Paul Revere's Metallurgical Ride: Craft and Proto-Industry in Early America

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ABSTRACT

This dissertation investigates Paul Revere's life and career from a technological perspective. Although several studies have already described Revere's patriotic exploits, his lifetime of work in many different metallurgical disciplines reveals much about his goals and methods. His "metallurgical ride" also provides insights into the economic and technological climate of early American society.

Paul Revere began his career as an apprentice in his father's silversmith shop and rose to the pinnacle of his craft. But after the Revolutionary War he aspired to a loftier position. He learned and practiced the trades of iron casting, bronze bell and cannon casting, malleable copper working, and finally the rolling of sheet copper, a naval technology previously restricted to Europe. This occupational trajectory provided him with moderate wealth as well as much of the social status he fervently desired.

Paul Revere's career straddles the Revolutionary War and illustrates the gradual nationwide transition from craft practices to the growth of industrial capitalism. By combining new technical and managerial practices with older craft traditions he continually improved his business while avoiding many of the disruptions that plagued more trend-setting establishments. His experiences indicate that the young and inexperienced federal government still found ways to promote national industry and technological endeavors. Government funding enabled him to overcome the capital shortage that limited his operations from the beginning. And Revere's ability to synthesize technological knowledge from different fields alters the prevailing model of early technology transfer, which emphasizes the emigration of skilled British laborers.

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For the past three and a half years this dissertation has been a major part of my life. But for the past five months it has been my life. Now, with the finish line stretched out before me, I can look back over these most recent experiences with the humor they deserve. The dissertation became a friendly but intrusive travel companion on a vacation to Nuevo Vallarta about four months ago. While the rest of my family enjoyed the beach, pool, and spa, I read and typed in my hotel room while baffling the maids with religious exclamations (I confused the terms for day and deity). A month later I was racing to complete a first draft for my dissertation committee before leaving for a long weekend vacation in San Francisco. I initially scheduled a three-day safety net between document delivery and my trip. Soon I realized it would be two days. Then one. I found myself asking certain fundamental questions about the dissertation as the deadline drew near. Did I actually need a conclusion? What's wrong with a one-page introduction? Do footnotes really make the world a better place? I finished an abridged version the night before my trip, and literally submitted it on the way to the airport. Five days later, a summer's worth of edits were waiting for me.

Every aspect of this dissertation is a group effort and I am greatly indebted to all of my friends and colleagues. My education at MIT was made possible by generous fellowships from the Dibner Institute, and I gratefully acknowledge all the support I have received there over the years. I have had the great fortune of performing this research in the Boston area, the home of many outstanding historical societies. These groups have offered me invaluable assistance with specific research tasks, and also provided provocative and creative communities for historical discourse and not-quite-historical fraternizing. The Bostonian Society has done a wonderful job of creating a graduate student collaborative society, and I hope their efforts continue in the years to come. I cannot begin to thank the Paul Revere Memorial Association for all the advice, funding, and friendship they have given me. I am indebted to Patrick Leehey and Nina Zanneri for bringing history to life and keeping it fun. When we talk about Revere's colonial activities I feel as if I am gossiping about a nearby friend, and this mentality has led me

to new ideas and insights. Anyone who has entered the Paul Revere House will know what I mean – walk in the door and enter a different world.

Most of my research took place in the friendly archives of the Massachusetts Historical Society, known to insiders as the MHS. Without the patience and enthusiasm of the many MHS historians and archivists I would still be in front of a microfilm reader. My friends there are too numerous to name, but I must thank Conrad White, Len Travers, Celeste Walker, and Bill Fowler for their extreme kindness. Peter Drummey, the greatest librarian in the western hemisphere, has provided me with information on all subjects from colonial technology to upcoming Hollywood movies. In fact, if anyone asks me about my dissertation in Peter's presence he will often answer the question for me, eloquently. Most of all, thank you Beth Krimmel. For those not in the know, Beth is my fairy godmother. When all else fails, I know I can ask Beth for help, she will wave her magic wand, and documents suddenly appear. She is also a truly wonderful human being. The MHS has spoiled me, and I will look for any excuse to work there again.

I have always been fortunate to have wonderful friends. The MIT program in the History and Social Study of Science and Technology (or HSSST for short – just make a hissing noise and people will know what you mean) has treated me better than I deserve. I think I have had too much fun. Among the faculty I must thank Deborah Fitzgerald, Leo Marx, Peter Perdue, Mike Fischer, Heather Richardson, and Wyn Kelley (who lives far away in the wonderful Literature department). Learning with these fine professors began in the classroom and extended to hallways, seminars, conferences, and social events. Administrative staff Debbie Meinbrese, Judy Spitzer, and Chris Bates have cheerfully kept me on course through storms and chaos. Among my peers I must thank Rebecca, Greg, Ben, Regan, Tim, Karen, Rachel, Anthony, Stephanie, Eden, Aslihan, Bill, and everyone else for all the good times, the philosophy, the beer, and the support. I must give special mention to a few heroic souls who have endured more of my company than is psychiatrically advisable. Nina, you are the best buddy anyone can ask for. Brendan ... you look familiar, stranger. Although you cannot beat the spread in football, you are a champion (and 18 point favorite) at everything else. And there is always next season. To Kendall Hoyt, fellow member of the glorious and bizarre class of '95: we survived MIT together, so anything is possible. Broadway? Politics? Let's do lunch.

Finally, to the magnificent Tony Falcone, what can I say? Philosopher, swordsman, dreamer, poet, hiker, student, teacher, friend. You cannot escape me, Tony. The dream team will live again.

My other friends can be found in the group known as TEAM: Pete, Jen, Jake, Cara, Kris, Carlos, Eric, and Doug. I hope I have helped you as much as you have all helped me. Often when I find myself in a challenging position I ask myself "What would my friends do?" One of you always leads me out of danger. I see a lot of adventures in our future. Everyone should have a TEAM in their lives.

I cannot possibly hope to convey my feelings toward my family, new and old. Thank you all for everything. I promise I will try to visit more often. Marybeth, you mean the world to me.

I have saved my dissertation committee – Pauline Maier, Harriet Ritvo, and Merritt Roe Smith – for last because this is their work as much as it is mine. If I am proud of any one feat throughout my graduate education, it is my choice of mentors. Pauline has earned the title of "guardian angel" for her ability to look out for me. Time and time again, adversity would present itself and Pauline would show me how to overcome the challenge. More importantly, she taught me to love history, to cherish the art, to craft my thoughts and words with care. Harriet is perhaps the wittiest person I know. Harriet can crack me up at the very beginning of a story, before finishing her first sentence. For all her incredible scholarly achievements, I think her biggest success is the way she taught me to think and write a bit more clearly. Finally, Roe. Picking Roe as my advisor was both the smartest and the easiest move I ever made. Roe has made a career out of opening doors for me. Everyone knows it is scientifically impossible to know Roe without growing fond of him. But it is also impossible to talk to him without learning something. I learned much from Roe, but my favorite lesson is the way he puts the story in history.

I learned more from following my committee's examples than from all my coursework. Calling you my teachers does not begin to explain your position. "Role models" comes a bit closer, since I take every opportunity to emulate you in my own work. Perhaps "friends" is the best descriptor of all. Let's leave it at that.

On to Revere!

A NOTE ABOUT SOURCES

All quotations from Paul and Joseph Warren Revere's writings are derived from the microfilm edition of the Revere Family Papers, located at the Massachusetts Historical Society in Boston. The Revere Family Papers are divided into 15 rolls of microfilm containing various loose manuscripts as well as 57 bound volumes of documents. The microfilm roll is listed for all loose manuscripts; otherwise the volume number is cited.

Revere's writing style is colorful and creative, though often incorrect by modern standards. I have not edited or altered his spelling or grammar in any way, and I only use [sic] when Revere misspelled a proper name. Without exception, all emphasis is contained in the original documents.

INTRODUCTION: THE REAL REVERE

On the 18th of April, in 1775, Paul Revere became a hero.

