The Navy Roots of American Mechanical Engineering

Part II – The Spread of Engineering After the Civil War

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By the 1870s, Annapolis engineering graduates possessed a unique education. Upon a foundation of science and mathematics, they built experience in practical design and operation of machinery. Their grasp of the theoretical underpinnings of their field placed them at the forefront of mechanical engineering in America. These men were primed for technical careers.

However, Navy career prospects were dim for young engineering officers. The number of ships in the fleet declined, reducing the availability of billets for all officers. Older line officers claimed that the Academy produced an overabundance of engineers, and recommended cutting their numbers. The line convinced Congress to pass anti-engineer legislation. These actions caused the line-staff controversy to flare again, and the rivalry continued to fester throughout the end of the century. The 1882 Naval Academy amalgamation of midshipmen and engineers could have been the foundation for a unified corps of officers. However, it failed to alleviate tension among junior officers, and the prejudices of senior men remained virulent.

The engineers responded in a variety of ways. Some of them persevered in the Navy. Others left the service to join industry. Most significantly, a group of officers advocated for legislation that allowed them to become professors at civilian universities. The men so detailed over the next decade were responsible for transferring the Naval Academy engineering pedagogy to the nation.

In 1878, engineers in the Bureau of Steam Engineering responded to shrinking prospects in the fleet by summoning support in Congress. They drafted a short bill, called "An act to promote the knowledge of steam engineering and iron ship-building among the

scientific schools or colleges of America." The bill proposed that up to twenty-five officers be posted annually as engineering instructors to technical schools, and it was passed into law in February, 1879.[1]

The bill's Navy proponents followed the lead of a few engineers who had already left the service for academia. The best-known example among these men was Robert Thurston. As a result of the turmoil within the shrinking Navy in the late 1860s, First Assistant Engineer Thurston vacated his position at the Academy as Assistant Instructor in Natural and Experimental Philosophy. He resigned in 1871 to assume an engineering professorship at the newly-founded Stevens Institute of Technology in Hoboken, New Jersey. After fourteen years at Hoboken, Thurston moved to Cornell University in 1885.[2]

Robert Thurston resigned from the Navy to pursue an academic career. Other engineers still on active duty had an even larger impact on the development of American engineering. Several details of active-duty Navy engineers to universities across the country resulted from the 1879 law. Lafayette College in Easton, Pennsylvania was the first school to see an active-duty Navy engineer. That engineer spent two years at the institution, 1879-1881. When his duty ended, the Navy instructor program gained momentum with four additional details. Union College in Schenectady, New York and the Franklin Institute in Philadelphia received Navy engineers. The University of Pennsylvania welcomed engineer Henry Spangler. The final instructor assignment for the year was Assistant Engineer Mortimer Cooley, sent to the University of Michigan.[3] Through these men and others soon to follow, the Navy made a lasting mark on the development of American mechanical engineering practice.

Mortimer Cooley's path to the private sector was similar to many of his fellow engineering officers. He rapidly became disenchanted with the Navy after graduating from Annapolis, partly due to the Navy's delay in granting his commission. Cooley complained in 1881 that his promotion examination was a year overdue. The added prestige of being a commissioned officer was surely one reason Cooley desired the promotion, but there were 700 other reasons. As a graduated Cadet Engineer, Cooley's sea-duty salary was $1000; after his promotion to Assistant Engineer, the salary would increase to $1700. The engineer was married soon after graduation, and his wife gave birth to a daughter during the engineer's second post-graduate cruise in 1880. Supporting a family on $1000 per year was hard to do, and it became even more difficult when he was detached from his ship and ordered to the Bureau of Steam Engineering. Cooley's shore duty pay was only $800 as a Cadet Engineer, but would be $1400 once his commission came through.[4]

In May 1881, Cooley finally received orders to report for his promotion examination in Philadelphia. He passed handily, and returned to Washington. His commission followed in June, finding him engaged in shore duty at the Bureau. His work there was not related to engineering, however; he spent the hot summer months re-organizing the department's old personnel records. Writing to his brother, Lyman Cooley, he tried to put a brave face on his dissatisfaction, "It is not the duty I wish, but until I secure that, of course I can or ought to rest satisfied with what is given me. I am no better pleased with the service than ever, but the favorable day for resigning has not yet come."[5]

Figure 25 - Assistant Engineer Mortimer Cooley, circa 1882, just before he reported for duty as professor of mechanical engineering at the University of Michigan. Image: Bentley Historical Library, University of Michigan.

