The Navy Roots of American Mechanical Engineering

Part I – Navy Engineers in the Civil War Era

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Steam Engineering Required

The United States Navy in 1861 was ill prepared for the enormous burdens suddenly placed upon it by the outbreak of Civil War. The fleet was very small, and boasted few steamships. Most of the Navy's thirty-nine steamers were deep draft vessels, intended for sailing alone in the open ocean instead of near shore. The largest, heaviest armed, and most advanced American steam warships of the pre-war era still carried masts and yards for full sail power. They were designed for two missions: worldwide cruising to show the flag, or in the event of war with Britain, *guerre de course*. The strategic and tactical mindset of the Navy was mired in commerce raiding at sea, coupled with the occasional ship-to-ship duel.[1]

Secession of the Southern states changed the Navy's strategic and tactical positions. Instead of global cruising, the Union's ships would patrol almost exclusively in North American waters. For the blockade strategy to be effective, squadrons of men-o'-war had to hover outside Southern ports for extended periods. The North needed steamers to intercept steam-powered blockade runners; sailing warships would have been inadequate. Armored steamers, dreamt about by naval officers for a generation, would have to be built to reduce Southern forts. The Union Navy also had to gain control of the major rivers in the Confederacy's interior. Steam ships were vital there, too, since vessels dependent on the wind could not navigate up and down rivers. The essential ingredient for the North's economic warfare was a large fleet of dependable steam powered warships.[2]

Reliance on steam plants brought increases in the numbers and importance of Navy steam engineers. An 1862 administrative reshuffling highlighted this new emphasis. The Navy split engineering from its former home as a division in the Bureau of Equipment and Repairs, and elevated it to Bureau status. At the head of the newly created Bureau of Steam Engineering and each of the other seven Bureaus sat a chief, administering operations. This was a major departure from the social traditions of the Navy. Until 1862, combat officers always overshadowed technically expert officers. Combat officers formed the "line," and had the authority to command ships, guns, and men at sea. Technical officers were part of the "staff," and were not held in high esteem by line officers. Staff officers had never been allowed authority over line officers, even if they nominally outranked them. Now, however, a staff officer from engineering would be a Bureau chief. This meant new prestige and authority, ranking an engineer with the fleet-commanding commodores. Commodore was the highest rank in the Navy until the introduction of admiral grades in 1862.[3]

The new Chief of the Bureau of Steam Engineering would wield enormous power. The government budgeted tens of millions of dollars for steamers, and decisions had to be made quickly as to the types of vessels, power plants, and boilers purchased or built by the Navy. The Chief of the Bureau of Steam Engineering was responsible for the design, construction, and repair of all the Navy's steam machinery. In March 1861, long-serving Navy engineer Benjamin Franklin Isherwood became the first Chief of the Bureau of Steam Engineering.[4]

In many ways Isherwood was ideally suited to be Bureau chief. He had combat experience in the Mexican War (1846-48), one of only eight engineers still in the Navy who saw action in that conflict.[5] He spent years at sea, running the engines of various ships and gaining a wide range of operational experience. That practical knowledge complemented a personal encyclopedia of engine performance data he had amassed in the 1850s. Isherwood instituted a series of scientific experiments in those pre-war years, gathering empirical data on different fuels, engine designs, and steam expansion. These experiments girded his comprehension of thermodynamics. In 1861 Isherwood's judgment was critical to implementing the wartime blockade strategy, for he understood better than anyone else the requirements for Navy steam engines.

Speed of Union warships was one factor in engine design, but engine reliability and durability became Isherwood's overriding concerns. He recognized that Navy engines had to withstand the abuse of wartime operations. The blockade required long weeks on station with banked fires under the boilers, ready to provide steam whenever lookouts spotted a blockade runner. Constant operation took a toll on machinery, causing breakdowns that diminished combat readiness. Another hazard was the inadvertent neglect of the volunteer engineers aboard ship. With scores of steamers added to the fleet each month after March 1861, the Navy put into uniform hundreds of civilian engine drivers. Many of these men were not familiar with the plants in their charge.[6] The Engineer-in-Chief took all of these factors into consideration when selecting engines for the fleet.

Engine designs originating on the Engineer-in-Chief's drawing table were characterized by heavily constructed primary components to make them robust. He also simplified where he could; Isherwood's designs were less complicated than commercial engines. One critical simplification was in the degree of steam expansion used in the