At some time after nine in the evening he responded to a summons from patriot leader Joseph Warren. A spy had just informed Warren that a force of British regulars would soon march to Lexington, possibly intending to capture Samuel Adams and John Hancock. Within the hour Revere was on the move. After asking several friends to light two signal lanterns in the steeple of the Old North Church to notify allies in Charlestown, he met another two colleagues at the waterfront and retrieved his concealed rowboat. With muffled oars they rowed north across the silent Boston Harbor, in the shadow of a British warship, toward the Charlestown landing. Waiting Charlestown patriots provided him with a fast Yankee horse, and he raced toward Lexington. He quickly ran into one of many British patrols, but outmaneuvered the first pursuer into a clay pit and left the second in his dust. By midnight he had reached Hancock and Adams, who decided that the true purpose of the British must have been the capture of the cannon and ammunition at Concord. With two companions he rode toward Concord, stopping at every farmhouse along the route to rouse the countryside. But a second British patrol captured him, interrogated him at gunpoint, and took his horse before attempting to flee the hundreds of militia Revere claimed had gathered in Lexington. Returning to Lexington, he saw Hancock and Adams safely leave the town and then helped carry Hancock's trunk of papers to a concealed hiding spot. As he struggled to lug the massive trunk into the woods he heard a single shot ring out across Lexington Green behind him, followed by chaos. The American Revolutionary War had begun.

This is the Paul Revere that all Americans have come to know and love, thanks to the inspirational words of poet Henry Wadsworth Longfellow. But it is not the only Revere. However spellbinding the "Midnight Ride" might be, it represents only a small piece of the larger story of Revere's life and times. In *The Colonial Craftsman,* historian Carl Bridenbaugh tells the story of a wealthy American woman visiting Boston after

spending her childhood in Paris. Upon discovering a statue of Paul Revere, she remarked "I suppose it is proper to erect a monument to a silversmith, but why the horse?"[1]

Everything about Revere's long career cries out for narrative study. As a historical subject, he saw, experienced, learned, discussed, and (perhaps most important of all) recorded many important events. Indeed, Revere played a pivotal role in two virtually simultaneous revolutions. As America broke the political bonds tying it to the British Empire it also began a gradual process of industrial development that would eventually transform all aspects of its society and culture. Revere actively participated in this industrial revolution, first as an artisan who wished to expand and modernize his business, and then as an entrepreneurial manufacturer who knew he could be the first to duplicate a secret British production process. Never content to rest on his laurels, Revere added new equipment, processes, and product lines to his business throughout his life. He eventually worked in three major metallurgical fields and constructed a diverse collection of manufacturing operations on his property in Canton. And in at least one instance he duplicated a secret technical process that shortened America's dependence on British technology.

As interesting as his successes might be, his failures clarify the story of his career even more, showing that the course of his life did not always proceed according to plan. Revere failed to become a merchant, received repeated rejections when he applied for government positions, gave up on his hope of becoming the navy's primary or exclusive sheathing contractor, lost a series of riparian conflicts, and wasted an enormous amount of effort trying to push a tariff proposal through Congress. These episodes round out the picture by illustrating that technical prowess and business savvy had their limitations; that some objectives were more achievable than others.

In addition to providing the occasion for an interesting narrative of his endeavors and their consequences, Revere's career is representative of larger national trends. This is somewhat peculiar, in view of the fact that he was a highly atypical American in almost every way. He crafted or manufactured metal goods and lived in a large city at a time when the country was overwhelmingly agrarian and rural. He employed relatively large numbers of workers when most people were self-employed in small shops or farms.

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[1] Carl Bridenbaugh, *The Colonial Craftsman,* (New York : New York University Press, 1950), p. 87.

And yet, the minority segment of society that he did represent was extremely important – a constituency that was to grow throughout America's history and play a dynamic role in political movements and national growth. Revere did not travel alone on his last ride, and although he occasionally took the lead he also benefited from the tracks of others.

All historians and all historical works must confront the tension between analytic and narrative goals. Although Revere's story demands a narrative framework, three themes connect the different endeavors comprising his career. These themes serve as filters, organizing a multitude of events and decisions into coherent sets of observations and conclusions.

Theme One: The Transition from Craft to Industry

"Craft" and "industry" are complicated terms. Each describes a system of labor, managerial, technological, economic, and social practices surrounding work and the production of commodities. A craft system generally denotes pre-capitalistic modes of production and management, often including features such as barter exchange, apprenticeships, small shop sizes, custom-made output, and the predominant use of hand tools by skilled workers. In contrast, an industrial system involves extensive use of machinery by wage laborers, cash transactions, large-scale factory production, standardized goods, the division of labor, and the establishment of separate classes of owners, managers, and workers.[2]

These ideal types do not apply to the confusing, changing, heterogeneous conditions throughout the first fifty years of the new republic. Craft shops had already adopted many "industrial" characteristics in the colonial era such as the use of wage labor, the division of labor, subcontracting, and the move towards standardized output. And early industrial endeavors retained many traditional practices, including the

[2] The nationwide transition between craft and industrial labor is discussed in Thomas C. Cochran, *Frontiers of Change: Early Industrialism in America* (New York: Oxford University Press, 1981); John F. Kasson, *Civilizing the Machine* (New York: Hill and Wang, 1976); Walter Licht, *Industrializing America* (Baltimore: Johns Hopkins University Press, 1995); Jonathan Prude, *The Coming of Industrial Order* (Cambridge: Cambridge University Press, 1983); and Merritt Roe Smith *Harpers Ferry Armory and the New Technology* (Ithaca: Cornell University Press, 1977).

employment of skilled laborers (who often considered themselves craftsmen), paternalistic managerial practices, and the continued reliance upon barter transactions. While craft practices gradually became more industrial, this evolution took place at different rates in different regions and in different fields, and the conversion was rarely painless or absolute. Indeed, elements of craft production still exist today.

Revere's experiences present an ideal case study of the transition from craft to industrial practices. His career bridges the time when the dusk of the craft system led to the dawn of industrialism. Over his long life he trained as an apprentice, achieved some fame as a skilled artisan, and began a manufacturing career that resulted in his ownership of a mill complex employing around a dozen workers. Revere lived and excelled in both worlds, and altered his own status and methods while observing the changes occurring around him.

This career trajectory raises several primary questions. *Why did Revere choose to abandon his craft roots?* At the heart of this question lies Revere's value system: his personal estimation of the costs and benefits of different occupations and the goals he wished to achieve by the end of his life. Many of these goals surrounded the changing social and economic class hierarchy, and the surest route to personal advancement. But some of his goals built upon his political views: he sought to further his country's development. One of the novel facets of the postrevolutionary culture was the remarkable overlap between private self-interest and public service.

A second question involves his methods. *What craft elements did Revere retain, and what industrial elements did he adopt?* Revere's rolling mill existed in a state of **proto-industry**, an interesting combination of old and new practices that enabled him to maintain a high degree of productivity and quality while avoiding unpleasant or excessively risky alterations to long-accepted work methods. This question relates to the larger issue of Revere's choice: *why did he change some methods and retain others?* No two manufacturers operated in the same manner, and Revere's decisions reflect his business philosophy and goals.

A third question shifts from intentions to execution. *Why did Revere successfully shift from craft to industry when many others failed to make the transition?* Revere's overall success can only be understood after looking at each of his endeavors in turn. In

particular, the startup process he followed each time he initiated a new product line or facility illustrates the combination of intentional preparation, composite experience, and innate talent that enabled him to expand his production. Revere's experience and skills also emphasize the growing distinction between managerial and technical aptitude, both of which were vital for success.

Finally, *what were the consequences of this ongoing transition?* This question applies to Revere as well as his human and natural surroundings. Although Revere never sat down and mused about the changes resulting from his career shifts, he was aware that significant alterations were taking place. Indeed, many of his decisions reflected new opportunities that he detected. He was oblivious to many other opportunities and impacts for various reasons such as the slow pace of change.

Theme Two: Technology Transfer and "Borrowing"

At the end of the 18th century Britain led the world in technological refinement and usage, manufacturing output, and economic strength. Much of America's colonial growth depended upon its relationship to the mother country, and to the favorable trade status it enjoyed. America's dependence and vulnerability were amply demonstrated immediately after the Revolution, when Britain completely dominated and depressed America's economy through the dumping of cheap manufactured goods and the extension and contraction of credit.