The assignment Cooley wished for was an expected transfer to the Bureau of Steam Engineering's drafting room, where he could practice the skills honed at the Academy. Instead, he was ordered to assist the Bureau of Ordnance in casting a bronze statue of Admiral Farragut.[6] In response to this disappointment, Cooley sought better duty away from Washington and the fleet: a billet at a college under the 1879 law.

In July 1881, Cooley's brother, Lyman, wrote to Professor Charles Greene at University of Michigan, explaining to him the "red-tape of the method" to win the assignment for Mortimer. Greene was to convince the university president to write a letter to Secretary of the Navy William Hunt, who would refer the matter to William Shock, Chief of the Bureau of Steam Engineering. If all went well, Shock would then order an engineer to the university. Cooley told Greene that a particular officer could be

requested for the detail, and that he hoped his brother would be favorably considered.[7] Patronage and personal connections were critical to engineers seeking university billets.

In Cooley's case, the transfer went smoothly. In less than one month, Cooley received orders from Secretary Hunt, detaching him from the Bureau of Steam Engineering and sending him to Ann Arbor. Immediately, Michigan's acting president, Henry Frieze, wrote an excited letter to the engineer. Frieze felt Cooley's presence was "of vital importance to the successful opening of the new course of engineering study." The university already had small programs in Civil and Mining Engineering; a new course in Mechanical would complete the Engineering school.[8] The university president informed Cooley that all studies in Mechanical, Steam, and Ship Building Engineering would be under the Navy man's personal direction. Cooley was charged with laying out and organizing the plan of classes, the selection of all textbooks, and establishing requisite shops for practical work. He would be responsible for creating a new academic program.

The opportunity spread before Cooley must have been exciting, but daunting. From the University of Pennsylvania, Henry Spangler informed Cooley that the task at Michigan was "too much work entirely for any one man." However, Cooley was not completely alone. He was connected to a wide network of competent men: his friends in the Navy engineer corps.[9]

Cooley solicited advice from his colleagues at both the Bureau of Steam Engineering and the Naval Academy. From the Bureau in Washington, one Passed Assistant Engineer provided a list of suitable articles and textbooks for the Michigan students to read. That engineer closed his letter with encouraging words: "I shall take

great pleasure in assisting you in every way possible, and I am sure Mr. [Chief Engineer] Shock feels in the same way." Other engineering officers voiced similar sentiments; they, too, buttressed their good wishes with helpful material. The two longest-serving Annapolis steam engineering instructors offered course outlines and classwork ideas for Cooley to follow. Passed Assistant Engineer Asa Mattice, described by his peers as "the smartest number of the Engineer Corps," also offered help. Mattice was busy preparing for his third year as an engineering instructor at the Academy, but promised to send copies of lectures from Annapolis.[10]

Cooley's professional network extended to the men enjoying instructor details at the other schools. Henry Spangler shared his experiences at Pennsylvania with his former classmate at the start of the 1881 academic year. That school offered a diverse engineering course, with 171 students enrolled in 1882. Spangler's position was in the special "Dynamical Engineering" branch, where Spangler joined two other engineering professors to instruct two dozen students. In his first year as a professor, Spangler's teaching load was limited to classes in Marine Engineering and Naval Architecture.[11]

Teaching was a skill Spangler had not yet mastered. After his initial day of lecturing to the students in ship building, he dashed off a letter to Cooley. Embarrassed, he told his friend that he had made "one grand blunder," and he hoped his letter would save Cooley from a similar mistake. Spangler had assumed his students knew more than they actually did, and the pace of his introductory lecture was far too fast. "I find my boys wonderfully ignorant," he intimated to Cooley, then related his plan for educating the various classes of students. After lecturing on ship stability to the senior class, he planned to have them take up thermodynamics, followed by the design of ships'

machinery. The juniors would study mechanics and practical work, including two visits to industrial shops per week. The day after the shop tours, Spangler intended to lead recitation discussions of what the students saw.[12] The shop tours were similar to those undertaken during the Annapolis practice cruises. Spangler's mix of theoretical instruction and practical experience at Penn directly mirrored the pedagogy of the Naval Academy.