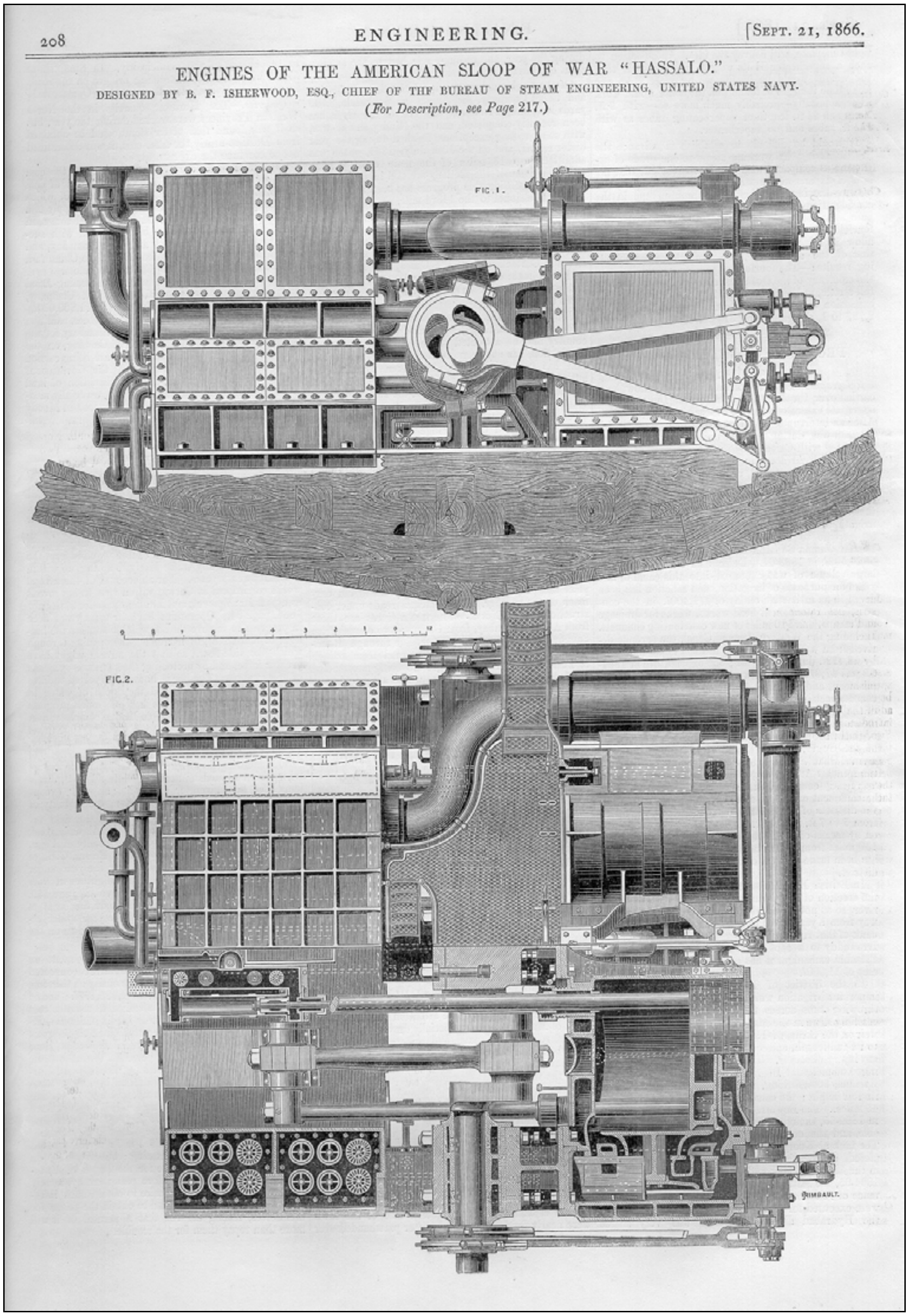

Figure 12 – Isherwood's engines for the sloop-of-war <u>Hassalo</u>. The engines were simple, reliable, and compact. At Dickerson's behest, an 1865 congressional panel investigated Isherwood, his designs, and the Bureau of Steam Engineering in general. It returned a report stating Isherwood's engines provided a great increase in speed and power over any others. Further, the panel concluded that his philosophy of long steam cut-off was theoretically sound and experimentally proven.
Image Source: <u>Engineering</u> (21 September 1866), p. 208

cylinders. Relying on his results from a series of 1858 engine experiments, Isherwood decided not to use steam expansively. He held that a short steam cutoff did not result in fuel savings great enough to justify the added expense and complication of a patent cutoff valve. The chief designed his compact engines to be set low in the hulls of the ships, as far out of the way of enemy shot as possible. With these considerations, he settled on a standard for Navy screw war steamers: a horizontal back-acting engine with steam cut off at 7/10 of the piston stroke.[7]

Expert Knowledge: Dickerson v. Isherwood

As the Navy purchased long cutoff engines at Isherwood's behest, proponents of the short cutoff trumpeted that he was wasting public funds on inefficient engines.[8] The most vociferous of Isherwood's critics was civilian Edward N. Dickerson, a New York lawyer-cum-engine-designer who applied political influence to win an 1858 engine contract for the Navy sloop, *Pensacola*. The lawyer was an aggravating thorn in the side of the Engineer-in-Chief, as Dickerson launched a dispute over steam engine design that ran longer than any of his engines.

Dickerson claimed expertise in steam engineering, but his track record suggested otherwise. His production pace for *Pensacola*'s machinery was nearly three times slower than any other engine builder then working for the Navy. Much of the delay resulted from Dickerson's continual design changes through the construction process. Redesigns forced follow-on changes in the vessel's interior layout and hull, slowing the entire project. When finally delivered late in 1861, Dickerson's engines were much larger and heavier than specified in the contract. *Pensacola*'s displacement was fixed, so heavier than expected engines entailed a reduction in weight elsewhere. The easiest way around the problem was to diminish the amount of coal carried on board. The ship's coal bunker space was cut by half, curtailing its steaming endurance and range. Operationally, this meant that *Pensacola* could maintain its blockade duty for only half the originally envisioned duration before leaving station to refuel. This was bad enough, but other problems with the engines soon became apparent. The ship never attained its contract speed, and the engines broke down completely after only two voyages.[9]