Matters started changing at the federal level in the late 1780s. A new Constitution, Alexander Hamilton's firm economic control, a growing domestic market, and booming commerce that exploited European wars all enabled America to establish its economic independence. This economic restructuring occurred alongside America's technological growth, and indeed, the two processes drew strength from one another. The almost medieval level of technology throughout colonial America was adequate for provinces on the fringe of a vast mercantile empire whose main goal was the harvesting of natural resources for British manufacturers, but America needed its own manufacturing to avoid a return to economic colonialism. Between independence and the

mid 19th century, America experienced an industrial revolution and became a world manufacturing leader.

Many historical studies oversimplify the learning processes that enabled Americans to develop their own technologies and industries. Although the term "technology transfer" encompasses all attempts to duplicate existing technical equipment or processes in new ventures, most studies restrict this phenomenon to the international transfer of technology via the emigration of skilled laborers. For Revere's time period, the direction of transfer was always from Britain to America. Samuel Slater personifies this process. Slater began an apprenticeship in 1782 in an British textile factory, where he received training in both the technological and managerial aspects of cloth production. In 1789 he tricked customs officials into allowing him to emigrate, a direct violation of British law. Within a few years he found a firm of merchants willing to fund his spinning mill, America's first successful textile factory. Innumerable artisans followed Slater's example and traveled to America in search of high-paying technical positions and entrepreneurial opportunities. These immigrants carried knowledge of machinery, production techniques, and managerial control, and advanced the state of American technology considerably. However, they were not the only source of technical information in America.[3]

Paul Revere spent a considerable portion of his career exploring new manufacturing ventures and researching the necessary equipment and background information. He therefore underwent the technical research and experimentation process not once, but many times. Revere realized both the importance and the difficulty of these learning periods, and to insure that he learned as thoroughly and quickly as possible, he drew upon various information sources before committing to a new venture. In mastering all of his technical endeavors, he truly mastered the learning process. Once he learned something, ne remembered it forever and often applied it to other tasks years later.

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[3] For an introduction to the subject of technology transfer see Nathan Rosenberg *Perspectives on Technology* (New York: Cambridge University Press, 1976); Svante Lindqvist *Technology on Trial* (Stockholm: Almqvist & Wiksell International, 1984); David Jeremy, *Transatlantic Industrial Revolution* (Cambridge: MIT Press, 1981); David Jeremy *Artists, Entrepreneurs, and Machines* (Brookfield: Ashgate Publishing, 1991); and, most recently, J.R. Harris, *Industrial Espionage and Technology Transfer* (Brookfield: Ashgate Publishing, 1998).

A key question pertaining to technology transfer is *How did Revere learn each new trade?* Although he never had access to a skilled British artisan or manager, he did identify Britain as the primary source of knowledge. Several of his efforts involved creative ways of gathering British secrets, such as reverse engineering from finished products or sending his son on a mission of industrial espionage. However, most of his education did not involve Britain at all, but merely the creative combination of different forms of expertise already well understood in America. Revere's learning methods also illuminate his contribution to American technology. While he did not design or produce anything that had not already existed in Britain, his facility for **borrowing** enabled him to advance American technology to a point where future manufacturers could break new ground.

Much of Revere's information came from fellow manufacturers or artisans. Unlike some competitors, he maintained an open shop throughout his life, available to anyone who wanted to know more about his methods. Revere's correspondence also reveals a host of letters to and from metallurgical experts, exchanging all manner of theoretical and practical information. This invokes the question: *What was the relationship between cooperation and competition in the early American technological community?* Even as a silversmith, Revere belonged to a close-knit community that recognized the contributions of individual practitioners as necessary components of the whole. The new Constitution included several institutions such as patents and corporate monopoly privileges that limited free and universal access to technical information, and natural resource limitations also cast a competitive shadow across the proto-industrial landscape. Revere's attitudes while working within well-established fields might conform to traditional practices, but by the end of his career he pioneered a new field and had full freedom to act however he thought best regarding the sharing of his hard-earned knowledge.

Theme Three: Government Sponsorship of Industry and Technological Innovation

The juxtaposition of the Revolutionary War and the American industrial revolution invites a study of the ways in which America's new government aided or hindered the growth of industry, and in particular, the development of technology. The paucity of scholarship in late 18th and early 19th century technology limits the breadth of the answer to this question.

Historians have catalogued a variety of indirect, and often unintentional, government influences upon technology in the early years of the republic. For example, patent law inspired many inventors and entrepreneurs to consider their innovations private property, although these innovations became public property after a period of time. This further connected private and public interests, allowing technological discoveries to benefit both individuals and their country. And different trade policies, such as Jefferson's Embargo, often caused merchants to seek new investments for their capital while protecting manufacturers from British competition. These actions and a host of others like them had major impacts upon early American industrial growth.

Direct effects were also important. One form of direct government aid, the influence of military research and purchases upon technological and industrial growth, has received some attention. Several studies have investigated the way that European military forces became huge consumers of ordnance, a process that gave a huge impetus to mining, metallurgy, and machine production.[4] While most American studies focus on the growth of the military-industrial complex in the 20th century, some have explored the military's support of early developments such as interchangeable parts, railroads, canals, and machine tools. Still, the earliest timeframe for most if not all of this work is the early 19th century, which featured critical events such as the drive towards interchangeable manufacturing at the Harper's Ferry and Springfield armories or the establishment of West Point and a military engineering academic program, both after 1811. The importance of these events and others like them cannot be overemphasized, but Revere's

[4] This section draws upon Merritt Roe Smith's introduction to *Military Enterprise and Technological Change,* (Cambridge: MIT Press, 1985) as well as Alex Roland's bibliographic essay in the same volume. Also see William McNeill *The Pursuit of Power* (Chicago, University of Chicago Press, 1982).

example illustrates that the story actually began earlier and involved other institutions besides the army.

The American government in general, and the War and Navy departments in particular, had sponsored technological development by direct and indirect methods since Washington's administration, at the very birth of the new republic. Once again, Paul Revere's experiences provide an excellent vantage point for the study of this phenomenon. Not only did he seek government support throughout the time period in question, but his various career changes and broad product line exposed him to the goals and procedures of different government branches at state and federal levels.

An immediate question is simply *Why did the government foster Revere's technological activities?* This question is problematized by the fact that "government" is not a unified entity, least of all during the early republic. The government consists of various departments and individuals often working at cross-purposes, something that was especially complicated during transitions between the earliest administrations when well-entrenched bureaucracies and precedents did not yet exist. Also, state and federal governments are drastically different. But each of these entities had its own goals, as well as resources it could use to further those goals. This relates to the first analytical theme, because Revere had his own goals as well. The intersection of these interests is more interesting and complicated than it might first appear. Revere and the government did not merely develop a producer-consumer relationship, but instead stumbled into issues such as status, partisanship, and honor.

Another related question is *How did different government agencies aid Revere?* Although the lack of precedent might appear to grant federal departments great latitude in carrying out their mandates, in reality they were constrained by funding limitations, strict construction concerns, and an endemic lack of expertise that slowed or halted all operations. Fortunately, government organizations usually offered assets that counterbalanced these liabilities, advantages that only the government could provide. These benefits were both direct and indirect, enabling Revere's story to be measured against other cases of government support of technological endeavors.

Narrative Framework and Chapter Description

Paul Revere's story lends itself to a narrative framework for many reasons. Above all else this is a study of a human life, and a chronological narrative places the reader, as well as the author, at Revere's side. Events rarely group themselves into thematic categories before occurring, and the juxtaposition of seemingly unconnected incidents is actually quite relevant to the manner in which people make their decisions.

