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The Men of Erie: Founding the American Engineering Tradition

"The engineer has been, and is, a maker of history." James Kip Finch[1]

Governor De Witt Clinton stood triumphantly aboard the *Seneca Chief* in the middle of New York City harbor, gazing at the multitude of cheering people and listening to the thunderous roar of cannon fire and fireworks. He hoisted the small, elaborately carved cask of water that had occupied the place of honor aboard the ship for the past week, and slowly poured a gallon of fresh water into the salt water of the harbor.[2] The "Wedding of the Waters" between Lake Erie and the Atlantic Ocean was now complete. Over the course of eight years, thousands of laborers had completed one of the most challenging engineering projects in the history of the United States, the Erie Canal. What made the completion of the canal so remarkable was not that it ran 363 miles through untamed forest or conquered a 565 foot elevation change by means of 83 individual locks, but what was truly remarkable was the entire canal was designed and constructed by amateurs. This was the last time this would be the case however, because the absence of trained American engineers to design and construct the Erie Canal was the catalyst for the establishment of a formalized engineering curriculum and the birth of the American engineering tradition.

As the United States began to expand beyond the seaboard of the Atlantic in the 18th century, George Washington was one of the first to realize that pioneers and settlers were moving westward with few ties to the young nation they had left behind. The Appalachian Mountains running from Canada to Georgia cut off most means of communication and trade of the Atlantic seaboard with the interior of North America. Washington recognized that these people felt little need or desire to formally remain citizens of the United States and *"the touch of a feather would turn them away"*.[3] He knew that the United States required a means of communication and trade to pierce the rugged mountains to the west to keep these pioneers as part of the United States. Washington was genuinely concerned that if some means of maintaining trade was not established, these pioneers and settlers could fall under the sway of one of the European powers present in the interior of North America. Or the pioneers could even establish their own sovereign nation west of the Appalachian Mountains leaving the United States trapped between the Atlantic Ocean and a foreign nation.[4]

At the beginning of the 19th Century, the only links connecting the Atlantic seaboard and interior of North America were a series of Indian trails and the National Road running from Cumberland, Maryland to the headwaters of the Ohio River.[5] The authorization for the formation of the National Road was passed in 1806 by President Jefferson, but construction did not begin in Cumberland until 1811.[6] Although the road was constructed of state-of-the-art macadam surfacing, the headwaters of the Ohio River were not reached until 1818, and travel along the road remained rugged, slow, and expensive. The average price to transport a ton of goods from the Ohio River to Cumberland averaged 30 cents per ton and could take weeks for the wagons to complete the journey.[7] Clearly a less expensive and faster route was needed if the interior of the continent was going to remain linked with the rest of the United States.

The United States found the solution to this problem across the Atlantic Ocean to the west in Manchester, England. In 1759, Duke Francis Egerton began construction on Great Britain's first truly modern canal to transport coal from his mines in Worsley to the emerging textile industry in Manchester 41 miles away.[8] The Bridgewater Canal is considered the first modern canal in England primarily due to its use of 10 locks to lower packet boats to the level of Manchester and the inclusion of an aqueduct over the River Irwell which allowed packet boats to travel from the coal mines along completely man made waterways.[9] With the completion of this canal in 1761, the price of coal dropped by over half in Manchester allowing the textile industry to expand immensely.[10] Not only did the canal allow for the textile industry to expand, but it also unified the region through interdependence on the coal and textile industry. The successful completion of this canal sparked a "Canal Mania" throughout Great Britain that would last into the 19th century as miles and miles of waterways were constructed throughout the countryside.

The United States was quick to notice the industrial expansion and regional unification that the Bridgewater Canal and others like it were bringing to Great Britain. Thus, when George Washington and others realized the need for a rapid and cheap mode of transportation to pierce the rugged mountains to the west of the United States, the immense success of the Bridgewater Canal meant that construction of a canal into the interior of the United States was seen as the best possible choice. Canals were cheaper to transport goods and far quicker than roads and turnpikes such as the National Road, but they were also more restrictive in buildable locations by such factors as topography and available water. Throughout the chain of mountains running from Georgia into Canada, the rugged peaks are passable in only a few select locations. In fact, through the entire state of New York, only the Mohawk River Valley provides an easy route through the mass of mountains. The Mohawk River Valley runs from the shores of the Great Lakes to Albany, NY where the Mohawk River merges with the Hudson River to eventually flow to New York City and the Atlantic Ocean. This physical restriction meant that the general route of the canal would have to closely follow the valley. Even with the route through the Mohawk River Valley being only one of few viable options and the urgency to construct a canal into the interior, the federal government was tentative about providing funding for such an audacious project. President Thomas Jefferson even called such a proposal "*little short of madness*".[11] Lacking federal funding, it was decided that the canal would be an endeavor solely undertaken by the State of New York. The New York legislature appointed a canal commission to study and survey the route from Albany to the Great Lakes.[12]