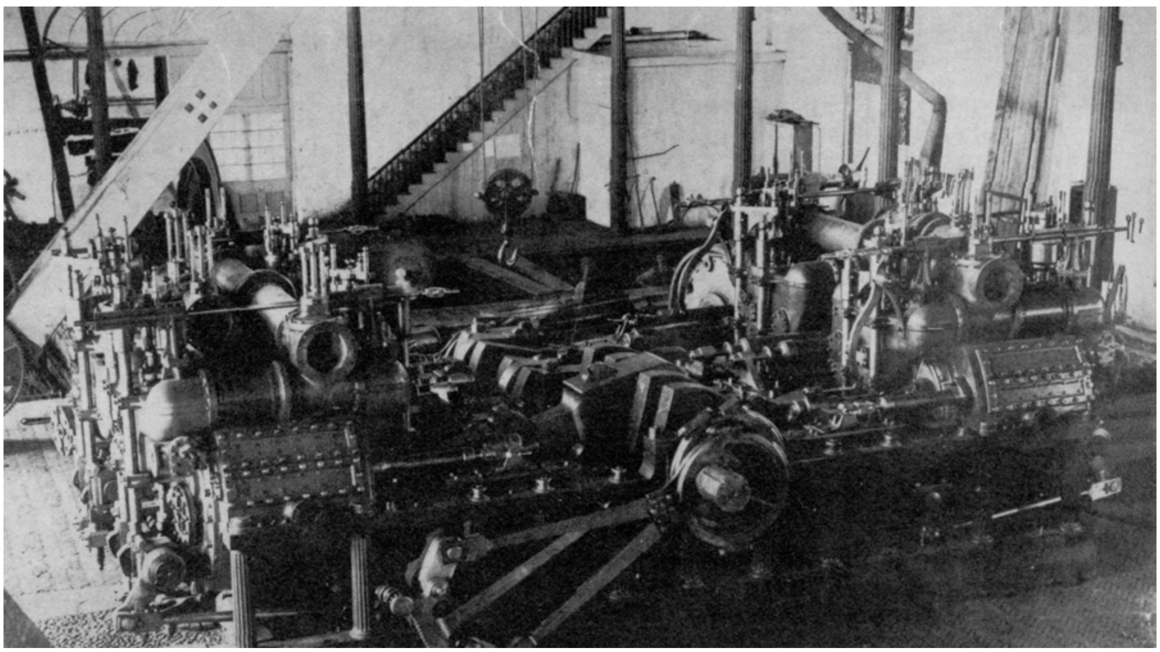

Figure 13 - Dickerson's engine for U.S.S. Pensacola, described as "bewildering" by Navy engineer Frank Bennett. Unlike the comparatively simple long-cutoff back acting engine designed as a standard by the Bureau of Steam Engineering, Dickerson's entire engine and the short cutoff mechanism in particular were complicated and prone to breakdown. Source: Rice, "Marine Engines," H.R. Report No. 8 (30 January 1865), 38th Congress, 2d Session, pp. 26-28. Image: Naval Historical Center.

The inadequacies of Dickerson's design were easily discerned as *Pensacola* sat idle and crippled at the dock. Disgusted, Isherwood denounced the engines to Secretary of the Navy Gideon Welles. In one official report, the chief termed the engines "absurd creations of ignorance" and Dickerson's theories "the conclusions of a charlatan."[10]

Isherwood typically used heated rhetoric when he criticized the work of engineering amateurs. In this case, the engineer met his match when it came to abusive language.

Dickerson defended his design by publishing vicious personal attacks aimed at Isherwood. In a letter to the New York Times written under the pseudonym *Vindex*, the New York lawyer railed that Navy engines were "a national disgrace." He accused Isherwood of being an "engine driver," raised beyond his station by wheedling political favors from Abraham Lincoln.[11] In a public letter to Gideon Welles, Dickerson dismissed Isherwood's experimental data as "nonsense in rows of figures," and ridiculed the Navy man's conclusions about the expansion of steam as "profound ignorance." As for the engine designs emanating from Isherwood's office, Dickerson termed them "ridiculous," "worthless," and "vastly *inferior* to their predecessors, and practically useless."[12] Pride was one reason for Dickerson's vigorous defense, but he had even more pressing concerns.

Prior to and early in the war, engine contracts seemed promising opportunities for financial gain. Dickerson wanted more lucrative government jobs. He used his political connections to win the bid for two other power plants, to be installed in *Algonquin* and *Idaho*. The lawyer's prewar Washington contacts eroded after secession, however. He had been closely allied with two member of the Naval Affairs committee, Senator Yulee and chairman Stephen Mallory, both from Florida. The pair of congressmen went south in 1861, and Mallory accepted Jefferson Davis' offer to be Confederate Secretary of the Navy.[13] Given his close prewar ties with Stephen Mallory, Dickerson had every reason to fear being branded disloyal. By claiming that the Bureau of Steam Engineering was not performing well for the Union, Dickerson deflected criticism of his own loyalties.

