Copper Sheathing, Industrial Espionage and an Eminent American Entrepreneur

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For millennia wooden ships that plied the world's oceans were plagued by biological problems. These were a multifaceted result of water temperature, salinity, levels of sunlight and the quantity of nutrients in the water. Vessel hulls, in time, collected seaweed affecting their speed and maneuverability. The ship's longevity was impacted by infestations of two marine borers: the shipworm, a wormlike clam and tiny crustaceans known as gribbles. Combined they largely destroyed the integrity of marine timber structures, often working together to bore tunnels in wood to make it spongy and friable. Countless schemes were tried over time to solve sea flora and wood-rot problems. Some produced limited success until, in the eighteenth century, a relatively simple and practical solution was found, one that would shape maritime history. The evolution of that discovery ultimately affected two American icons, one a storied ship, the other a patriot, entrepreneur and an industrial opportunist.

Of weeds, quasi-worms and "lice"

Continuous attack by saltwater flora meant that seaweed and barnacles had to be laboriously and mechanically scraped off from a careened ship[1]. In a procedure called "graving," a graving compound, a mixture of tar, tallow and sulfur, was smeared on the cleaned hull. It was effective against seaweed for several years (though not against borers), but had to be refreshed frequently at great labor costs. This process helped with the weed problem, but it did not affect shipworm infestations, a far more complex, problematic conundrum.[2]

The term "shipworms," is a misnomer. They are not really worms, but boring mollusks that work their way into timber by means of sharp teeth at the end of the shell. Once inside, the pests feast along the wood's grain and deposit their eggs in the holes they have bored. These long, naked saltwater bivalves are members of the family *Teredinidae*. Fully-grown, they range from several centimeters to about a meter in length.[3] These shellfish particularly thrive in warmer saline oceans and have tiny "teeth" that rasp their way into submerged wood and bacteria in their gut digest its cellulose into fine particles found in long cylindrical holes. Therefore, *teredo*

worms aptly earned the title "termites of the sea." The gribble worms, pale white marine "wood lice" about only 1–4 millimeters long, are members of the family *Limnoriidae*. Infestations of *Teredinidae* and *Limnoriidae* created a multitude of burrows, wood spicules lined with a thin film of calcium carbonate that undermined ship hulls, wooden piers and floating docks.

Structural deterioration clearly affected a vessel's durability. Merchant ships generally had a profitable life of roughly five-plus years, but naval ships were expected to last far longer. Warships needed to be strong to support the dead weight of very heavy armament and a weakened hull made it more vulnerable to damage in storms and hostile cannon fire. Roughly two millennia ago Greeks and Romans sheathed the hull of their vessels with lead panels as physical shields, but they were difficult to fasten and easily dislodged in heavy seas. Later, another fleeting strategy to protect the hull was using a heavy canvas impregnated with tar laid between two layers of planking.[4]

In 1708, Charles Perry proposed the use of copper sheathing on ships' hulls based upon chemistry; but the British Navy Board rejected this because of cost and perceived maintenance difficulties. Oxygen-containing salt solutions chemically react with copper to produce an oxychloride film and a complex of copper salts. As they gradually dissolve, marine life has difficulty attaching itself to the sheathing. The British experimented with copper sheathing in the late 1750s, and the British Admiralty copper sheathing was tried as a remedy on the frigate *Alarm* in 1761. Unfortunately, the seawater created galvanic reactions when the iron bolts used in the construction of the ship contacted the copper nails holding the plates to the hull causing widespread corrosion.[5]

By 1770 eight British warships had been coppered and after the American Revolution the Royal Navy attempted to copper sheath the bottoms of its entire fleet. Strategically, coppering would permit ships to remain at sea for much longer periods without the need for hull cleaning and repairs. In 1783, galvanic-induced corrosion problems with iron hull bolts were becoming increasingly apparent. Eventually, a suitable alloy for hull bolts was procured, according to various sources either copper-zinc or copper-tin.[6] Copper sheathing was roughly six times more expensive than wood, but Britain's supremacy at sea was at stake. "The decision to change all naval ships to the new bolts was made in 1786, finally bringing an end to the controversy."[7] The Admiralty ordered the re-bolting of every naval warship, a process that took several years.