While the need for a canal to penetrate the rugged terrain of the Appalachian Mountains was great indeed, the planning for such a momentous task had been poor. The route through the Mohawk River Valley was apparent as the only viable route by the canal commissioners, but other preparations were completely lacking.[13] The only professionally trained engineers in the United States at the time were the military engineers of the United States Military Academy. West Point had been formally training cadets in the intricacies of military engineering since 1803 and the Army Corps of Engineers had established a reputation as one of the elite engineering establishments focusing on such topics as fieldworks, road construction, and terrain obstacle removal.[14] Although these men were arguably the best American candidates to undertake the design and construction of the canal the General Survey Act limited army engineers working on a civilian project to only the initial surveying, plans, and estimates.[15] This continued until the 1830's when Congress outright forbid army engineers from undertaking any work with private companies while retaining their officer commission.[16] The next possible source of engineering experience was to hire a European engineer, such as William Weston. Weston designed and led the construction on the Middlesex Canal, one of the only two other canals in operation before the Erie Canal.[17] But when the New York Legislature looked for willing European engineers, Weston passed on the offer due to his poor health and old age.[18] Few other European engineers were willing to travel to the United States, and those who were willing charged extravagant wages for their travel to the United States as well as their time.[19]

Given the inability of the New York legislature to employ the West Point engineers and the high cost and low availability of European engineers, the only choice left was to use local American engineers. However, at this time there were no professionally trained American civil engineers or even the mechanism to train engineers within the United States outside of West Point Academy. Establishing an engineering program could not be completed overnight, and the canal commissioners needed a solution as soon as possible. After years of political battles over the decision to construct a canal, the commissioners knew that an interim solution was needed before the public and legislature tired of further delays and cancelled the project all together.

The canal commissioners appointed Nathan Roberts, Canvass White, Benjamin Wright, and James Geddes as the chief engineers of the Erie Canal, with Wright being named the chief overall engineer.[20] The appointed engineers then set about devising a plan to successfully complete the canal. They were aware that each of them lacked the formal training that an engineer would ideally have, but these men made use of what resources and experience they had available to them. They found their solution observing past European projects, through available local knowledge, and the experience that each gained through trial and error during construction.

While New York was unable to hire a European engineer, the chief engineers were not hesitant to draw upon the much larger public work construction experience of Europe, primarily France and Great Britain. The observance of European successes and failures was due primarily to the drive and initiative of a man named one of the chief engineers at the onset of construction. But by 1825, Canvass White arguably had more to do with the successful completion of the canal than any other engineer. White gained permission from Nathan Roberts to travel throughout Europe at his own expense for over a year observing, noting, and researching the canal projects of France and Great Britain.[21] During his travels he maintained journals, sketches, and plans of every aspect of canal construction he deemed important, particularly lock construction, maintenance, and operation. He also purchased numerous French and British engineering works concerned with hydraulic and fluid mechanics. Canvass White returned in 1818 as the most prepared and formally trained engineer that contributed to the construction of the Erie Canal.[22]

The chief engineers then set about surveying and planning the specific route that the canal would follow through the Mohawk River Valley. After resurveying the entire route previously chosen by the original canal commissioners, the chief engineers laid out the course, lock location, and terminus of the canal. Their plan made the Erie Canal 363 miles long from the Great Lake terminus at Buffalo, NY to its eastern terminus at Albany, NY, making it at time of its completion the longest canal in North America. This daring plan was estimated to cost the State of New York nearly seven million dollars.[23] Closely following the path of the Mohawk River meant that the canal only changed 563 feet in elevation from Buffalo to Albany, quite impressive considering over 300 miles of waterway were to be constructed. Even with the relatively small change in elevation, the canal plan still called for the construction of 83 locks that raised or lowered packet boats by 8 feet with each cycle. Each of these locks were technical nightmares for the engineers and one of the most persistent problems throughout construction. Although left out of the original plans, the engineers eventually decided to use aqueducts to pass over the larger rivers and streams. These aqueducts were an engineering feat themselves because they allowed boats to travel on a manmade waterway while floating over natural rivers and streams. Outside of the technically difficult locks and aqueducts, the majority of the canal was a simple ditch 40 feet wide with a depth of four feet. The four foot depth was partially achieved using the excavated soil to build banks that served as towpaths for the mule teams. The four foot depth meant the Erie Canal could accommodate boats drawing up to 3.5 feet in draft.[24] The typical packet boat that worked on the canal accommodated 60 to 70 people, up to 100 people when necessary. Freight and cargo were transported using working boats that carried up to 1000 bushels of wheat or about 30 tons of other cargo.[25]