Always a theatrical orator in the courtroom, Dickerson was equally entertaining in his attacks on Isherwood. He accused the Engineer-in-Chief of "childish ignorance" and in reference to the long cutoff, ridiculously averred that Isherwood did not comprehend basic physical properties and engineering principles. Secretary Welles regarded Dickerson's complaints as "the vilest misrepresentations and fabrications that could well

Figure 14 - An illustration from "Uncle Sam's Whistle" depicting Dickerson catching pennies from heaven in the form of government engine contracts. He sits on a throne of oil dash-pots, in which he collects the money falling from above. He uses Isherwood's published engineering texts as a footstool. Watt and Mariotte look down on him, and the "gentle breeze of fame" pushes him through the clouds. Source: "Uncle Sam's Whistle," pp. 12-13.

be gathered together." He believed the accusations against Isherwood to be "wholly unjustifiable and inexcusable." However, the lawyer made his complaints very public. He went so far as to claim that Isherwood forced contractors to provide kickbacks to him. Accusations of corruption in the Bureau of Steam Engineering made good press and Dickerson's newspaper friends played along by airing his views. With the lever of public notice, Dickerson used his remaining contacts in Washington to force the Committee on Naval Affairs to launch an investigation of the Bureau of Steam Engineering.[14]

Dickerson's attacks forced the Engineer-in-Chief to protect himself and his Bureau. In 1863 Isherwood attempted to discredit the lawyer's short cutoff argument by collecting more engine performance data. Under Isherwood's orders Navy engineers tested several types of engines and noted the benefits, drawbacks, and relative efficiency of each variety. The results of these trials were published in a two volume series, *Experimental Researches in Steam Engineering*.

In the preface to those volumes, Isherwood argued that knowledge of the physical laws of steam was too imperfect to allow confident application of descriptive mathematics. To state this another way, thermodynamic theory was not well enough understood to apply calculus to design effectively. Only by "honest sagacious experiment, long and frequently repeated" could true knowledge be distilled: he needed empirical evidence to compare against theory. Isherwood fully expected his experimental evidence to be subject to counterattack by Dickerson and other supporters of the high-expansion theory, but accepted that as a burden concomitant with his position as an engineering reformer.[15] Under Isherwood, Navy engineers conducted an extensive series of practical experiments to ascertain the true physical properties of operational steam engines. The experiments showed conclusively that the theoretical gains of short cutoffs were offset during normal operation by an increase in condensation in the cylinder, which reduced the engine's power.

Despite the experimental results obtained by Navy engineers, the dispute between Dickerson and the Engineer-in-Chief dragged on interminably. Dickerson continued to denigrate Isherwood and Navy engine designs, and his political connections in Washington and financial links in New York helped him win engine contracts for four vessels during the war. Was Dickerson correct in his engineering opinions?

The evidence is against Dickerson. Just after the war, the respected British journal, *Engineering*, reported on a competition between Isherwood and Dickerson engines. The paddlewheel steamer *Winooski* was equipped with Isherwood engines, while the identical ship *Algonquin* was fitted with a Dickerson design. The two ships sat side-by-side at the dock, ready to engage in a head-to-head competition under actual working conditions. The engineers started the machinery during dock trials, and immediately Dickerson's engine broke down. Extensive repairs were necessary to ready it for another attempt. This was embarrassing enough for Dickerson, but things got worse. The engine was poorly balanced, leaving *Algonquin*'s port paddlewheel immersed nearly four feet deeper than its starboard companion. This absurd situation was corrected temporarily only by stowing 73 tons of ballast on *Algonquin*'s deck. The message was clear: Dickerson's machinery was a failure, and the Navy rejected it.[16] Yet even this demonstration combined with operational experience and a large body of scientifically collected experimental data could not silence Dickerson's public assaults on Isherwood.

An 1865 congressional investigation into the replacement of Dickerson's *Pensacola* engines with Isherwood designs vindicated the Engineer-in-Chief. The Committee on Naval Affairs studied ships' deck logs, engine room steam logs, and repair records from the Bureau of Construction and Repair. The committee concluded that despite Dickerson's claims to the contrary, Navy engines were more robust and economical than others, and that ships powered with them were faster than those driven with civilian designs. Further, the committee noted that the long cutoff of Isherwood's engines was very close to the accepted British practice for marine engines. Dickerson had posited that Navy engines' long cutoff was an engineering aberration, but the committee showed that Dickerson's short cutoff diverged from common practice to a far greater extent.[17]

Even with the support of Welles and the favorable results of the 1865 investigation, Isherwood was never quite able to stifle Dickerson's criticism. This was only one front in the battle he and the engineers fought for mechanical engineering authority and professional prestige. The long cutoff dispute gave birth to a new movement among Navy engineers. In the postwar period they began a long siege to establish sole possession of expert mechanical engineering knowledge. They needed to organize a sequential program to gain this expert knowledge, for some very visible wartime problems called into question their supposed expertise.

Alban Stimers and the Light Drafts

The most damaging wartime Navy engineering debacle was the complete failure of the Union's shallow water ironclad program. Deeply involved with the project was Union Chief Engineer Alban Stimers. He joined the Navy as an engineer in 1849 and worked his way through the ranks to Chief Engineer by 1858. Soon after the Civil War broke out, the Navy assigned Stimers to supervise construction of John Ericsson's ironclad, *Monitor*. Stimers served aboard that ship when it dueled the Confederate ironclad *Virginia*, taking charge of the gunnery division in the turret after the Executive Officer left it to relieve the injured captain on the bridge.[18] Stimers' behavior on this and other occasions made him a great favorite of Assistant Secretary of the Navy Gustavus Fox, who became a powerful patron for the engineer.