"Responding to the economic impacts of this new technology, British Navy Comptroller

Charles Middleton estimated that copper sheathing might double the number of ships at sea at any given time. As a result, he gave coppering precedence over all other ship repairs . . .”[8]

The process of rolling malleable copper sheathing was a by-product of the industrial-age. The tonnage of metal needed for sheathing was immense. For example, one first-rate ship-of-the-line required about thirteen tons of copper plates. In building the ship’s hull once the planking and joints were caulked with oakum, yellow/orange pitch was smeared over the hull below the waterline. A layer of tar-impregnated brown paper was placed on the pitch, and thick felt placed under the keel. The standard size plate, four feet by fourteen inches, was laid to follow the line of the planking. The copper sheets were fastened with copper tacks starting on the keel at the stern and ending with the thickest leaves near the bows.[9]

Copper was expensive and difficult to forge, but foreign navies began to introduce copper sheathing to their ships so as not to leave Britain with too great a military advantage. In general, it was not cost effective to copper the merchant fleet and the priority went to the armed forces. In time, British civilian contractors saw copper sheathing as a valuable commodity and sold the materials to competing European naval powers. These businessmen made large profits and, in turn, spurred Britain’s post-war domestic economy. After the Revolutionary War, however, American shipbuilders were denied access to British copper and the technology of copper plate production. This was a major problem for American merchant vessels. Many engaged in trade in tropical waters that promoted heavy seaweed growth and where the *teredo* was endemic. One cooper mine, the Schuyler Mine in New Jersey, produced a high-grade copper ore that was readily available. Now the upstart Yankees had to acquire the British secret rolling technology to protect their own vessels.

The need for a United States Navy

Before the Revolutionary War the nascent United States was a collection of seaboard colonies whose merchant vessels sailed largely unmolested protected by the large formidable British Navy. When the war ended however, the fledgling independent nation was now extremely vulnerable. America had a heavy postwar debt and Congress felt that the country had neither the financial resources nor the inclination to maintain a navy in time of peace. The American merchant fleet was largely unprotected, however, and international trade could raise much needed revenue. America appeared relatively secure with potentially threatening European

nations three thousand ocean-miles away, but ship-owners and merchants soon realized that the nation did need to protect its commerce and guard its borders. [10] With the ratification of the Constitution, two important provisions enabled the creation of a navy, the power to set and collect taxes and the proviso that the state should provide and maintain a Navy.[11] America did not have the financial solidity to immediately create a navy, but the need became apparent and was authorized by 1790's legislation.

In 1794, Congress passed "An Act To Provide A Naval Armament" for the building of four ships of 44-guns each and two ships of 36-guns each or to purchase an equivalent force plus funding for officers and men. Secretary of War Henry Knox consulted several shipbuilders and accepted the ideas and plans of Philadelphian Joshua Humphreys for six vessels to be built at private shipyards in six different cities: Portsmouth (*Congress*); Boston (*Constitution*); New York (*President*), Philadelphia (*United States*), Baltimore (*Constellation*) and Gosport (Norfolk) (*Chesapeake*). America had skilled labor and industrial capacity, but lacked an essential—the ability to roll copper plates for its new warships.

Entrepreneur

The Hartt shipyard on Boston's northern shore received the contract to build *Constitution*. Paul Revere, a sixty-year-old Bostonian artisan, businessman and opportunist learned that this vessel and another was to be built locally.[12] He wrote to an unspecified government official:

"Dear Sir: I understand that there are to be two Ships built in this State, for the General government, and that they are to be Coppered, if so, they will want Composition bolts, Rudder braces, &c. &c. I can purchase several tons of Copper here, and my works are fitted for such business…I will do them as cheap as anyone and as well."[13] Subsequently Henry Jackson, the Boston Naval Agent for obtaining materials, signed a contract with Revere to make the copper and brass fittings for building of the frigate *Constitution*.[14] Revere's foundry produced fifteen tons of copper that was drawn into bolts, nails, and spikes to fasten the hull planking to the live oak frames, however, Revere did not manufacture the first copper sheathing for *Constitution.*

The bottom of each of the six frigates was to be covered with overlapping copper sheathing, imported from British sources. Enterprising Revere became the broker for its acquisition. Naval architect Joshua Humphreys recorded the amount of copper needed for the frigates as: "12,000 feet of Sheet Copper at [blank] [weight per] foot/240,000 Nails for Sheathing."[15]

On July 27, 1797, before *Constitution's* October launching in Boston Harbor, Secretary of War James McHenry wrote to George Claghorn, *Constitution*'s Naval Constructor: "It being of importance to the United States that the Frigate *Constitution* should be coppered on the Stocks before she is Launched into the Water—you will therefore be pleased to cause the said Ship to be coppered as high as light water mark as soon as the Bottom is prepared, as it will prevent heaving down afterwards and a Consequent heavy expense." [16] When a contract was put up for bid for the construction of the frigate *Essex* in Boston, Revere, in a 1798 letter to Secretary Stoddard, once again stated his qualifications and said, "I supplyed [sic] the *Constitution* with Dove-tails Staples, Nails, &c. &c. The Frigate building here has upwards of 5000 lbs. of Bolts & Spikes already in her, of my manufacture…My greatest difficulty is to get old Copper, Could I get a sufficient supply of Copper I could undertake to roll Sheet Copper for Sheathing Ships, &c."[17]