With the route and design planned, the chief engineers knew that now their plan would be put to the ultimate test during construction. Instead of beginning at either terminus, the engineers decided it would be best to begin in the middle of the canal route, from Seneca River to Rome, NY.[26] This decision to begin construction in the middle would prove vital to the eventual completion of the canal. The middle section of the canal was deemed as the easiest to construct. The section was through some of the most heavily forested areas, but there was a much smaller change in elevation. This meant that much of the canal construction was excavating soil, and not constructing the technically difficult locks.[27] During construction of the middle section, the use of local available knowledge was most heavily implemented. The ingenuity that countless “non-professionals”, such as carpenters, surveyors, mathematicians, and common laborers brought to the canal construction was invaluable. Probably the best example of on hand knowledge being used was a local scientist who discovered a quick drying hydraulic cement. This discovery was vital as the engineers had been forced to build large portions of the locks out of wood that would decay, were inefficient, and would have to be replaced in only a few years. However, with a hydraulic cement the locks could be far stronger and more durable. Canvass White traveled to Chittenango, New York and after an experiment at a local bar inexpensive local cement was discovered that cured underwater. Now they could build locks that were of higher quality and for a far cheaper price than if they had been forced to import hydraulic cement from Europe.

The engineers also made another important decision in how the labor would be contracted out for the digging and construction of the canal. Initially, they made the decision to contract out small portions of the canal to the local labor force, instead of a single massive labor force. The contracting out of small portions of the canal at a time meant that some crews were certainly less effective than others, but this also resulted in a much wider range of laborers and non-professionals taking part in the construction of the canal. Therefore a greater input of new creative ideas was present than the stagnation that would have likely occurred using only one crew. Nathan Roberts believed that if construction had begun on either the east or west section these valuable lessons would have not been learned and the canal ultimately would have failed.[28] Eventually this method of contracts was phased out when large numbers of Irish and other European immigrants began to permanently work on the canal, but by that point the competition between the smaller contracted crews had produced many of the innovative techniques used during the rest of the construction.[29]

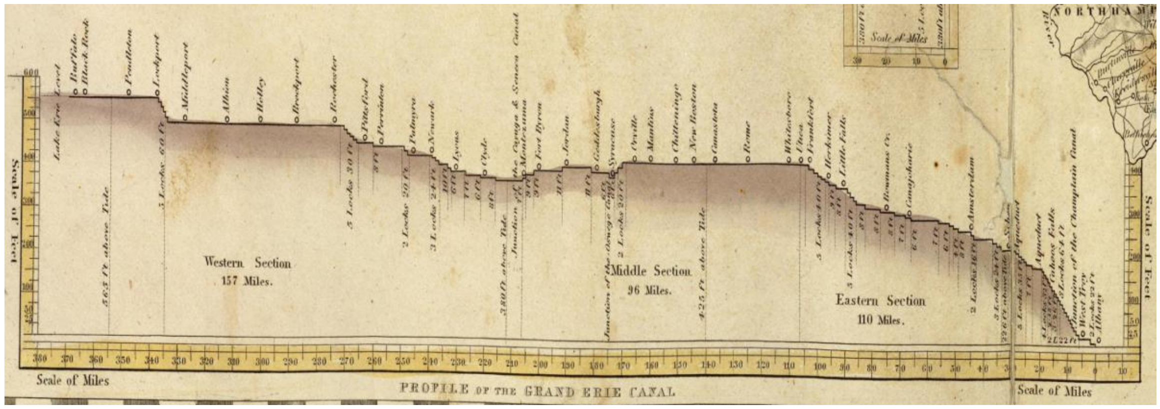

Figure 1. 1832 profile of the completed Erie Canal. The reasoning for beginning construction in the middle section is evident by its relatively small change in elevation compared to the western and eastern sections.

