worthwhile. Second, the canals are used to supply process and condenser water to the mills. Even if a central steam plant were built, process water would still be needed, and additional cost would be involved to lay pipes for that service. Third, waste water from processes and toilets is discharged into some of the canals, so that provision would also have to be made to conduct these wastes to the river. Fourth, the existing water wheels, boilers, steam turbines and generators belonging to the mills would have to be scrapped. Lastly, to be effective, all waterpower users would have to agree to the necessary changes.

The question has been asked, "Why wasn't the rate for Permanent Powers raised?" It might have been done before the depression, when all water users were also stockholders in the Locks and Canals, if the legal problems could have been solved. Apparently no one fully appreciated, not only how much the dollar had already depreciated since 1853, but more particularly, how much more it was going to depreciate in the future. During the depression and after World War II, many of the waterpower rights became separated from the stock in the Locks and Canals. This would make the renegotiation of the leases very much more difficult. A mill having only waterpower

rights would naturally want to get its power as cheaply as possible and might not be willing to voluntarily increase their costs. On the other hand, those who are only stockholders would undoubtedly like to see income increased so that dividends might be paid. The complexities of standby power and the small amount of firm power available, make the possibility of increased total income slight and to date, no move has been made to increase Permanent Power rentals.

What is the future of the Proprietors of the Locks and Canals? We have seen them fulfill a demand for power and spark the founding and growth of the textile city of Lowell, which was proudly displayed to visiting celebrities of this country and Europe. We have seen them survive the depression and two wars. But now the newer industries do not want to own and operate their own power plants to supplement the water. The "Permanent Mill Powers" are available to the lessees for only 15 hours per day, and yet, we all want electricity available 24 hours a day at the flick of a switch. Today, in contrast to the early 1800's, the amount of power available from the Merrimack is very small in relation the loads which have developed. If additional capacity is needed in a Public Utility system, a single large unit of perhaps 140,000 or 150,000 kw. is installed. Compare this with the firm power available from the Merrimack of less than 4,000 kw. and the maximum development, which at one time reached nearly 20,000 kw.

So it would appear that the contribution of the Proprietors of the Locks and Canals on Merrimack River and its Engineers, while most important in the past, has seen its peak. The company may go on supplying what power it can to the waterpower owners for some years to come, but an era is past, and it seems as though a short history of the accomplishments and the men of those days should be in the records of this Society with which they were so closely associated.