Cooley digested all of the information and suggestions arriving in the post from his friends, then designed the new Michigan mechanical engineering curriculum. He knew that 1881-82 would be a building year, not given to convening all of the courses necessary to an aspiring mechanical engineer. The university's course in mechanical engineering, originally codified in 1868 but dropped in 1872, had been re-instituted. It contained many of the now-standard technical foundation classes: geometry, trigonometry, calculus, and drawing. Surveying the incoming class, Cooley concluded that they were not properly prepared for the most advanced courses he could teach: thermodynamics and naval architecture. He also concluded that due to a lack of facilities, mechanical laboratory work was out of reach for the first year.[13]

Cooley wanted to provide his students with practical experience as soon as possible. He drew on his own experience of Annapolis summer practice cruises and Spangler's report of shop tours. Beginning in the winter of 1881-82 he campaigned with industries in the region, arranging visits to shops and manufacturing establishments.[14]

Industrial tours were only one aspect of Cooley's master plan. He wanted to erect an engineering laboratory on campus for his students. Informed by the president that a $2500 state allocation was available, Cooley went to work. He contracted for the erection

of a small building, then spent the remaining funds on an engine and tools for the shop. Not satisfied with the meager supply of practical instruction material afforded under the allocation, he filled his letterbook with inquiries to manufacturing establishments and machine shops around the country. Cooley asked firms to donate examples of their products for the instruction of his students. In exchange, the professor offered to test equipment and provide assessments of the apparatus donated.[15]

By the end of Cooley's first year he had generated impressive results. Not only was the new laboratory building ready, but dozens of firms had responded to his requests with donated apparatus. From Schenectady, Westinghouse Air Brake Company sent a complete air brake outfit, valued at $500. Boston's American Steam Gauge Company sent engine indicators and gauges; Deane Steam Pump Co. in Holyoke, Massachusetts provided a steam pump in section. Several other firms made less expensive but significant donations.[16]

The largess of American manufacturing firms continued the next year. William Sellers and Co., Nathan Manufacturing Co., and L. Schutte and Co. each shipped a variety of locomotive injector; Henry Worthington contributed a steam water pump and meter, worth $250. The total value of the apparatus accumulated by Cooley in his first few years was nearly $1300. By 1884, Cooley had filled the new engineering laboratory, and required more space. The university agreed to move the carpenters' shop to a position abutting the engineering lab, and convert it to Cooley's use.[17] Michigan students learned engineering in the Navy tradition, a unique combination of theoretical and basic scientific knowledge, and practical training in the shop.

Figure 26 – University of Michigan Mechanical Engineering Laboratory buildings, circa 1885. When Cooley arrived in Ann Arbor, the university had no building or laboratory dedicated to mechanical engineering. Cooley spent $1500 in 1882 to build the stone structure at left. Soon after, the University approved his request to move the carpenter's building (white building to right) to adjoin the engineering lab, increasing the floor space available for his students. Cooley then filled the buildings with machinery purchased from or donated by American manufacturing firms. Image: Bentley Historical Library, University of Michigan.

Once Cooley's students were adequately prepared to enter the workforce, the professor helped them find good jobs in their field. Frequently the directors of manufacturing firms contacted Cooley, requesting that he send capable young engineers to them for employment. For instance, the superintendent of the Detroit Wheel Company informed Cooley in 1887 that he was leaving his position to take a job with another company. The Wheel Company was looking for a college-educated engineer with practical experience to take the superintendent's place, and the directors solicited Cooley's advice. In an 1888 example, the president of the Middlings Purifier Company based in Jackson, Michigan hired two skilled men for his factory at Cooley's suggestion. Cooley's interest in his protégés did not end once they landed employment. After placing

Michigan graduates, Cooley inquired with the firms' management to check on their performance.[18]

The education of University of Michigan's first generation of professional mechanical engineers was based entirely on the Navy style of engineering. Within a few years, universities across the nation followed Michigan's example. They clamored for Navy engineers to jump-start their mechanical engineering programs, and the engineers responded enthusiastically.