Figure 0.1 presents an overview of Revere's primary endeavors, as well as some personal milestones that affected his career:

Figure 0.1: Major Events in Paul Revere's Career

Year	Event
1734	Born in Boston (unspecified December date)
1748	Begins his apprenticeship as a silversmith to his father
1754	Inherits and begins operating his father's silvershop
1757	Marries Sarah Orne
1760	Birth of Paul Revere Junior (apprentice and silverworking partner)
1773	Sarah Orne dies; Marries Rachel Walker
1775	Midnight Ride; Revolutionary activities begin taking him from silverworking
1777	Birth of Joseph Warren (later partner and successor)
1779	Return to silverworking after the war
1781	Failed attempt to become a merchant
1788	Begins iron founding
1792	Begins bell casting
1794	Begins cannon casting
1795	Begins working with malleable copper to produce bolts and spikes
1801	Begins copper sheet rolling in Canton mill
1804	Forms partnership with Joseph Warren: "Paul Revere and Son"
1805	Moves all operations and equipment to Canton

1811	Retires, Joseph Warren becomes manager.
1818	Dies May 10, 1818.

This study is divided into four main chapters, exclusive of the Introduction and Conclusion, and each chapter begins with a survey of the analytical issue most relevant to it. Although this breakdown involves some arbitrary divisions, for the most part it follows the course of Revere's manufacturing career and groups events as he would group them, according to the most recent process in his repertoire at any given time. Revere did not focus upon one product or process at a time, however. He played a major role in all the day-to-day operations of his different businesses, particularly when technology was concerned. It is only natural that he would direct most of his energies to the newest process: not only were new operations most prone to break down, but they also were most intriguing to a curious bricoleur. To emphasize this important point, the narrative occasionally takes a nonlinear turn to follow one product line to its end before backing up to follow a new thread. The reader must remember that even after Revere shifted his attention to his next project, he continued overseeing all former endeavors.

Chapter one (1754-1789) begins with a study of Revere's early life and silverworking endeavors. Revere practiced silverworking longer than any other enterprise, and altered his practices dramatically after the Revolutionary War expanded his horizons. Any study of this phase of his career must include a survey of the traditions that influenced him from the beginning: artisanal practices in general, and the history of silversmiths in particular. Although silversmithing is one of the most artistic of the craft trades, postrevolutionary examples set by Revere and others reveal that many silversmiths adopted practices closer to what we would now consider industrial capitalism. Revere's long silverworking practice also displays the wide range of his skills, which were still insufficient incentive for him to devote his undivided personal attention to the business.

Chapter two (1788-1795) covers only eight years of Revere's life, but this was a period of constant learning and experimentation. After building an iron furnace in 1788, the largest piece of equipment he had owned up to that point, Revere used it for different applications over the next few years, beginning with iron casting and moving to brass bell

and cannon casting. Although these practices involved the same general casting principles they differed greatly in technical and (perhaps more importantly) entrepreneurial details. The different details of these three practices help reveal several common elements in Revere's approach to all of his endeavors. In particular, this period gave Revere the opportunity to amass some capital, redefine himself as more than a skilled craftsman, and develop new technological and entrepreneurial contacts, particularly within the government.

Chapter three (1795-1802) describes the greatest shift in Revere's career, as he entered the worlds of government contracting, large scale standardized output, and British competition. After learning to duplicate the secret British process for making malleable copper bolts and spikes, Revere successfully lobbied the new Navy Department for a loan that would enable him to finance a rolling mill to produce copper sheathing. This was by far the most ambitious technological and economic undertaking of his career, and he entered it with a confidence and energy that would be pushed to the limit by a series of bureaucratic problems. Revere's successful duplication of two advanced, highly prized British secrets presents a new model for technological transfer. His relationship with the government tells much about his goals and methods, as well as the government's inexperience and inconsistency. But in spite of its shortcomings, only the government could give Revere the support he needed.

Chapter four (1802-1811) concludes Revere's career with a study of his Canton enterprises. Beginning with a single rolling mill and five employees, he gradually expanded his operations until he supervised a multi-building manufactory employing at least ten workers on a variety of metallurgical tasks. Everything about his operations changed during this period, from his managerial techniques to his use of waterpower, machinery, labor practices, and product line. Revere took many actions that align his business with what we now consider modern industrial practices. For example, he changed the ownership structure of his business to a partnership, entered lawsuits to protect his water rights, looked into building worker housing, and expanded his use of machinery for the production of standardized output. However, he also retained many older practices such as the provision of board for his workers and continued to deal with employees and clients on a personal level, often with verbal contracts.

Revere's story begins with his silverworking experiences and the artisanal background that preceded them. The year is 1768, and we find him at his table, pensively pondering a teapot in need of engraving...

CHAPTER ONE: THE RELUCTANT CRAFTSMAN

Artisan, Silverworker, and Would-be Merchant (1754-1789)

In 1768, John Singleton Copley painted a portrait of Paul Revere that now hangs in Boston's Museum of Fine Arts. Revere sits at a polished wooden table, his white shirt in sharp contrast with the dark background. His right hand supports his head, which thoughtfully meets the gaze of the viewer, while his left hand holds a polished silver teapot that lacks engraving but is otherwise complete. This invaluable painting is one of the few surviving illustrations of colonial artisans at work.

Anecdotal evidence implies that Revere's family did not appreciate this painting, and hid it in the attic. How might they have viewed it? Unlike the gentry and statesmen in Copley's other portraits, Revere is not garbed in elegant clothing. Instead, he wears the functional dark vest of a workman, and his white shirt is unbuttoned. His sleeve has fallen slightly, revealing some of his forearm and wrist, and traces of dirt are visible under his fingernails. The presence of engraving tools on the tabletop leaves no doubt that this is a man who works for a living. All of Revere's financial success, technical and entrepreneurial skill, and artistic reputation could not change his artisan status. However, one must not exaggerate Revere's dissatisfaction with his position. He could take solace in the knowledge that he was a prince of skilled laborers, the biggest fish in the working class pond. After all, it was not every artisan who had his picture painted by Copley. And his relief would increase if he had any way of predicting the changes that would soon affect society, artisans, and his own life.

Paul Revere's long career straddled the Revolutionary War, providing a vivid illustration of the changes that took place in the American workplace following the great political upheaval. Of his many vocations, Revere's silversmithing[1] career provides the only direct pre- and postwar comparison, as he first entered the field as an apprentice around 1748 and ceased working on silver items in the late 1790s when he shifted his full attention to copperworking. His own writings, activities, and products tell an interesting story of changing methods and goals. These changes were gradual and have their origins in much earlier times, in European craft traditions

[1] The terms "silversmith" and "goldsmith" were completely interchangeable at this time. Because all American artisans using this title worked far more with silver than gold, I will use the term silversmith throughout this study.

that defined the education, practices, and social status of artisans. Early colonists carried these traditions to colonial America but many of the details failed to take root in the cultural climate of the new world. As a result, a different system evolved, and continued changing throughout the colonial period. By the time Revere entered the silverworking field, some of the elements of industrial capitalism were already in place. And others would soon develop.

Background: The "Art and Mystery" of the Artisan

Although Revere's early education focused upon the details of silverworking, in a larger sense he received an education in the artisan tradition, inherited from his father who, in turn, learned from John Coney, whose own educational lineage extended to England. Artisans have existed since antiquity, and their skills and products are mentioned in the earliest written documents. The terms "craftsman" and "artisan" typically describe all skilled technical craft practitioners in pre-industrial and some postindustrial societies who make a living by producing durable goods.[2] Despite the many differences between artisans in different trades, cities, and economic classes, most practicing artisans shared several experiences, such as an apprenticeship education, functional dress, workers' neighborhoods, fraternal societies and social clubs, and often a common political identity.[3] In an urban center such as Boston, Revere would realize, even as a child, that he had more in common with the children of other artisans than with the children of either laborers or gentlemen. As he learned to work silver, he also learned to perpetuate the tradition by training and providing for apprentices, managing his accounting, interacting with customers and other silversmiths, and participating in the artisan community.

[2] The terms "artisan," "craftsman," and "mechanic" are often used interchangeably. "Artisan" was the most popular term in the seventeenth and early eighteenth centuries, "craftsman" most popular in the late eighteenth century, and "mechanic" gained ascendancy after that. Thomas J. Schlereth, "Artisans and Craftsmen: A Historical Perspective," in *The Craftsman in Early America,* Ian Quimby, ed. (New York: W.W. Norton, 1984), p. 37. This study uses the term "artisan," although the sources often use other terms.

[3] Paul A. Gilje, "Identity and Independence: The American Artisan," in *American Artisans: Crafting Social Identity,* ed. by Howard B. Rock, Paul A. Gilje, and Robert Asher (Baltimore: John's Hopkins Press, 1995), p. xii; and Schlereth, "Artisans and Craftsmen," p. 39.