Stimers' wartime duties and a close association with Ericsson made the Navy engineer an enthusiastic advocate of the monitor-style ironclad. A monitor craze swept the Navy and nation after the engagement with *Virginia*, and production of a variety of the type became a top priority. Chief Engineer Stimers had no formal training in shipbuilding, but he had overseen aspects of the Stevens Battery and original *Monitor* construction. After the national press reported his performance at Hampton Roads, he was a public figure, and Gustavus Fox selected him to oversee the highly visible construction of the light drafts. The subsequent travails of the light draft monitor program brought into sharp relief the limits of Navy engineering.[19]

Stimers' project ultimately foundered on a variety of rocks. In 1863 the nation's industrial machine was still maturing. Wartime production in weapons, railroad locomotives, and other iron-intensive goods increased demand for labor and iron far above available supply. Another problem with the light draft monitor program occurred in the design process. Alban Stimers redesigned throughout the construction process, slowing construction and increasing costs.[20]

Additional problems saddled the light draft program. Stimers had sole authority over the design and construction process, with no oversight from higher-ups. When the Chief Engineer launched his first long overdue and over budget monitor hull, he was dismayed to learn that he and his assistants had quite literally miscalculated. The vessel was supposed to sit in the water with fifteen inches of freeboard, the distance between the water's surface and the top of the deck. Instead, the bow sat about seven inches out of the water, and the stern was two or three inches *below* the surface. When all requisite equipment and stores were put aboard the ships, the entire class of vessels designed and built under Stimers' guidance simply would not float. At the base of the problem was an error in a lengthy but straightforward hydrostatic calculation.[21] If Stimers and his Navy engineer assistants had accurately predicted the mass and displacement of the finished ship and its machinery, all other problems would likely have been forgiven. Instead, the Navy Department was left in 1865 with a very public multimillion-dollar humiliation. The light drafts and Stimers became laughingstocks for a bitter Congress.[22]

The light draft monitor debacle and the continuing dispute between Isherwood and Dickerson pointed out shortcomings in the training of the Navy's engineer corps. These difficulties forced the Navy's leaders to recognize the need for theoretically and scientifically educated, practically skilled men to design and operate the fleet's technical systems. When the war ended in 1865, the Naval Academy returned to Annapolis from its wartime home in Rhode Island. The next year the Navy moved toward rectifying the situation in its engineering corps.[23]

Postwar Engineering at Annapolis, 1866-69: Fixing the Engineer Corps

Steam engineering education for all midshipmen was the highest priority for the Academy under its first postwar superintendent, Vice Admiral David Dixon Porter. In his 1866 report to the Secretary of the Navy he commented on the large appropriation for Annapolis' new Department of Steam Engineering. Porter spent the $20,000 allocation to put up a new building and equip it with "a beautiful propeller engine" designed by Isherwood. The admiral was complimentary to Isherwood, and termed the engine "a monument to the skill and perseverance of the engineer-in-chief." In a reference to the dispute between Isherwood and Dickerson, Porter averred that this was the best type of engine available, "although efforts have been made to bring it into discredit." The engineering building also held classrooms and laboratories; henceforth all midshipmen would undergo "a full theoretical and practical course of steam" during their four years at the Academy.[24]

Contemporary ideas about the Academy's curriculum can be further discerned by the report of the 1866 Board of Visitors. All but one of the members approved of the new prominence of engineering in cadet training. The Board deemed engineering knowledge "indispensable for the efficiency of a naval officer" and ranked it second only to seamanship in importance. The Visitors were of the opinion that every midshipman at the Academy needed practical steam training and "should understand the construction of steam machinery, and the methods of using, repairing, and preserving it."

Congress and the Navy recognized that practical knowledge of steam engines was requisite for the next generation of line officers, but Navy engineers needed a deeper theoretical understanding of their subject. Unsure how best to achieve this, in 1866 the Academy introduced an experimental curriculum. The strategy for this program was to take men already competent in the science and theory of engineering and enhance their knowledge with an additional two years of study, combined with practical operational experience with engines. The Navy recruited this group of men from leading scientific schools: Harvard, Yale, Rensselaer Polytechnic Institute and a few other colleges. About fifty engineering students responded to the Navy's posted advertisements for steam engineers. They submitted to a competitive exam at Annapolis, and the top sixteen accepted the Navy's offer to enter a two-year program in steam engineering. These men had earned engineering bachelor's degrees already: the Annapolis program would be graduate education for them.[25]

The originator and chief proponent of this plan was Benjamin Isherwood. He outlined his idea in a report to Welles in early 1866, then actively encouraged it as part of his drive for increased rank for engineers. In his annual report for 1866 he wrote, "…elevating the status of the corps…[and] making first and second assistant engineers commissioned officers, renders it practicable to now obtain for the lower grades the graduates of the first scientific schools of the country."[26]

Gideon Welles also saw value in a scientific corps of naval engineers. In his annual report for 1866, he noted that "the gross loss, delay, and embarrassments experienced during the war in consequence of the ignorance, inefficiency, and incompetency of many of the engineers, admonish the government of the necessity of educating and training men of ability to this highly responsible profession." This was a direct reference to Alban Stimers' light draft debacle. Welles continued that the cadet engineers would form a "highly scientific and useful class, indispensable to the service and more useful, perhaps, in the design and construction of engines than in duty afloat."[27] The Academy's new course of study achieved this while simultaneously setting a national precedent for engineering education.