Source: *New York State Archives*[30]

Long before 1825, when New York City Harbor celebrated the completion of the canal in the “Wedding of the Waters”, the need for a professional cadre of American trained engineers had been realized. The completion of such a momentous project such as the Erie Canal, could not be left in the hands of amateurs learning through trial and error. Various institutions, individuals, and the United States’ government itself began to gather the best teaching methods to form a professional American approach to training engineers. They would draw upon the practical British tradition of apprenticeship, the theoretical French approach, and the experience and attitudes of the men who designed and constructed the Erie Canal to create a unique American curriculum.

Across the Atlantic Ocean, throughout Great Britain, a much more traditional method to engineering training was used. Outside of continental

Europe, primarily France, engineering training had maintained a much more traditional nonacademic approach that was similar to an apprenticeship. In Great Britain, engineering was seen more as a craft instead of an applied science. Training and experience was gained through practical application of the craft similar to a mason, carpenter, or artisan. A successful engineer in Great Britain was seen more as the combination of various construction professions into a single entity.[31] While British engineer training did include some study in mathematics, this was largely limited to what simple mathematic formulas needed to be used while surveying land. The largest amount of learning and training would occur in practical on the job training under the watchful eye of a master engineer.[32] When new problems and difficulties were encountered on a project, the solution was usually found through trial and error by the master engineer which was then passed on to the engineers training under him. The informal nature of this training meant that the quality of British trained engineers could be very uneven, depending upon the knowledge and competence of the master engineer. Thus, the British engineer was trained almost exclusively while under real world conditions. This did have its drawbacks however, because even though an engineer may know what sort of solution should be used when encountered with a particular problem, the reasoning behind why it should be used was minimal or completely lacking. However, the continuous trial and error experiments undertaken by British engineers meant that new and radical solutions to problems were more often attempted than solutions presented by conservative academic French engineers.

Across the English Channel, the next aspect that was included in the emerging American method was the intensive theoretical learning heavily used throughout France. As the French Revolution swept through France in 1789, the country was transformed into a republic guided by the strict laws of science and logic. This transformation had a profound impact on the training undertaken by French engineers as well. The rest of Europe continued to view the engineer as a craftsman, but the French saw the engineer as a professional of applied science and their training reflected this. At this time, France boasted a number of prestigious engineering schools with the most acclaimed institution being Ecole Polytechnique. Entry to this school was through an intensive test that eliminated all but the brightest talent of France and a few select foreigners.[33] After passing the entrance exam, the students would then undergo a two year program that was heavily focused on courses in pure and applied sciences, as well as a focus upon high level mathematics. Most of these courses were heavily theory based such as fluid mechanics, calculus, and differential equations. The typical French Ecole Polytechnique student had little practical application of their coursework through laboratory time or real world exposure while in school. However, upon completion of the two year course, graduates could then immediately enter into government service as civil or military engineers.[34] Additionally, the best and brightest students could then attend other institutions such as Ecole des Mines, which were similar to today's graduate degree programs.[35]

As the canal fever of the early 19th century swept across the United States, the men who had worked on the Erie Canal were rarely employed on just a single project. Their completion of the foremost engineering project in the United States instantly propelled them to be regarded as experts in the art of canal building. In fact, nearly all major public works, including railroads, harbors, sewer systems, as well as canals, either included a man who had worked on the canal or had been trained by someone who had.[36] These men were in such demand that in some cases construction on the canal was delayed until an expert from New York could be brought in, as happened with the Ohio and Chesapeake Canal in 1828.[37] These men were certainly one of the cornerstones of the foundation of American engineering because many went on to found their own engineering schools, continued designing public works, and training other young engineers. But the most important aspect that the men of Erie introduced was not something that is easily as seen as the British and French approaches to training and curriculum. The continuous adaptation and learning through failures that became part of the American approach could just as easily be attributed to the informal nature of British training as it could to the experience gained on the Erie Canal. Instead the experiences learned by the men of Erie gave the developing American engineering tradition a sense of confidence and willingness to attempt not only the difficult, but the impossible. The "*little short of madness*" that President Jefferson claimed about the canal was transformed by the amateur engineers from madness into wildly, successful reality and in the process infused the growing engineering tradition with boldness and daring. Within the next century and a half the United States began construction on a railroad to unite the entire country from the Atlantic to Pacific Ocean, became the first nation to harness the very nature of the universe with the atomic bomb, and had the boldness and experience to transport two humans a quarter of a million miles to the Moon and safely return them home. There is no doubt that the Erie Canal served as the incubator for American engineering, and it is difficult to measure exactly what impact those men who labored and toiled on its banks had, but their willingness to be bold had a far deeper impact upon the materializing American method than any other influence.