European Guilds and American Changes

The history of artisans in Europe centers on the dominance and actions of guilds. Craftsmen organized guilds in the Middle Ages to protect the interests of all practitioners of a particular craft through collective action and internal regulation. In particular, guilds acted as defenders of the status quo. Guilds monitored and regulated the quality of work and the consistency of education, to help justify the high monopoly prices for their products. And, perhaps more importantly, guilds regulated the relationship between the different ranks of craft practitioners, by restricting the number of new apprentices and imposing fees upon the families of apprentices, maintaining stable wages for journeymen, and slowing the rate at which journeymen could become masters. This created a closed labor market in which the demand for skilled labor remained high, and the supremacy of masters remained unchallenged.[4] The relationship between apprentices, journeymen, and master craftsmen was an essential ingredient in craft dynamics in both Europe and America.

All artisans began their careers as apprentices, continuing a tradition that began in Western Europe in the middle ages.[5] Apprenticeship typically included written articles of indenture that contractually bound both master and student. The apprentice pledged a fixed period of his labor and loyalty in exchange for a practical education in the "art and mystery" of a craft. "Art" in this sense referred to technical skill (and, in earlier times, to magical aid) while "mystery" suggested a combination of secret rites and essential knowledge. British apprentices usually served seven years beginning at age 14, as opposed to three to five year terms in France and Germany.[6]

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[4] W. J. Rorabaugh, *The Craft Apprentice* (New York: Oxford University Press, 1986), pp. 4-5. The silversmith's guild was exceptionally powerful. Over 500 years old by the time of the first American colonies, it maintained a complete monopoly in Britain, and oversaw all aspects of the trade. It had no authority in the colonies. Graham Hood, *American Silver, A History of Style, 1650-1900*, (New York: Praegar Publishers, 1971), p. 15.

[5] In America, merchants, lawyers, doctors, and clergymen also acquired their skills through versions of apprenticeships (although they were not formally called apprenticeships), studying and practicing under an established mentor for a fixed amount of time. Jack Larkin, *The Reshaping of Everyday Life,* (New York: Harper & Row, 1988), p. 34.

[6] British lawmakers and guilds mandated lengthy apprenticeship terms in part to correct the chronic unemployment problem. Along these lines, the Statute of Artificers forced artisans to work as journeymen under established masters (as opposed to running their own shop) until they turned 30. Ian Quimby, "Some Observations on the Craftsman in Early America," in *The Craftsman in Early America,* Ian Quimby, ed. (New York: W.W. Norton, 1984), p. 5; and Edmund S. Morgan, *American Slavery, American Freedom; the Ordeal of Colonial Virginia,* (New York: W. W. Norton & Company, 1975), p. 66; Ruth Schwartz Cowan, *A Social History of American Technology*, (New York: Oxford University Press, 1997), p. 47.

The apprenticeship tradition changed radically in the American colonies. The enormous labor shortage, prestige associated with land ownership, and lack of guild regulation produced an apprentice deficit and demand for craft practitioners which often compressed the seven-year apprenticeship period into four or even three years. Craft apprentices were perpetually in short supply during the colonial years, as illustrated by numerous advertisements in newspapers from every community. Considering the labor shortage, the British custom of families paying masters to train their sons only made sense for the most elite colonial trades, and even then was only practiced rarely. In addition, orphans were often made compulsory apprentices, representing colonial America's matter-of-fact attempt to address both labor and child welfare problems.[7] Apprenticeships and all other forms of written contracts became more formal and explicit throughout the 18th century, often delineated in monetary terms. In earlier times, these contracts defined a spirit of personal obligation that bound both parties, rather than specific promises of action and compensation.[8]

Journeymen occupied the middle step of the craftsman hierarchy. As "graduated" apprentices, their skills qualified them to begin practicing their craft, but they lacked the capital needed to set up their own shop. As their name implies, they would often travel in search of the highest wages (a practice that infuriated masters in need of steady labor), and could settle down as masters after amassing sufficient money. With regard to silverworking, journeymen were qualified to assist master silversmiths with complex tasks, although some specialized in one or more skills. Only the master's mark appeared on final products, so these journeymen are often anonymous.[9]

Master artisans dominated the craft hierarchy. The master's skill at his craft, as well as the indefinable skills pertaining to business operations, determined whether his shop succeeded or failed. The master owned and managed the shop, purchased tools and raw materials, trained and supervised apprentices and journeymen, designed products, determined what to produce, handled sales and advertising, and oversaw quality control. As head of the household, he was also responsible for feeding, clothing, and educating his family, which included apprentices and

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[7] Carl Bridenbaugh, *The Colonial Craftsman* (New York, Dover Publications, 1950), pp. 130-133; and Rorabaugh, *The Craft Apprentice,* p. 4.
[8] Gordon S. Wood, *The Radicalism of the American Revolution,* (New York: Vintage Books, 1991), pp. 53, 162.
[9] Rorabaugh, *Craft Apprentice*, p. 8; Deborah A. Federhen, "From Artisan to Entrepreneur: Paul Revere's Silver Shop Operations," in *Paul Revere -- Artisan, Businessman, and Patriot*, (Boston: Paul Revere Memorial Association, 1988), p. 73.

journeymen. Despite the skilled labor scarcity, nearly half of artisan shops failed, usually because of inadequate business acumen and unstable economic conditions.[10]

In response to the lack of skilled labor, unpredictable economy, and diverse needs of a widespread population, most American artisans were versatile rather than highly specialized. Of course, this was easier in some trades than others. The metalworking crafts were most specialized, partly due to the close-knit metalworking communities in most large cities, high skill requirements, and substantial material and equipment costs. Metal craftsmen in large urban centers often formed a collective versatility to compensate for their individual specialization: they sold their goods not only to the public, but also to each other.[11] In this manner, an early form of subcontracting permeated many craft trades, such as silverworking. Revere and his father would grow very familiar with this practice.

The Silver Tradition

Scarce and beautiful, silver has always exceeded common metals such as iron or copper in value. While silver refining and finishing processes are technically complex, the luxury status of silver also placed silverware into the category of art, earning silversmiths a reputation for both technical and aesthetic skill. Since silversmiths typically produced highly visible objects for the most wealthy and powerful segments of society, earned the highest craft salaries, and required extensive skill and capital in order to work, silversmiths occupied the pinnacle of the craft hierarchy.

Revere was well situated for his silverworking career. Boston and New York were the primary silversmithing centers in the 17th century, although Philadelphia joined them in the 18th century.[12] These cities had more contact with London than with each other until the 18th century, and quickly adopted and emulated the newest British fashions. However, competition and cooperation in large cities often resulted in distinctive local interpretations of prevailing styles.[13]

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[10] Bridenbaugh, *The Colonial Craftsman*, pp. 1, 126-7.
[11] Ibid. p. 85; Larkin, *Reshaping of Everyday Life,* p. 44.
[12] Boston was and is considered by many experts to be the colonial leader in the production of fine silver objects, particularly during the late 17th and early 18th centuries. Philadelphia was the undisputed leader in most other crafts. Barbara McLean Ward, "Boston Goldsmiths, 1690-1730," in *The Craftsman in Early America,* ed. by Ian Quimby (New York: W. W. Norton and Co., 1984), p. 126; Bridenbaugh, *The Colonial Craftsman,* p. 143.
[13] James A. Mulholland, *History of Metals in Colonial America* (Alabama: University of Alabama Press, 1981), pp. 87-88; Bridenbaugh, *The Colonial Craftsman,* p. 143.

Changing silver styles provide a unique window on changing societal values. New England silver during the early 1600's was extremely plain, corresponding to the Puritan emphasis upon simplicity. In Massachusetts, many of the pre-1640 Puritans belonged to the middle or upper middle classes and brought family silver (along with an appreciation for fine silver objects) with them, insuring a steady demand for the services of silversmiths to repair or add to their collections. With the rise of merchant prosperity in the mid to late 1600's, foreign silver flowed into New England, and Puritan restrictions upon conspicuous consumption relaxed.[14] By the end of this century, the increasingly cosmopolitan colonists embraced the vivid, three-dimensional complexity of the Baroque style emanating from the court of Charles II. By the early 18th century, the Queen Anne (or Early Rococo) style achieved dominance, promoting a return to simplicity, elegance, and formality. The fully developed Rococo of the mid 18th century expanded upon this with fairly simple forms adorned by rich decorations usually favoring "natural" forms such as shells and flowers. Finally, the neoclassical or federal style gained acceptance after the Revolution, and emphasized a return to purity, restraint, and geometric forms.[15] The finest silversmiths, like Revere, demonstrated their skill and improved their reputation by mastering multiple artistic styles.