Promoting himself, Revere sent a letter to Jacob Sheafe, Naval agent at Portsmouth, New Hampshire, "…no man but myself in the four New England States [actually Vermont had become a state in 1791, but Maine was not to become a state until 1820], can melt the Copper & draw it into Spikes."[18] Revere knew how to draw copper nails and spikes, but he saw the Navy's desire for copper sheathing as an additional profit opportunity. Revere began primitive copper rolling experiments using his metallurgical knowledge as a silversmith and bronze metal caster, but copper rolling proved to be a complex process. Revere's initial copper sheets were inferior to those of the British, who closely guarded their methods. Meanwhile, Nicholas Isaac Roosevelt of New York City, a manufacturer and inventor became interested in New Jersey's Schuyler Copper Mine.[19] He was also awarded a contract to erect rolling works and supply the navy with copper. Roosevelt experimented with various rolling techniques, but failed to deliver on his government contract.[20]

On February 26, 1800 Revere wrote to Benjamin Stoddard, Secretary of the Navy: "I learn that…there are no persons in Philadelphia and New York…that can make Copper, so malleable that it can be drawn in Bolts, Spikes, &c. under the Hammer." Revere wrote to Congressman Gray Otis on March 11, 1800: "I…found that it was a Secret, that lay in very few Breasts in England. I determined if possible to find the Secret & have the pleasure to say, after a great many tryals [sic] and considerable expense I gained it."[21]

In his quest to furnish the copper the Navy needed, Revere purchased an ironworks mill in

1800 at Canton, Massachusetts near the Neponset River to provide a dedicated copper producing facility in which he installed, eventually, large iron rollers through which copper ingots could be inserted and compressed. This was partly accomplished via an unusual governmental loan to a private citizen for an unproven industrial project for the Navy Department.[22]

Espionage

Revere decided that by surreptitiously gathering information about the British heating and working process and purchasing some British rollers, he should be able to equal or even improve upon their sheathing product. On January 13, 1801, Revere asked a friend who was about to travel in England to obtain these rollers and engage in industrial espionage for him. "I can procure them here," he explained, "but not in such perfection as the English ones, neither are they so good." [23] In addition to specifying the roller's dimensions he asked his friend to try to observe some British copper works and determine how they heated their copper. [24] He managed to gain the dimensional specifications of the rollers and discovered some secret British sheath manufacturing practices including liquifying the ore with coal fueled fires, a brazen theft of intellectual property. Armed with the filched knowledge, Revere combined his ingenuity with experimentation and testing to both master, and ultimately advance, the rolling process. By the end of October 1801, Paul Revere was rolling just short of a ton of copper into sheets similar in quality to those of the British by using wood for fuel.[25] Revere rolled them hot with a final cold pass after they were annealed. Revere's technique produced flexible and strong sheets that were less brittle, allowing nails and bolts to pass through to form a tighter seal with the ship's hull. It had the potential to provide the thousands of sheets of copper needed for the restoration of *Constitution's* sheathing.

Revere rolled the first high quality copper sheets in the United States on October 24, 1801. Eighteen hundred pounds of copper was refined using only wood for fuel, then an American abundant energy. Within two years the Revere and Son copper foundry had gross sales of $14, 610.24, an impressive sum in those days.[26]

In 1803 *Constitution* was about to be deployed in the Mediterranean against the Barbary corsairs, but after five years of service, new sheathing was needed. Secretary of the Navy Robert Smith wrote to Samuel Brown, United States Naval Agent in Boston, on May 28, 1803: "[*Constitution*] is to be hove down and coppered from light waterline to the bottom of the

keel…If you have enough [copper] in store of the proper kind…engage with Mr. Revere to replace what you may so furnish."[27] At the time, Revere had the only practical and operating copper rolling mill in the nation and provided the bulk of the material that was stockpiled at the Charlestown Navy Yard. Last, from his recollection, in December 1809 Revere wrote Josiah Quincy that "the sheets with which the Constitution's Bottom was cover'd before she went to the Mediterranean [in 1803] was manufactured by us."[28]

Paul Revere, the Revolutionary War figure, engraver, militia artillery lieutenant colonel, silversmith, goldsmith, bell caster, dental technician and briefly a forensic dentist provided the copper sheathing for *Constitution*'s pre-Barbary War refit.[29] Revere's coppersmith enterprise impacted America's place in the pantheon of nineteenth-century nations helping to make the United States Navy a respected military power, propel America's international maritime trade and the country's early economy.[30]