The Lure of Academic Life for Navy Engineers

News of Cooley's quick successes at Ann Arbor circulated among the engineers serving aboard Navy ships, and excited great interest. Some senior engineers took a long view of the possibilities of university assignments. Passed Assistant Engineer David Jones, one of Cooley's and Spangler's Academy teachers, frequently wrote encouraging letters to Cooley. From U.S.S. *Nipsic* in Spain, Jones shared his outlook with Cooley. He thought the program of sending Navy engineers to colleges was "of great advantage to us, by making us known as a body of scientific men." He continued, "…it is a chance to extend our name and influence through all parts of the country."[19]

Younger engineering officers also took this view. Walter McFarland wrote to Cooley from Lake Erie in the fall of 1882, expressing his fervent hope to be detached from the old 1842 lake steamer U.S.S. *Michigan*. "Mac" wanted the Navy to send him to Cornell as an instructor, an opportunity he felt was extremely important: "…if the men in Washington look at it as I do, they would realize that the detailing of officers to colleges in the biggest thing for our corps that has happened in a long time. It will make us known

throughout the country and let people see that we are a body of educated gentlemen and not mere engine drivers."[20]

Like Isherwood in the 1860s, Navy engineers in the 1880s realized that they needed to be respected as professionals if they hoped to win equal footing with line officers in the fleet. Navy engineers consciously moved toward professionalization in their field: the clearest evidence was the creation of the American Society of Mechanical Engineers in 1880. ASME elected officers, published a journal of scholarly and technical articles, and limited its membership to a select group of educated, practicing engineers.

Navy engineers were the foundation of ASME and professional mechanical engineering. Former Navy engineer Robert Thurston was elected ASME's first president in 1880, and served two consecutive terms. The ASME Secretary during Thurston's second term was Passed Assistant Engineer Thomas Whiteside Rae, a former Annapolis instructor in steam engineering. In that same term, former Navy engineer Charles Copeland served as Treasurer. Thurston's vice president was also a Navy man: Erasmus Darwin Leavitt; he succeeded Thurston as ASME president in 1882.[21]

Active-duty Navy engineers joined the Society as soon as it was formed. Senior Navy engineers encouraged the entire corps to join. For example, ASME member Passed Assistant Engineer David Jones used his influence with his subordinates to increase ASME membership. Early in 1882, Jones wrote to Cooley in Michigan, "I am inducing as many of our people as I can to join the Am. Soc. Mech. Eng. as I believe it a good organization. Unless you are already provided with proposers, and wish to join, I will be one of your proposers with much pleasure."[22]

Cooley was an early member of the professional society, and other Navy men asked him for nominations so they could join, as well. Walter McFarland asked Cooley to support his membership bid, and to provide any possible assistance to get him an instructor's position at Cornell. In return, McFarland dedicated time during a brief trip to Washington to arrange for technical models and books to be sent to Ann Arbor. McFarland also spread the word among Navy engineers about Cooley's work in Michigan.[23]

News and gossip about Cooley's experiences at University of Michigan spread among Navy officers, and letters began to stream in to Ann Arbor from graduated Cadet Engineers and Assistant Engineers. Some friends just sent congratulatory letters and shared news. However, many more engineers asked Cooley about life on shore and the prospects of more men getting positions like his. Some had very personal reasons for seeking university positions: they wanted to settle down to married life. Others "had quite enough ship" after a few years in the service, and desired escape from the line-staff conflict, incompetent commanding officers, and obsolete, unsafe ships.[24]

The letters written to Cooley by Assistant Engineer Frank Bennett are enlightening, and convey the frustrations of Navy engineers at the time. In the spring of 1883, Bennett described to his friend the conditions aboard his last ship, the old Civil War double-ender, U.S.S. *Ashuelot*. The ship had recently been run onto a rock in the Pacific and lost due to the captain's negligence. Bennett wrote that the vessel was "about as near an approach to a hell on water as any ship could be" because "her officers were all at swords points with the commander and with each other." The crew was "a motley gathering of outcasts from all lands but America – undisciplined, dirty, and worthless."