Colonial Class and Labor

Pre-revolutionary society recognized one "horizontal" division above all others: the vast, almost unbreachable gulf between gentlemen and everyone else. Although nearly all colonial gentlemen would have fallen into the middle class (or upper middle class) in Britain, they held a virtual monopoly on higher colonial political offices from the mid to late 1700's, and had much freer access to education, credit, or influential administrators than others. Gentlemen exploited these opportunities and entered prestigious professions befitting the leaders of society. Should a gentleman perform non-intellectual labor, he would lose status in the eyes of other gentlemen, and the thought of a manual worker entering the gentry class or receiving similar privileges would be either ludicrous or terrifying. In the words of John Locke, "Trade is wholly

[14] Hood, *History of Style,* p. 11; Hermann Frederick Clarke, "The Craft of Silversmith in Early New England," *New England Quarterly* Vol. 12:1 (March 1939), pp. 68-9.
[15] Hood, *History of Style,* pp. 58, 92, 127, 163.

inconsistent with a gentleman's calling."[16] Large landowners, merchants, doctors, lawyers, and government officials comprised the highest classes, and although they occasionally had lower incomes than the wealthiest artisans, they still enjoyed greater social status. In New England, merchants became the most visible gentry members and directed the economy and often the political agenda as well. Large landowners held a similar position in the South.[17]

The remainder of society did not possess a class consciousness as the term would later be understood. Farmers and artisans generally enjoyed more income and a higher standard of living than soldiers, unskilled laborers, and slaves, but it is difficult to generalize about such vast labor categories. By the time of the American Revolution, artisans comprised one third to one half of the population of large cities.[18]

All artisans were not considered equal. Within any trade, individuals were ranked according to their skill and material success. Most artisans could aspire through hard work and astute business instincts to become a "respectable" or "reputable tradesman." This usually involved ownership of one's own shop and property, acknowledged skill in their trade, the ability to read and write (if not a greater education), material success, and participation in respectable charities or organizations. In contrast, less skilled and poorer "inferior mechanics" often performed simpler tasks or even worked for other artisans.[19] Through the end of the colonial era, artisans could never become gentlemen based on their craft successes alone. However, several routes to social advancement did exist, none of which involved continued labor. The most common artisan advancement strategy was to begin a successful merchant career, often using artisanal contacts with merchants and members of the gentry. Land speculation, a government position, or membership in a prestigious organization could also convert wealth into social

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[16] These attitudes would dramatically change after the Revolution, when the "useful arts" were viewed as a vital productive element in a successful enterprising society. Quote from Wood, *Radicalism,* p. 37. See also Bridenbaugh, *The Colonial Craftsman*, p. 96; Wood, *Radicalism,* p. 23; and Gilje, "Identity and Independence," p. xiii.

[17] Even a famous and respected painter such as John Singleton Copley was regarded by many of his wealthy clients merely as a skilled laborer, which infuriated him. Gordon S. Wood, "The Enemy is Us: Democratic Capitalism in the Early Republic," in *Journal of the Early Republic,* 16:2 (Summer, 1996), p. 301; Wood, *Radicalism*, pp. 21-16; Patrick M. Leehey, "Reconstructing Paul Revere; an Overview of his Ancestry, Life, and Work," in *Paul Revere – Artisan, Businessman, and Patriot*, (Boston: Paul Revere Memorial Association, 1988) p. 15; Rorabaugh, *Craft Apprentice,* p. 5; Gary B. Nash, *The Urban Crucible* (Cambridge: Harvard University Press, 1986), pp. 163-166.

[18] Bridenbaugh estimates that artisans constituted 18 percent of the total laboring population, representing the second largest occupational class (next to husbandmen). Bridenbaugh, *The Colonial Craftsman*, p. 1. In contrast, Ruth Schwartz Cowan estimates that artisans comprised approximately 10% of the colonial population in 1750. Cowan, *Social History of American Technology,* p. 45.

[19] Bridenbaugh., p. 162.

power. And a final, highly effective option was marriage into a prominent family. Although most artisans never escaped from the laboring class, some managed to achieve large fortunes and at least adopt the trappings of the gentry.

The second and more important division occurred between craft trades. Before and during the 18th century, artisans typically classified themselves "vertically" according to their craft. Masters, journeymen, and apprentices of one craft shared more camaraderie than apprentices or journeymen across different fields. These divisions resulted in an informal hierarchy of trades. Tailoring, shoemaking, candle making and similar trades involving minimal startup costs, material costs, and skills occupied the lowest rung. Blacksmithing, carpentry, and other careers requiring greater skill, risk, and income filled the middle of the hierarchy, and printing and silversmithing remained elite.[20]

This artisanal heritage had three major impacts upon Revere. First, because of local conditions and the incomplete transatlantic transmission of artisan traditions, American craftsmen enjoyed enormous leeway in their business decisions. Apprenticeship duration, the education and employment of apprentices and journeymen, prices, and the quality of finished goods were all regulated to some degree by British guilds, but an American master craftsman could do as he pleased. As a result, Revere's future largely lay in his own hands. Second, some of the traditions that were reproduced in colonial America had more in common with industrial practices than one might think. In particular, the use of journeymen as wage laborers, the division of labor among different skilled and unskilled workers, and the practice of subcontracting labor among different shops based on their specialties, while not common, occurred with increasing frequency. And third, America's class system combined freedom and hierarchical rigidity. A clever artisan could certainly amass a fortune, and would not feel trapped by a non-privileged birthright. At the same time, the gentry class would always remain a breed apart, gifted with exclusive privileges.

[20] Wood, "The Enemy is Us," p. 300; Rorabaugh, *Craft Apprentice,* p. 6; McLean Ward, "Boston Goldsmiths," p. 129; Nash, *The Urban Crucible*, pp. 235-9. Note that any craft hierarchy was poorly defined, if at all. Trades such as millwrights and clockmakers also required skill and capital, and often carried considerable prestige.

Youth and Heritage

Before his midnight ride, before working with copper, iron, or silver, and before beginning his apprenticeship, Paul Revere was a child of French and English descent coming of age in colonial Boston. He was born in late December 1734 to silversmith Apollos Rivoire (1702-1754), a first generation French immigrant, and to Deborah Hitchborn (1704-1777) of an old New England family. His family background, apprenticeship, and early activities played a large role in shaping his character. This background thoroughly prepared him for the life of a master craftsman, but also exposed him to other ideas that made him wish for more.

Rivoires and Hitchborns

Apollos Rivoire was born in 1702 in southwest France. The Huguenot (Calvinist Protestant) majority of this region had a long history of religious and political strife with the Catholic kings of France, causing hundreds of thousands of Huguenots to leave France. Only a few thousand, including Apollos Rivoire, emigrated to British North America.[21]

Rivoire traveled to Boston in 1716 and became an apprentice to John Coney, perhaps the finest silversmith in America at that time. Coney determined that this apprenticeship would end in 1725 (nine years being somewhat longer than average), but he died in 1722. The remaining three years of Apollos' indenture appeared as a commodity on the inventory of Coney's estate, and Apollos won his freedom by paying 40 pounds to Coney's widow. He established his own silversmith shop sometime in the 1720's in Dock Square near the center of Boston.[22] Eventually, Apollos Rivoire anglicized his name to Paul Revere.[23]

On the other half of Paul Revere's genealogy laid the Hitchborn family, which contained some wealthy and influential members. The Hitchborns migrated from England to America in 1641, and by the 18th century owned a small wharf in Boston's North End, where they lived and owned various businesses such as boat repairs, cargo loading, liquor sales, and possibly

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[21] The Huguenots' political rights were lost in the early 17th century, and their religious rights vanished in 1685 when King Louis XIV outlawed the Protestant faith. Leehey, "Reconstructing Paul Revere," p. 17.