The 1866 Annapolis curriculum differed from that offered at contemporary American technical and scientific universities. Technical education was in its early adolescence at the time of the Civil War. While West Point and a handful of established colleges convened courses in civil engineering, mechanical engineering education was rooted in shop culture. The three best respected American colleges offering engineering curricula were Rensselaer Polytechnic Institute, Lawrence Scientific School at Harvard, and the Sheffield Scientific School at Yale.[28] Only RPI differentiated among branches of engineering. It offered tailored programs for mechanical, civil, and mining, but the four RPI graduates entering the Naval Academy engineering program in 1866 earned their degrees in Civil Engineering.[29]

The classes taught in the Engineering division of RPI in 1865-66 provide the benchmark for mechanical engineering education of the time. The nineteen students of that year's senior class had studied for four years in the civil engineering program. In their first year, they undertook algebra and geometry, natural philosophy (physics), geodesy and drawing. More algebra, geometry, physics, and drawing followed in the second year. Subjects in their penultimate year included calculus, electricity, chemistry, and more geodesy. They also studied mechanics of both solids and fluids. Building on the natural philosophy presented in the first year, professors taught the physics of acoustics and optics in year three. In the final year at RPI, more solid and fluid mechanics, more chemistry and drawing, machine theory, and geology rounded out the civil engineering course. The course in mechanical engineering program was identical to it, with two exceptions: machine drawing replaced construction drawing, and a class on the construction of machines and their placement was substituted for road engineering.[30] In 1866, the RPI course was the standard against which all others were judged.

In contrast, the engineering course at Harvard's Lawrence Scientific School varied a great deal from Rensselaer's. Unlike the four-year RPI engineering curriculum, Harvard conferred a Bachelor of Science degree after one year of instruction. Often men left the school without completing the requirements for the degree, studying only a few subjects before departing.

The Naval Academy inaugurated a rigorous program in response to the inadequacies of engineering curricula offered at civilian institutions. Annapolis drew sixteen engineers in 1866 from the best technical schools in the country. The men's performance on the admissions test demonstrated their mastery of integral and differential calculus, so this group did not study those subjects at the Academy. Though already proficient at the drafting table, the men expanded their skills with pen and ink by practicing mechanical drawing. Plans and estimates for the construction of boilers and engines, iron ships, and mill works were other areas of study. The Navy instilled practical skills in iron ship-building to correct the shortcomings made apparent by the light draft debacle.[31]

The engineers at the Academy also focused attention on management of machinery, consisting of practical exercises with steam engines and boilers. This experience was vital to the engine-driving roles they would fulfill as Third and Second Assistant Engineers aboard ship. Once joining the fleet, the engineers would also command the fire room. Their course in Chemistry acquainted them with lubricating oils, coals and fuels, and ores. Additional practical exercises included working with hand tools in wood and metals shops.[32]

On the theoretical side, the men studied physics, particularly steam and heat. An extensive course in mechanics covered engines and motors. The Annapolis program bolstered the standard practical and theoretical education acquired by the 1866 engineer class in civilian institutions, but in one critical way it was not simply more of the same. In a significant contribution to engineering education, in 1867 the Naval Academy introduced thermodynamics into the theoretical training of American engineers.[33]

Years earlier Benjamin Isherwood had pointed out mechanical engineers' woeful incomprehension of thermodynamic theory: this was the root of his fight with Dickerson. The engineering students who entered Annapolis after the war studied thermodynamics to correct this. The first and second laws of thermodynamics had been proposed one and two decades prior respectively. The Annapolis curriculum's distinct sections on thermodynamics set the Naval Academy program apart from all others in the country. The new curriculum served as a model for other schools: in 1870 the premier civilian technical institution, RPI, added thermodynamics to its engineering courses.[34] With the foundation of calculus and descriptive mathematics in place and an understanding of thermodynamics, Annapolis-trained mechanical engineers in the late 1860s possessed the most advanced theoretical engineering education in the nation.

While education of naval officers improved, social and professional relations between Navy engineers and line officers became more and more of a problem in the years immediately after the war. Although Naval Regulations prohibited officers from publishing anything "having in view the praise or excuses of any person in the naval service,"[35] officers refused to be gagged. Anonymous articles featuring the invective of both sides appeared regularly in the pages of the *Army and Navy Journal, New York Times*, and *New York Tribune* throughout the late 1860s. The tensions between officers of the line and staff would nearly consume the Navy in the following years. Evidence that it affected the 1868 engineers is found in their subsequent careers. Within one year in the fleet, a quarter of the graduating 1868 class of "indispensable" engineers resigned from the Navy.[36]

Conclusions

The Civil War illustrated in high relief the shortcomings of the Navy's steam engineering. Alban Stimer's failed light draft monitor efforts were an example of a flawed administrative system more than anything. Stimers' patron, Assistant Secretary of the Navy Gustavus Fox, had placed him in a position for which he was not qualified. Stimers was not a naval constructor, and the demands of the task exceeded his professional abilities. Construction of the complete vessel was a systems engineering project, but such holistic approaches to technical programs were far in the future.

After the war, the Navy's budget shrank, officers and men left the service in droves, and Congress forced a reduction in the number of ships to prewar levels. It seems contradictory to this policy of retrenchment for the Naval Academy to have recruited a new group of engineers in 1866. The explanation is that Gideon Welles and Benjamin Isherwood retained enough power to carry through on the idea, which was originally proposed by the Bureau chief. The two men saw in the plan a way to pre-empt future engineering difficulties like those experienced during the Civil War.