The young engineer told Cooley that his new ship, U.S.S. *Monocacy*, had a splendid set of officers and a decent crew, but problems remained. The ship was at the end of its life and was unsafe. "She is so antique in design and so debilitated by long service," the engineer complained, "that it makes us ashamed to go into port with her."[25]

Bennett's discontent did not end at poor equipment; he was dissatisfied with a member of his own corps. The ship's senior engineer, W.L. Nicoll, was "as near an approach to an idiot as one can be…; he knows nothing and is continually nagging at some body." The ship's three junior engineering officers were all Annapolis classmates, and believed they knew much more about engineering than the "ancient officer." Bennett and the others felt justified in snubbing him "all the time," and believed it was payback for sins committed against them by Nicoll. Part of Bennett's ire no doubt had its roots at Annapolis: Nicoll was one of the engineering instructors during Bennett's education at the Academy in the 1870s, and his eccentricities then infuriated cadet engineers.[26]

Letters such as these made Cooley realize that his duty at Michigan was far more rewarding that service aboard ship. He was therefore dismayed when the Navy Department detached him from Michigan in the summer of 1885 and ordered him to prepare for sea service. This news sparked a stream of letters between Cooley and the Department. He wanted to extend his duty at Michigan another year, and offered to resign his commission effective June 1886. The Secretary of the Navy refused to grant this courtesy, citing "the limited service rendered by you since leaving the Naval Academy." Clearly the Secretary did not see the value in sending naval personnel to American universities. In the end Cooley resigned, effective January 1886.[27]

Cooley's naval service ended, but his connection to active-duty engineers did not. The engineers who maintained the steadiest correspondence with Cooley sought duty as engineering instructors ashore. Frank Bennett was one of these men. From 1884 to 1887, he taught at the Chicago Manual Training School, described by Bennett as "a grade or two above a high school." This duty was not as prestigious as assignment to a university, but Bennett was happy to relax. He envisioned the duty as "one long picnic." Though he was supposed to be in charge of machine shop instruction, there were no students advanced enough for that class. Instead, Bennett taught physics, focusing on electricity. He also served as a "sort of adjutant or assistant to the director" of the school. [28]

Walter McFarland also frequently wrote to Cooley of his desire to serve at Cornell. In 1883 the Navy granted his wish. In the opinion of another Navy engineer, the college was more a school of mechanic arts than a school of mechanical engineering when McFarland arrived. McFarland's appointment indicated a change in attitude at the college, a determination to improve engineering education. This resolve was heightened in 1885, when Cornell hired Robert Thurston away from the Stevens Institute of Technology to be the director of the Sibley College of Mechanic Arts. Thurston joined McFarland and a handful of other instructors, and began to build Cornell engineering into a highly regarded program. Cornell mechanical engineering was deep in Navy officers: Passed Assistant Engineers Alfred Canaga (USNA 1874) and Frank Bailey (USNA 1875) each served tours there in the 1880s. In 1891 Durand (USNA 1880) joined the faculty; he stayed in Ithaca for fourteen years, leaving for a professorship at Stanford in 1905.[29]

As director of Cornell's Sibley College, Robert Thurston understood the value of Navy engineers as instructors. He worked to hire as many of them as possible. In the fall

of 1890 he planned to extend the school's capabilities by instituting a new program in Maritime Engineering and Naval Construction. He wrote to Cooley, seeking candidate suggestions to chair the new department. Cooley responded that the best men probably would be found in England, but a new tariff law might prevent them from being imported. He put forth the names of three Navy-trained American engineers as well.[30] Thurston did not take his advice, for he already had the ideal candidate in mind. Thurston repeatedly sent letters to Cooley, enticing him to leave Ann Arbor for Ithaca in order to chair the department. The Michigan professor politely refused each time. He cited the lucrative consulting business he had built in Michigan, and his belief that his academic duty lay in Ann Arbor.[31]

The trend evident at Michigan and Cornell of hiring Navy engineers as faculty was a national phenomenon. Navy engineers actively sought billets at universities around the country, and the new land grant universities welcomed them. Schools that would form the Big Ten conference were particularly interested in starting engineering programs with Navy help. Michigan, Purdue, Wisconsin, Illinois, Ohio State, and Penn State all received active duty engineers in the 1880s and 1890s. Officers detailed to those universities wrote to Cooley for advice and counsel. As his friends in the Bureau of Steam Engineering had done for him, Cooley shared with new professors his lecture notes, class outlines, textbook lists, and suggestions for setting up engineering laboratories. Other Navy men adapted Cooley's pedagogy at University of South Carolina, Madison University, Union College, and elsewhere.[32]

Civilian professors took notice of the new engineering pedagogy Navy men brought to academia, and mimicked it. From Vanderbilt University in Nashville,