[22] Ibid. pp. 19-20. No records reveal whether someone loaned him money to pay this indenture fee and buy the initial equipment and raw materials needed to start a silversmith shop. Perhaps he paid it from his journeyman income.

[23] To distinguish him from his son, Paul "the patriot," the name Apollos will be used throughout this study.

shipbuilding. Deborah Hitchborn, Paul Revere's mother, also descended from Captain Richard Woody, a soap-boiler and saltpeter manufacturer, and Thomas Dexter, a very wealthy landowner and an original promoter of the Saugus Iron Works.[24]

Unfortunately for Paul Revere, his mother received few monetary benefits from her well-off relations. Deborah's older brother Thomas inherited the bulk of the Hitchborn property, and achieved reasonable monetary success. His ten children, Paul Revere's cousins, entered different professions. Oldest son Thomas eventually inherited the Hitchborn wharf and the lion's share of the family wealth, and probably employed several of his younger brothers, who received training in relevant fields such as shipbuilding and sailmaking. Benjamin, the second youngest Hitchborn son, received a gentleman's education at Harvard, and became a prominent lawyer and member of the Boston upper class. Samuel, the youngest Hitchborn son, became a silversmith, possibly an apprentice to Paul Revere.[25]

The Hitchborn family had a profound influence upon Revere. Many of his children and nearly all of his siblings received Hitchborn names, his cousins loaned him money at critical points during his career, and Thomas' example constantly demonstrated the advantages of property and social standing, which Revere relentlessly strove to attain. But despite his early death, Apollos Rivoire had a far greater impact on his son than the entire Hitchborn family. Paul Revere literally followed in his father's footsteps, serving as an apprentice under his watchful eye, mimicking his techniques, and gaining familiarity with his molds and tools while patiently awaiting the day when he would work alongside his parent and mentor as a master craftsman.

The Apprentice and his Father

Apollos Rivoire learned the art and mystery of silverworking from John Coney. Although Coney died three years before Apollos' apprenticeship was officially completed, Apollos still received six years of instruction, not much less than the usual seven-year term. From 1690 until his death, Coney's reputation among his peers was second to none. He mastered three artistic styles throughout his long career, and surviving pieces attest to his unrivaled versatility and productivity. In particular, his skill at engraving distinguished him from his contemporaries, and

[24] Ibid., p. 21.
[25] Ibid., p. 23.

earned him a commission to engrave the paper money for Massachusetts in 1702, and probably 1690 as well. Other silversmiths purchased more ornamental hollowware items (the most lucrative of all silver commissions) from Coney than other practitioners. Governments, churches, and colleges repeatedly turned to him for their most elaborate orders, and his output even remained high during the periodic economic instability between 1710 and 1720. A valuation of his estate placed him among the wealthiest ten percent of all Bostonians.[26]

Apollos received two great gifts from Coney. After years of training by a respected master, Apollos was a highly skilled craftsman, fluent in all contemporary styles. Also, as a student of Coney, his reputation even at the beginning of his career received a considerable boost. Museum curator and historian Janine Skerry describes Apollos as a "capable, even talented, silversmith, who produced a variety of objects in an economical fashion."[27] The few surviving examples of Apollos' work testify to his exceptional skill at engraving, which is to be expected from a student of Coney.

One tankard produced by Apollos indicates that he subcontracted some of his work to other silversmiths. The back of the tankard handle is stamped with the initials "WS," probably referring to the contemporary silversmith William Simpkins. Apollos contracted with Simpkins and possibly other silversmiths to produce specific, specialized components for some of his popular products, and probably performed his specialized tasks such as engraving for them. Since each silversmith had a limited quantity of molds and other equipment, widespread "jobbing" of tasks enabled them to specialize while still handling all their clients' orders. Subcontracting relationships demonstrate the communal nature of the silverworking field and also reveal the reputation and unique knowledge and skills possessed by individual practitioners.[28]

Of course, Apollos would not subcontract if he could utilize his own equipment and have his apprentices perform some of the work at no cost. Paul Revere became an apprentice to his father at age 13, followed approximately five years later by his younger brother Thomas. No

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[26] McLean Ward, "Boston Goldsmiths," pp. 131-8; Kathryn C. Buhler, *American Silver from the Colonial Period through the Early Republic in the Worster Art Museum* (Worster: Worster Art Museum, 1979), pp. 10-11; Kathryn C. Buhler, *American Silver in the Museum of Fine Arts* (Meriden: Museum of Fine Arts, 1972), p. 39, Hood, *History of Style,* p. 74.

[27] Janine E. Skerry, "The Revolutionary Revere: A Critical Assessment of the Silver of Paul Revere," in *Paul Revere—Artisan, Businessman, and Patriot,* (Boston: Paul Revere Memorial Association, 1988), pp. 43-46.

[28] Ibid. p. 45; Stephanie Grauman Wolf, *As Various as their Land,* (New York: Harper Collins, 1993), p. 184; and McLean Ward, "Boston Goldsmiths," p. 147.

surviving records describe the experiences of Paul or any other apprentice to Apollos. These years can be approximated from stories of "typical" apprenticeships throughout the colonies. One aspect of colonial apprenticeship not common in Britain was the frequent requirement of one or more years of "book learning." Paul Revere received his "book learning" at Boston's North Writing School before starting his formal apprentice training. Unlike the more prestigious Boston Latin School whose curriculum was oriented towards upper class children, the North Writing School focused on reading, writing, ciphering, and "manners."[29]

Typical terms of apprenticeship often included stipulations that the boy must not drink, marry, fornicate, or gamble. Obedience to these rules was highly irregular, as attested by numerous reports of "wild" apprentices. Many states passed laws forbidding taverns to serve alcohol to apprentices and other servants, but these laws were rarely enforced.[30] Many apprentices tried to escape, leading local governments to pass laws to protect the investments of masters. As Benjamin Franklin's example illustrates, runaway attempts even took place when the apprentice worked for members of his own family. But young Paul stayed in his father's shop until the end, and never saw reason to complain about his training period.[31]

Apprentice silversmiths began their training with routine duties such as cleaning the shop, collecting silver dust and filings for reuse, and tending the fire. Masters gradually increased these responsibilities as apprentices grew older and became more skilled. Paul Revere's apprenticeship years taught him more than just a set of silverworking techniques. From his lessons, his father's example, and the conversations of other apprentices, silversmiths, and customers, he learned what it meant to be a craftsman. This glimpse of the workload, the lifestyle, and the profits and the rhythms inherent in this career shaped the remainder of his life. As an apprentice in his father's shop, he focused upon a seemingly endless series of short-term goals that would culminate in his attainment of master status. A family tragedy would soon replace these goals with an even larger and more important series of responsibilities, which affected not only his own future, but that of his entire family as well.

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[29] Leehey, "Reconstructing Paul Revere," p. 25; Wolf, *As Various as their Land,* pp. 124-128; Bridenbaugh, *The Colonial Craftsman*, p. 130; Jayne E. Triber, *A True Republican* (Amherst: University of Massachusetts Press, 1998), p. 13.

[30] Bridenbaugh, *The Colonial Craftsman,* p. 131; Larkin, *Reshaping of Everyday Life,* p. 282.

[31] Bridenbaugh, pp. 130-133; Rorabaugh, *Craft Apprentice,* p. 11; Federhen, "Artisan to Entrepreneur," p. 72.

Head of the Household: Master Paul

Apollos Rivoire died on July 22, 1754, leaving 19 year old Paul Revere as the oldest male of the family. This had major impacts upon the Revere household above and beyond the distress caused by a beloved patriarch's death. Paul was technically still an apprentice, too young legally to inherit the family silver shop. In the absence of records before 1761 we can only speculate whether he ran the shop in his own name, ran it in his mother's name, or worked under a more experienced silversmith. At any rate, he soon operated his father's shop, and had to confront the realities of management. Even if he had fully mastered the technical aspects of silverwork by this time, which is by no means certain, he would now need to learn to keep his shop profitable during the slow economic period following the end of King George's War in 1748. Initially, the going was tough. Newly widowed Deborah Revere made her first rent payment in rum, cash, and a silver thimble, and Paul paid some of the next quarter's rent by making ten rings for his landlord.[32]

Fortunately, Revere could draw upon several powerful assets. In addition to inheriting knowledge and training from his father, he also received a fully stocked silversmith's shop.[33] Substantial evidence indicates that he used his father's molds to cast silver objects throughout his career, but he certainly relied upon them exclusively for the first ten years. He continued using some items, such as his father's porringer handle molds, until the end of the century. In a less tangible sense, he also benefited from his father's network of business connections with customers, merchants, and other silversmiths. In some cases these categories meld; for example, Boston merchant Benjamin Greene was both a supplier and customer to Revere and his father.[34] Neighbors, Hitchborn relatives, and friends all figure prominently in his early sales.