Benjamin Isherwood's problem during the conflict was an inability to close the debate with Dickerson over expert knowledge. The Navy engineer was armed with reams of experimental data and the proof of reliable steamers blockading the Confederacy, but criticism of his engines continued throughout the war and after. Dickerson's power lay not in his own engineering capabilities, but in his political, financial, and press connections. Saddled with an enormous engineering and administrative workload, Isherwood could not devote enough attention to quelling the cries of his main detractor. In 1866 Gideon Welles, Isherwood, Porter, and other high-ranking naval officers and administrators cooperated to remedy some problems in the technical training of officers. The curriculum changes effected at the Naval Academy in 1866 were direct responses to the light draft disgrace and the debate over thermodynamic theory. Welles probably was the most high-minded of the triumvirate. His writings show that his support for the new curriculum was based on the long-term best interests of the Navy and nation. Isherwood was self-interested; he wanted increased rank and prestige for engineers. By attracting bright, well educated engineers to the Navy, he could achieve that end. Porter probably believed that by increasing cadet midshipmen's education in steam engineering, he could all but eliminate technically expert engineer officers from ships. In Porter's mind the ideal naval officer was a warrior, not an engineer.

[1] George Henry Preble, *Complete List of the Vessels of the United States Navy from 1797 to 1874* (Washington, D.C.: Government Printing Office, 1874), p. 4; Harold Sprout and Margaret Sprout, *The Rise of American Naval Power, 1776-1918* (Annapolis: Naval Institute Press, 1990. Originally published 1939), pp. 178-179; K. Jack Bauer, "Naval Shipbuilding Programs 1794-1860," *Military Affairs* Vol. 29 No. 1 (Spring 1965), pp. 38-39.

[2] Karl Lautenschlager, "Technology and the Evolution of Naval Warfare," *International Security* Vol. 8 No. 2 (Autumn 1982), pp. 8-9.

[3] *Report of the Secretary of the Navy, With an Appendix, containing Reports from Officers. December, 1862.* (Washington, D.C.: Government Printing Office, 1863), pp. 39, 45; Paullin, *Paullin's History*, pp. 260-261.

[4] Edward Sloan, *Benjamin Franklin Isherwood Naval Engineer: The Years as Engineer in Chief, 1861-69* (Annapolis: United States Naval Institute, 1965) pp. 46, 83.

[5] Combat veteran engineer data compiled from Frank M. Bennett, *The Steam Navy of the United States: A History of the Growth of the Steam Vessel of War in the U.S. Navy, and of the Naval Engineer Corps* (Originally published Pittsburgh: W.T. Nicholson Press, 1896; reprinted Westport, CT: Greenwood Press, 1974), Appendix A, and Lewis Randolph Hamersly, *The Records of Living Officers of the U.S. Navy and Marine Corps Compiled From Official Sources, Fourth Edition* (Philadelphia: L.R. Hamersly & Co., 1890).

[6] Benjamin Isherwood, "Report of the Bureau of Steam Engineering," in *Report of the Secretary of the Navy 1864* (Washington, D.C.: Government Printing Office, 1864), p. 1095; James M. McPherson and Patricia R. McPherson (eds.), *Lamson of the Gettysburg: The Civil War Letters of Lieutenant Roswell H. Lamson, U.S. Navy* (New York: Oxford University Press, 1997), p. 23; Sprout and Sprout, *The Rise of American Naval Power*, pp. 180-181 (fn).

[7] Sloan, *Isherwood*, pp. 14, 33, 41, 89; A.H. Rice, "Marine Engines" House of Representatives 38th Congress, 2nd Session, Report No. 8, p. 17.

[8] See Sloan's clear and concise discussion of Isherwood's decision process on the steam cutoff. Sloan, *Isherwood*, pp. 82-96.

[9] Sloan, *Isherwood*, pp. 106-107; "Letter of the Secretary of the Navy, Communicating, In answer to a resolution of the Senate of the 15th of January, information in relation to the war steamers *Ossipee* and *Pensacola*," (23 February 1863) *Senate Executive Document No. 45,* 37th Congress 3rd Session, pp. 4-8.

[10] Isherwood, "Report to Welles" (17 February 1863) *Senate Ex. Doc. No. 45*, p. 6.

[11] Vindex, "Letter to the Editor," *New York Times* (29 December 1862).

[12] Edward N. Dickerson, *The Steam Navy of the United States: Its Past, Present, and Future. A Letter to the Hon. Gideon Welles, Secretary of the Navy, From Edward N. Dickerson, of New York* (New York: John A. Gray, 1863), pp. 5, 7, 9.

[13] Sloan, Isherwood, pp. 45, 106; Craig L. Symonds, *Confederate Admiral: The Life and Wars of Franklin Buchanan* (Annapolis: Naval Institute Press, 1999), pp. 117, 146; Isherwood, "Report to Welles" Senate Ex. Doc. No. 45, p. 4.

[14] Dickerson, *The Steam Navy of the United States*, pp. 3-4; Gideon Welles, *Diary of Gideon Welles, Secretary of the Navy under Lincoln and Johnson, Vol. I-III: 1861-March 30, 1869* (Boston and New York: Houghton Mifflin Co., 1911), v. 1, p. 50. For examples of the long continuation of Dickerson's derogatory views of Isherwood expressed in newspapers, see "Letter to the Editor," New York Times (29 December 1862); "Naval Engineering" New York Times (1 January 1866), p. 5; "Naval Engineering" New York Times (8 January 1866), p. 2; "Naval Engineering" New York Times (22 January 1866), p. 2; "Reform and Reconstruction in the Navy" New York Times (29 November 1869), p. 4.