Professor William Magruder requested from Cooley a catalog describing the Michigan course of study. He was particularly interested in learning about shop practice and manual technology for engineering students, and asked Cooley to send information about outfitting a practical laboratory.[33] Another request came from Pennsylvania State College in 1888. Plans were in the works for a major expansion of the Penn State Mechanical Engineering department, including construction of a new engineering building with laboratories, recitation rooms, drawing rooms, and shops. Cooley duly sent floor plans and laboratory layout suggestions. When the new engineering building was ready, Penn State invited two Navy engineers to serve as instructors. At Penn State and other universities, Navy engineers provided an intellectual boost to emerging mechanical engineering departments.[34]

Navy Engineering Practice as American Engineering Practice

The emphasis Cooley, Spangler, and their fellow Navy engineer instructors placed on practical experience for their students resulted from their Annapolis education. Annapolis instructors drilled their students in the mathematical and scientific basics, then assigned practical projects to the Cadet Engineers. Practical application of theoretical knowledge has been identified as a defining characteristic of American engineering practice, and it derived from Navy engineering practice.

A comparison of nineteenth century engineering education in France and the United States shows that French technical institutions focused on mathematics and engineering theory, but largely eschewed experimental, industrial research. French theoretical contributions in mechanics, hydrodynamics, thermodynamics, and theory of

the strength and elasticity of materials became the foundation for engineering practice throughout the world. American engineers by comparison made few theoretical contributions to their fields.[35]

However, practical application of theory was a defining feature of American engineering pedagogy in the later part of the nineteenth century. Dozens of US firms and institutions including the Navy consistently carried out industrial research and testing. That research "became the basis for technological innovations of international importance in every imaginable field."[36]

Conclusions

Naval engineering careers in the late nineteenth century were not attractive for the many of the intelligent, ambitious young men graduating from the Naval Academy. They possessed the best technical education in the nation, but service in the fleet left them frustrated. The ships of the U.S. Navy were obsolete, uncomfortable, even dangerous at sea. Socially, the situation for engineers was equally undesirable. Chances for promotions were few, exacerbating in the 1880s tensions between line and engineer officers. A few highly publicized groundings and sinkings of ships due to incompetent commanding officers cast line officers in a negative light, but those officers were the exceptions in an otherwise professional corps. All of these factors contributed to engineers' move toward professionalization.

If the engineers were seen as a scientific, professional body of experts, they would gain national political influence. That could be translated into authority within the Navy, which could improve the situation of active-duty engineers. The formation of the American Society of Mechanical Engineers was one certain path to professionalization.

ASME was largely a Navy clubhouse in its first years, with Navy engineering officers filling the key leadership positions.

Another avenue toward professional status for engineers was increasing the barriers to entry. This was accomplished through academic training at universities. Again, Navy engineers guided their field. The legislative efforts of Navy engineers in 1879 allowed Mortimer Cooley, Robert Thurston, Henry Spangler, William Durand, and dozens of other Navy engineers to establish themselves as eminent professors across the nation in ensuing decades. Those men took with them the Annapolis style of engineering instruction. It was built upon foundations of advanced mathematics, basic science, and theoretical knowledge; these underlay experimental laboratory investigations and practical shop experience. Navy engineering practice became American engineering practice, and it was distinct from European styles. By the 1890s, American universities turned out thousands of professional mechanical engineers trained in the Navy style. This group of technically competent men was one reason for American industrial dominance at the turn of the century.