Over the next decades these three major influences combined into a distinct American method of training and curriculum. One of the first civilian institutes to be established in the United States that made use of this approach was Rensselaer Polytechnic in Troy, New York. Established by Stephen Van Rensselaer in 1824 even before the completion of the Erie Canal, this was one of the first institutions in the United States to provide professional engineering training outside of West Point. While the school had been established in 1824 with a coursework and curriculum that could produce competent and able civil engineers, a formalized civil engineering degree was not introduced until 1835, and the influence the construction of the Erie Canal had on Rensselaer is apparent. The mixture of hands on experience that was gained through trial and error, practical British training, and French theoretical training is evident in the public notices published around Troy, New York announcing the establishment of a formalized civil engineering degree. The students were given eight weeks in the practical use of engineering and surveying tools such as sextants, compasses, and telescopes.[38] The stress placed on the use of surveying tools was a byproduct of the on the job training that men such as Rensselaer had undergone working on the Erie Canal as well as training that a British engineer would typically undergo. During the next eight weeks, the students would focus on the theoretical design of engineering principles such as mechanical powers, conic sections, and structure design. This eight week section heavily focuses upon applied sciences and mathematics, which shows the influence of the academic French training. The last eight weeks of their training at Rensselaer Polytechnic was divided between theoretical work with steam and fluids. This theoretical learning was then practically applied to steam engines and canals with an emphasis placed on canal structures such as lock, bridge, and pier design showing once more the influence of applied science.[39] However, upon completion of the 24 week course, the student would not be finished, but was encouraged to study under a master engineer until he had deemed the student ready to operate on their own, which was similar to the practical apprenticeship approach favored by the British.[40]

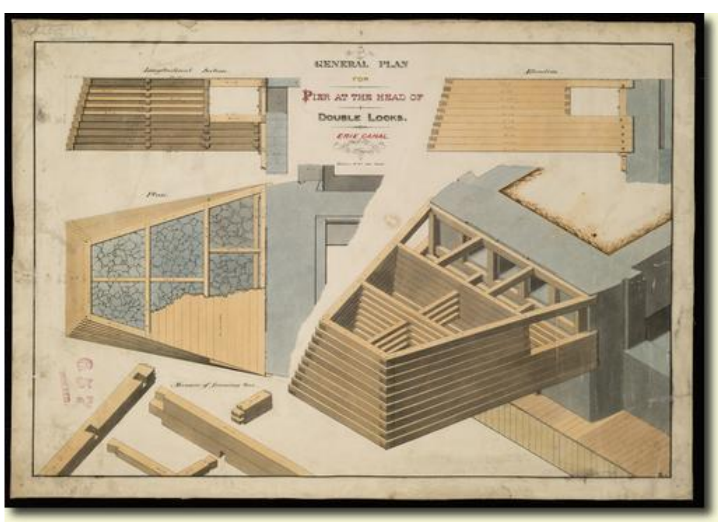

Figure 2. Pier plans drafted for the first enlargement of the Erie Canal. Plans such as this would have been unimaginable before the founding of the United States' first engineering schools and institutions.

Source: *New York State Archives*

Civilian institutions such as Rensselaer Polytechnic emerged with a curriculum evenly balancing the experiences learned on the Erie Canal, the practical British approach, and the theoretical French approach, but the military engineers of West Point emerged with an approach that was much more heavily influenced by the theoretical approach favored by French institutions. When West Point Academy formally introduced courses in military engineering in 1803, they looked to emulate the masters of military engineering of the day, the French Imperial Engineers of the Guard. West Point sought to copy the French approach to training its military engineers which began the West Point tradition of heavily focusing upon theoretical training instead of practical hands on learning. However, after the completion of the Erie Canal, West Point implemented some aspects of trial and error and on the job training into its curriculum, but would still largely maintain coursework that favored a theoretical approach to engineering training. While this focus by West Point continued, the subject matter that was covered began to rapidly expand beyond the narrow scope of military engineering. After the completion of the Erie Canal, West Point, as well as pro-expansion politicians, realized that infrastructure construction and improvement to trade patterns was just as vital to the nation as purely military related matters. This realization transformed the military engineers of West Point Academy from a "military aristocracy" into the Federal government's key to westward expansion.[41]