[15] Benjamin Franklin Isherwood, *Experimental Researches in Steam Engineering Vol. I* (Philadelphia: 1863), pp. xv, xxv. One of Dickerson's counterattacks came in the form of a speech made during a court case. The resulting published document runs to 80 pages. See Edward N. Dickerson, *The Navy of the United States. An Exposure of its Condition and the Causes of its Failure, etc.* (New York: John A. Gray and Green, 1864). Ultimately Isherwood replaced Dickerson's *Pensacola* design with low-expansion engines, and the ship served faithfully until 1912.

[16] Engineering, v. 1 (March 23, 1866): 183; *Report of the Secretary of the Navy with an Appendix Containing Bureau Reports, Etc. December, 1866* (Washington, D.C.: Government Printing Office, 1866), p. 41.
[17] Rice, "Marine Engines" *H. R. Rep. No. 8,* 38th Congress 2nd Session, pp. 32, 38; *Congressional Globe* (6 February 1865), 38th Congress 2nd Session, p. 621.
[18] Monte Calvert, *The Mechanical Engineer in America, 1830-1910* (Baltimore: The Johns Hopkins Press, 1967), p. 252; Bennett, *Steam Navy*, Appendix A; Alban C. Stimers, "Chief Engineer Stimer's [sic] Report," *Report of the Secretary of the Navy in Relation to Armored Vessels* (Washington, D.C.: Government Printing Office, 1864), p. 21.
[19] Roberts, *Civil War Ironclads*, p. 206. "Light draft" is the maritime terminology for vessels that draw a small amount; that is, vessels that are submerged only a few feet below the waterline. Light draft usually decreases a ship's stability, so most ocean-going vessels are deep draft.
[20] Roberts, *Civil War Ironclads*, pp. 59-60, 66-68, 134.
[21] Roberts, *Civil War Ironclads*, pp. 159, 161.
[22] See comments by Senator Hale, *Congressional Globe* (30 January 1865), p. 491. Hale got the chamber laughing by his criticism of the light drafts and those associated with it, particularly Asst. Navy Sec. Fox.
[23] *Report of the Secretary of the Navy 1866*, p. 33.
[24] *Report of the Secretary of the Navy 1866*, p. 75.
[25] *Report of the Secretary of the Navy, 1866*, pp. 33, 82; Bennett, *Steam Navy*, pp. 665-666.
[26] *Report of the Secretary of the Navy, 1866*, pp. 178-179.
[27] *Report of the Secretary of the Navy 1866*, pp. 33.
[28] Charles Riborg Mann, *A Study of Engineering Education Prepared for the Joint Committee on Engineering Education of the National Engineering Societies* – Bulletin No. 11 of the Carnegie Foundation for the Advancement of Teaching (New York: 1918), pp. 4-6.
[29] The RPI graduates were John Q.A. Ford, Charles Rae, Holland Stevenson, and Francis Trevor. Source: *Annual Register of the Rensselaer Polytechnic Institute 1866*, p. 13.
[30] *Annual Register of RPI 1866*, pp. 24-26.
[31] Letter, "Welles to Porter," (14 February 1867) RG 405 Letters Received by the Superintendent, 1865-67: Box 9, Folder 11. *Annual Register of the United States Naval Academy at Annapolis, MD., for the Academic Year 1867-68* (Washington, D.C.: Government Printing Office, 1867), pp. 37, 41; *Annual Register of the United States Naval Academy at Annapolis, MD., for the Academic Year 1868-69* (Washington, D.C.: Government Printing Office, 1968), pp. 40, 43. Calculus remained part of the USNA Cadet Engineer course. C.P. Howell, the sole remaining participant in that program, studied calculus in the first term of his second year.
In addition to Yale, Harvard, and RPI, some other schools contributed men to the class of Acting Third Assistant Engineers. Charles Bray studied Civil Engineering at Brown prior to his admission at Annapolis. Source: Orren Henry Smith (ed.), *The Tufts College Graduate: A Quarterly Magazine Published by the Alumni Association* Vol. 28 (September 1919 – August 1920), p. 121.
[32] *Register of the Naval Academy 1867-68*, p. 41; *Register of the Naval Academy 1868-69*, p. 43.
[33] *Register of the Naval Academy 1867-68*, p. 41; *Register of the Naval Academy 1868-69*, p. 43.
[34] *Annual Register of the Rensselaer Polytechnic Institute, Troy, N.Y., for the Academical Year 1870-71* (Troy, NY: Wm. H. Young and Blake, 1871), p. 23.
Course catalogs for the other leading technical institution, Massachusetts Institute of Technology, are not extant in MIT Archives. The earliest Mechanical Engineering course catalogs date to 1892, when thermodynamics was well established at MIT.
[35] George M. Robeson, "Circular," (12 March, 1870) *General Orders and Circulars Issued by the Navy Department From 1863 to 1887* (Washington: Government Printing Office, 1887), p. 96.
[36] The four men who resigned in 1869 were Frank Symmes, Charles Bray, Theron Skeel, Francis Trevor.