Notes

[1] Bennett, *Steam Navy*, p. 732.
[2] *Annual Register of USNA* 1868-1871; William F. Durand, *Robert Henry Thurston: A Biography* (New York: American Society of Mechanical Engineers, 1929), pp. 58-59, 93. See also Robert Kwik, *The Function of Applied Science and the Mechanical Laboratory During the Period of Formation of the Profession of Mechanical Engineering, as Exemplified in the Career of Robert Henry Thurston, 1839-1903*, unpublished History PhD dissertation (Cornell University, 1974).
[3] *Navy Register 1881*, p. 68; *Annual Register USNA 1875-76*, p. 37; *Navy Register 1882*, pp. 72-74; *Annual Register USNA 1878-79*, p. 25, Bennett, *Steam Navy*, pp. 733.
[4] Letter, "Mortimer Cooley to Lyman Cooley," (13 April 1881) Box 1 – Correspondence, 1873-1887, and undated, Folder – General, 1881, Cooley Papers; Cooley, *Scientific Blacksmith*, pp. 52-56; pay figures from *Navy Register 1880*, p. 3.
[5] Order, "Navy Department to Mortimer Cooley," (13 May 1881); Order, "William Hunt to Mortimer Cooley," (16 June 1881); Letter, "Mortimer Cooley to L. Cooley," (13 April 1881). Cooley, *Scientific Blacksmith*, p. 54.
[6] Letter, "M. Cooley to L. Cooley," (16 April 1881); Order, "Admiral David D. Porter to Cadet Engineer Mortimer Cooley," (16 April 1881, forwarded 18 April 1881) Box 1, Folder – General 1881, Cooley Papers.
[7] Letter, "L. Cooley to Charles Greene," (5 July 1881) Box 1, Folder – General 1881, Cooley Papers.
[8] Order, "William Hunt to Mortimer Cooley," (2 August 1881); Letter, "Frieze to Cooley," (4 August 1881): Box 1, Folder – General 1881, Cooley Papers
[9] Letter, "Harry Spangler to Mortimer Cooley," (21 September 1881), all in Box 1 Folder – General 1881, Cooley Papers.
[10] Letter, "Harrie Webster to Mortimer Cooley," (15 August 1881); Letter, "John C. Kafer to Mortimer Cooley," (24 August 1881); *Navy Register* and *Annual Register USNA* 1867-1883; Letter, "Charles Manning to Mortimer Cooley," (15 August 1881); Letter, "Asa Mattice to Mortimer Cooley," (24 August 1881); Letter, "George McElroy to Mortimer Cooley" (13 November 1881); Letter, "Asa Mattice to Mortimer Cooley," (21 November 1881): all correspondence located in Box 1, Folder – General 1881, Cooley Papers. Asa Mattice graduated first in the class of USNA engineers in 1875.
[11] *Catalogue of the Trustees Officers and Students of the University of Pennsylvania 1881-2* (Philadelphia: Press of Edward Stern & Co., 1882), pp. 22, 36.
[12] Letter, "Spangler to Cooley," (21 September 1881).
[13] Mortimer Cooley, "Report of Professor Mortimer E. Cooley of the Department of Mechanical Engineering," *University of Michigan Regents Proceedings of June 1882* (Ann Arbor: University of Michigan, 1882) Box 48 Folder – U-M Mechanical Engineering, Cooley Papers.
[14] Letter, "Henry Frieze to Q.W. Ruggles, Michigan Central Railroad," (11 January 1882); Letter, "Pennsylvania Railroad: James Wood to Henry Frieze" (20 January 1882); Letter, "Lake Shore and Michigan Southern Railroad: John Newell to Henry Frieze," (24 January 1882): all in Box 1, Folder – General 1881, Cooley Papers; Letter, "Detroit and Cleveland Steam Navigation Co.: C.D. Whitcomb to Harry Soule, Univ. of Michigan," (25 May 1885): Box 1, Folder – General 1885 (April, May June), Cooley Papers.
[15] Cooley, "Report, 1882."
[16] *University of Michigan Regents Proceedings 1884*.
[17] "The Beginning of Mechanical Engineering at the University of Michigan," Box 48 Folder – U-M Mechanical Engineering, Cooley Papers
[18] Letter, "Willard Clapp to Cooley," (17 March 1887), Box 1 Folder – 1887 March; Letter, "George Smith to Cooley," (20 August 1888), Box 1 Folder – 1888 July-August, Cooley Papers.
[19] Letter, "David Jones to Cooley," (12 March 1882) Box 1 Folder – 1882, Cooley Papers.
[20] Letters, "Walter McFarland to Cooley" (7 October 1882) and "McFarland to Cooley," (21 December 1882) Box 1 Folder – 1882, Cooley Papers.