After the founding of Rensselaer Polytechnic and the adaptation of West Point Academy, the challenges confronting this first generation of American engineers evolved constantly. Just as the challenges have evolved, so too has the engineering curriculum to prepare future engineers for problems they may encounter. Present day engineering curriculum still shares many topics that 19th Century institutions covered, such as chemistry, engineering physics, and surveying.[42] But where the first graduates of Rensselaer Polytechnic spent only eight weeks covering structural design, civil engineering students will now typically spend six 18-week long courses on structural design alone.[43] Whereas the 19th Century student could earn a degree in 24 weeks, the same now takes more than 140 weeks.[44] And just as the curriculum taught evolved, so too did the engineer's tools. The 19th Century engineer was a master of instruments such as sextants, compasses, and telescopes. These tools and their role in construction has now largely been given over to project managers and surveying teams. The sextant and compass have evolved into handheld global positioning systems, telescopes into satellite readouts, and structural plans into three-dimensional computer aided designs.

But even now, when computer models can theorize how and when buildings or structures will fail, educators maintain that hands on learning and real world training are absolutely vital just as Rensselaer did. He recommended that graduated engineers train under a master engineer until they had exposed themselves to enough real world application of what they had learned in their coursework to become truly independent engineers. Just as Rensselaer encouraged, engineering degrees now highly recommend or even require engineering students to have real world experience through internships with industry or engineering firms.[45] Present day engineering degree requirements have taken this real world exposure a step farther by requiring students to attend monthly seminar hearings.[46] At these seminars representatives from industry, engineers, and others present speeches covering everything from research and development to the typical work day. The American engineering degree process has certainly developed into a highly professional program that prepares its graduates for topics unimaginable to their 19th Century counterparts. But, while the real world exposure, course length, and requirements have increased, these institutions still follow the precedent that began with the founding of such schools as Rensselaer Polytechnic.

As settlers and pioneers moved westward over the Appalachian Mountain range in the 18th century they left with little ties to the United States, and numerous individuals in the government realized the need to maintain communication and trade with these peoples. The startling success of the Bridgewater Canal in Manchester, showed the impact that canals had upon trade and unification. The United States was eager to copy the huge success of those canals. However, the only professionally trained engineers in the United States were military engineers of West Point Academy, and America had no means to formally train native engineers. The Erie Canal Commission still managed to find a solution that would implement previous European public works, local available knowledge, and the heavy use of trial and error techniques in the construction of the canal. After the successful completion of the canal, the need for formally trained American engineers was realized, and various individuals and institutions set out to blend practical British training, academic French training, and the confidence and daring gained during the construction of the Erie Canal into a unique American method. This new American approach was then used during the founding of the first professional institutions of Rensselaer Polytechnic and curriculum adaptation of West Point Academy. Throughout the rest of the 19th century, numerous other engineering institutions were founded throughout the United States, but each essentially followed either the precedent set at Rensselaer Polytechnic or West Point Academy. These two institutions and all others that followed served as the blue print for the founding of the American engineering tradition during the 19th century. Even though modern engineering curriculum and engineering tools have evolved to meet the requirements of a world that is evolving daily, American engineering curriculum still follows the basic outline that was first formed at West Point Academy and Rensselaer Polytechnic that has allowed American engineers to challenge what was previously held to be impossible.

At the turn of the 19th Century, only two canals were in use throughout the entire United States, the establishment of the West Point Academy military engineering program was still three years away, and New York City was simply another port of choice on the Atlantic seaboard. By 1840, less than 15 years after the completion of the Erie Canal, the United States could boast over 3,000 miles of canals spanning mainly throughout the north and west of the country, the port of New York was one of the busiest in the world shipping more tonnage than Boston, New Orleans, and Baltimore combined, and an estimated 766 professionally trained engineers were working throughout the United States where before there had been none.[47] Governor De Witt Clinton had every reason to feel optimistic about the future as he stood aboard the *Seneca Chief,* but even his optimism could not have possibly foreseen the incredible impact that the amateur men of Erie would have in founding the American engineering tradition as they completed one of the most challenging public works projects in the United States and truly became makers of history.

Endnotes

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[24] Bernstein, *Wedding of the Waters : The Erie Canal and the Making of a Great Nation*, 448

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[33] Peter A. Ford, "Charles S. Storrow, Civil Engineer: A Case Study of European Training and Technological..." *Technology & Culture* 34, no. 2 (04, 1993), 271.

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