End notes

[1] Careening is to heal a ship off her keel to expose the vessel's bottom for cleaning or repair.
[2] Mark Staniforth, "The Introduction and Use of Copper Sheathing—A History," *The Bulletin of the Australian Institute for Maritime Archaeology,* 9:2, 1973, 21.
[3] Ibid., 21.
[4] Honor Frost, "First season of excavation of the Punic Wreck in Sicily," *International Journal of Nautical Archaeology*, 2:1, 1973, 33.
[5] Robert Martello, "Paul Revere's Last Ride: The Road to Rolling Copper," (MA Dissertation, Massachusetts Institute of Technology, 1997, 220.
[6] Michael McCarthy, ed., *Ships' Fastenings: From Sewn Boat to Steam Ship* (College Station, TX: Texas A & M University Press, 2005) 134 and 174-175.
[7] Op. cit., Staniforth, 25.
[8] Op. cit., Martello, 220.
[9] Brian Lavery, *Nelson's Navy: The Ships, Men and Organization, 1793-1815* (Annapolis, MD: Naval Institute Press, 1989) 70.
[10] Harold Sprout and Margaret Sprout. *The Rise of American Naval Power, 1776-1918.* (Annapolis, MD: Naval Institute Press, 1939, 1990 reprint). 448 pp.
[11] *The Constitution of the United States,* Article 1, Section 8.
[12] Edgard Moreno, "Patriotism and Profit: The Copper Mills at Canton" in *"Paul Revere--Artisan, Businessman, and Patriot: The Man behind the Myth" The Journal of American History*, 76:3, December 1989, 852-857.
[13] Elbridge Henry Gross, *The Life of Colonel Paul Revere* (Boston, MA: Howard W. Spurr Publisher, 1899, 544.

[14] Esther Forbes, *Paul Revere and the World He Lived In* (Boston, MA: Houghton Mifflin Company, 1943) 378.
[15] Joshua Humpreys, Letter Book. Volume 1, 1793-1797, The Historical Society of Pennsylvania, Joshua Humphreys Papers, Coll. #306, 93.
[16] Dudley Knox, ed., *Naval Documents Related to the United States Wars with the Barbary Powers*, Volume 1 (Washington, DC: Government Printing Office, 1939) 205.
[17] *The Revere Family Papers*, Volume 53 (Boston, MA: Massachusetts Historical Society) December 31, 1798.
[18] Ibid., July 4, 1799.
[19] Nichols Isaac Roosevelt was a remote ancestral cousin of two future United States presidents.
[20] James G. Wilson, and John Fisk, eds., *Appleton's Cyclopaedia of American Biography* (New York, NY: D. Appleton and Company, 1900) 317.
[21] Op. cit., Gross, 546-547.
[22] Op. cit., Martello 1997, 14-17.
[23] Robert Martello, *Paul Revere's Metalogical Ride: Craft and Proto-industry in Early America*. PhD thesis, Massachusetts Institute of Technology, February 2001, 231.
[24] Revere to Eben, January 13, 1801, Revere Family Papers (Massachusetts Historical Society), Volume 53.2.
[25]Op. cit., Martello 1997, 14.
[26] *Canton Ledger*, 1802-6, vol.29, roll 10 and Jayne E. Triber, *A True Republican: the Life of Paul Revere* (Amherst, MA: University of Massachusetts Press, 1998) 183.
[27] Op. cit., Knox, 426.
[28] Op. cit., *Revere Family Papers* and Patrick M. Leehey, "Paul Revere and the Re-coppering of USS Constitution in 1803," (Paul Revere Memorial Association, 1992.
[29] The multitalented Revere also dabbled in dentistry. Because of this, he was able to identify Major General Joseph Warren within a mass grave at Bunker Hill through a dental apparatus that he had made for the martyred doctor. The identification of Warren's body may have been the first example of forensic dentistry in America.
[30] In a technological evolutionary note, rolled pure copper was exclusively used on wooden ship's hulls until 1832 when Englishman George Frederick Muntz, a Birmingham industrialist, patented an alpha-beta brass alloy containing 60 per cent copper and 40 per cent zinc. (The α phase refers to a crystal structure that is a surface-centered cubic, while the β phase is body-centered.) This alloy became known either as Muntz metal or "yellow metal" in the shipwright trade. It largely replaced copper sheathing on the bottom of ships, because it provided the anti-fouling properties of unalloyed copper for approximately two thirds the price. Therefore, it became the material of choice for sheathing and was also widely used on wharf pilings.