[21] Frederick Remsen Hutton, *A History of the American Society of Mechanical Engineers from 1880 to 1915* (New York: ASME, 1915), p. 78-80, 83-85; Bruce Sinclair, *A Centennial History of the American Society of Mechanical Engineers 1880-1980* (Toronto: University of Toronto Press, 1980), pp. 23, 27.
[22] Letter, "Jones to Cooley" (12 March 1882).
[23] Letters, "McFarland to Cooley" (7 October 1882) and "McFarland to Cooley," (21 December 1882).
[24] Letter, "George McElroy to Cooley," (2 December 1885) Box 1 Folder – 1885 October-November-December; Letter, "William F. Durand to Cooley," 25 April 1886) Box 1 Folder – 1886 March-April; Letter, "Arthur T. Woods to Cooley," (1 February 1887) Box 1 Folder – 1887 February; letter, "Woods to Cooley," (15 June 1887) Box 1 Folder – 1887 June-July, Cooley Papers.
[25] Letter, "Frank Bennett to Cooley," (20 April 1883), Box 1 Folder – 1883, Cooley Papers.
[26] Letter, "Bennett to Cooley," (20 April 1883), Cooley Papers.
[27] Letter, "William C. Whitney to Cooley," (29 June 1885) Box 1 Folder – General, 1885 (April, May, June); Letters, "Whitney to Cooley," (7 August 1885); "Cooley to Whitney," (10 August 1885); "D.M. Manning to Cooley," (13 August 1885) Box 1 Folder – General, 1885 (July, Aug., Sept.).
[28] Letters, "Bennett to Cooley," (20 April 1883); "Bennett to Cooley," (4 March 1884) Box 1 Folder – 1884.
[29] Letter, "Walter McFarland to Cooley," (24 June 1883) Box 1 Folder – 1883, Cooley Papers; Letter, "Frank Bennett to Cooley," (4 March 1884), Box 1 Folder – 1884; Durand, *Robert Henry Thurston*, pp. 95-96; Durand, *Adventures*, pp. 38, 47.
[30] Letter, "Cooley to Robert Thurston," (26 October 1890) Box 58 – Correspondence January 12, 1889 to December 24, 1890 (Letterpress book), Cooley Papers.
[31] Letters, "Cooley to Thurston," (16 May 1891) and "Cooley to Thurston," (9 June 1891) Box 58 Correspondence December 26, 1890 to August 5, 1893.
[32] Cooley generously shared his experience and knowledge with his fellow officers. See letters in the Cooley Papers: from University of South Carolina, telegram, "G.W. McElroy to Cooley," (28 February 1885) Box 1 Folder – General, 1885 (Jan., Feb., Mar.); from Ohio State, letter, "Frank Eldridge to Cooley," (24 May 1885) Box 1 Folder – 1885 April-May-June; from Chicago Manual Training School, letter, "Frank Bennett to Cooley," (9 December 1885) Box 1 Folder – 1885 October-November-December; from University of South Carolina, letter, "George McElroy to Cooley," (3 March 1886) Box 1 Folder – 1886 March-April; from the Michigan Military Academy in Orchard Lake, letter, "Andrew Hunt to Cooley," (28 February 1886) Box 1 Folder 1886 January-February; from Univ. of Illinois, "A.T. Woods to Cooley," (16 July 1887) Box 1 Folder – 1887 June and July; from University of South Carolina, letter, "John Edwards to Cooley: (6 August 1888) Box 1 Folder – 1888 July-August; from University of Wisconsin, letter, "George B. Ransom to Cooley," (9 July 1888) Box 1 Folder – 1888 July-August; from Madison University in Hamilton, New York, letter, "William Eaton to Cooley," (18 August 1888) Box 1 Folder 1888 July-August
[33] Letter, "William Magruder to Cooley," (1 November 1887) Box 1 Folder – 1887 November; letter, "Magruder to Cooley," (19 December 1887), Box 1 Folder – 1887 December. See also letter "Secretary of the Technical School of Cincinnati to Cooley," (2 February 1888), Box 1 Folder 1888 January-February, Cooley Papers.
[34] Letter, "Louis Reder to Cooley," (15 October 1888) Box 1 Folder – 1888 September-October, Cooley Papers; Michael Bezilla, *Engineering Education at Penn State: A Century in the Land-Grant Tradition* (University Park, PA: The Pennsylvania State University Press, 1981), pp. 20-22, 27.
[35] Eda Kranakis, "Social Determinants of Engineering Practice: A Comparative View of France and America in the Nineteenth Century," *Social Studies of Science* v. 19, (1989), pp. 5-6.
[36] Kranakis, "Social Determinants," pp. 6-7.