In February of 1756, at the age of 21, Revere enlisted in the Massachusetts militia as a Second Lieutenant in an artillery train, to fight in the French and Indian War. Although this might appear to be a shirking of his duty to run the shop and support his family, Revere probably had their interests in mind when he enlisted. As an artillery lieutenant he would receive £5 6s 8d per month, an ample cash wage roughly double the salary of a typical enlisted man. In six months he would earn 32 pounds, or two years' rent on his family's house. A novice silversmith

[32] Triber, *A True Republican*, p. 21.
[33] Unfortunately, surviving records do not list the equipment owned by either Revere at any point.
[34] Federhen, "Artisan to Entrepreneur," p. 65.

in an uncertain market could not guarantee he would earn this much money. Also, the artillery company he joined was the only such unit in the Massachusetts' force, an elite skilled group twice the size of an infantry company, allowing Revere to gain a prestigious rank at a young age. And military titles certainly carried over to private life, as illustrated by innumerable instances of Revere referring to himself or being referred to by his militia title. He remained in the military until November of 1756, and although his regiment at Lake George never took part in combat, his experience serving under the often strict and condescending British officers probably altered his perceptions of status and colonial-metropolitan differences.[35]

In August of 1757, less than a year after returning from his military service, Revere married Sara Orne of Boston, who also moved into the cramped accommodations of his mother's house. Less than eight months later their first child was born, a daughter named after Revere's mother Deborah. With a family, including a new wife, depending on him, with his military adventures behind him, and as a master craftsman legally running a shop in his own name, he was ready to devote all of his time and attention to his craft.

Revere's childhood and early experiences suggest two conflicting drives that explain many of his subsequent decisions. An artisan's awareness of class and hierarchy would be reinforced by Revere's visits with his wealthiest relations, interactions with upper class customers, and service in the militia under the supervision of the British military hierarchy. His own position as a silversmith and artillery lieutenant placed him comfortably above the median, but this probably only made him wish for more, for the privileges and influence of the gentry. At the same time, his later skills and attitudes reflect his love for the production process, a fascination that must have began in his apprenticeship. Science, equipment, and technical secrets would always intrigue him and occupy much of his attention. As a result, he had the ability to succeed as a first rate craftsman, although he aspired toward different goals.

The Revere Shop: Before the Revolution

Revere's early silverwork period portrays the rising fortunes of a young, ambitious, talented artisan. In the late 1750s, when he first entered the field, he had to continue his education on the

[35] Triber, *A True Republican,* pp. 23, 204.

job while attempting to support a growing family. By the eve of the revolution his reputation was solid, his sales were large and steady, and he even had time for other pursuits. Revere succeeded because of a combination of artistic talent, technical versatility, and good connections.

Equipment and Technical Procedures

Revere's surviving records do not contain an inventory of the equipment or raw materials present in his silvershop at any point in time. However, silversmiths' equipment and procedures remained fairly constant throughout the colonial and early federal period despite dramatic changes in artistic styles. Typical equipment owned by 17th and early 18th century silversmiths included hammers, anvils, files, burnishing stones and pumice powder, furnaces, soldering equipment, wire drawing benches, drop-press and screw-pressure dies, and molds.[36] These tools and the knowledge of their use defined the silversmith profession and affected Revere's entire life. They are described below.

The primary tools for a silversmith were hammers, anvils, and files. Hammering occupied most of a silversmith's time, and a good variety of hammers and anvils allowed him to form a variety of shapes, while files, pumice, and other finishing tools produced the final form. Labor costs accounted for most of the value of silver plate; in 1760, one silversmith estimated that an unengraved coffeepot required 10 working days to create, but new methods were developed by the late 18th century to decrease the time spent hammering and working the silver. Skilled craftsmen could then add ornamental embellishment such as engraving or chasing. Engraving is the process of gouging lines out of a flat surface using a pointed tool called a burin, while chasing is a painstaking process of denting metal with repeated blows from a steel punch or chisel, forming continuous indentations without removing any metal. Most difficult of all, repoussé ornamentation involved denting indentations into sheet silver from the inside, by use of a curved rod called a snarling iron.[37]

Small silverworking furnaces typically used charcoal for fuel and a hand bellows to control the air supply, enabling every shop to melt old silver or coins and cast them into new forms. Silversmiths poured a mixture of silver and copper into wood or iron molds and

[36] Mulholland, *History of Metals in Colonial America,* pp. 88-89.
[37] Ibid., pp. 88-89; Hood, *History of Style,* pp. 18-19, Edwin Tunis, *Colonial Craftsmen* (Baltimore: Johns Hopkins University Press, 1965), p. 84.

hammered it into its final form. However, the hammering and shaping process added stress to the metal, gradually making the silver hard and brittle. This phenomenon was known as work-hardening and could be reversed by the annealing process, in which craftsmen carefully heated metals at a specific temperature for a specific duration until they softened again, and then plunged it into water or acid. A balanced application of annealing and hammering produced strong metal, neither soft nor brittle. The furnace also allowed silversmiths to make their own solder by melting an amalgam of silver and brass and combining it with borax paste. The soldering process allowed silversmiths to fuse two silver sheets together by applying the pasty solder mixture to the connecting point of two metals and heating the seam over a fire or with a blowpipe until the joint became smooth. Sulfuric acid removed traces of the borax, and when this was done properly, as Revere learned to do, the soldered seam is virtually invisible.[38]

Many silversmiths soldered wire onto their flatware as an extra embellishment. Silversmiths made their own wire from thin silver sheets by using a wire-drawing bench. One end of the bench had a huge crank that pulled on a leather strip and clamp, and the other end had a secured iron die containing different size holes. The silversmith tapered the silver strip at one end so it would fit through the largest hole on the die, passed it through the die, and secured it to the clamps. A strong journeyman turned the crank, which pulled the silver strip through the hole in the die. Since only the end of the silver strip had been tapered, the strip would not fit easily through the hole. Strenuous pulling compressed and forced the silver into a longer and narrower shape. Once all the wire passed through the hole, the silversmith tapered the end some more and pulled it through a smaller hole, and so on until it attained the desired diameter. All of the compression and stretching hardened the silver, making it increasingly brittle. The silversmith therefore had to heat the wire after each "draw" through the die, again using the annealing process.[39]

Dies and molds both allowed silversmiths to configure silver into specific three-dimensional shapes. Molds were valuable blocks of hard wood or iron with specific shapes cut into their surfaces. Silversmiths placed them on a level surface, poured molten silver into them, and let it cool. Dies might later be used to add depth to a casting. For example, when spoons and all silver pieces were first cast, they were flat and two-dimensional. The bowl of a spoon

[38] Tunis, *Colonial Craftsmen*, p. 82.
[39] Ibid. p. 83.

needs to be rounded and deepened, so a silversmith placed it over the lower part of the die, which was a lead block containing a depression in the exact shape of the spoon. He then struck the spoon once with the upper part of the die, an iron mallet also curved in the spoon's shape.[40]

The prior descriptions only brush the surface of the intricacies of silversmithing, but reveal the array of skills and metallurgical knowledge required for competent practice. Processes such as annealing and wire drawing not only served a variety of silverworking purposes but also prepared Revere for many of his later metalworking endeavors. The elite status of silverworking partially resulted from the amount of equipment required, and the diverse range of skills and knowledge needed to make so many different objects. Revere's diversity was one of his greatest strengths.

The Versatile Craftsman

Although the bulk of Revere's early activities involved routine work such as cleaning, dent removal, and small commissions, he provided a wide range of products and services during his early silver shop years, more diverse than in any other period in his life. He produced over ninety different kinds of objects, and many of the most unusual forms such as a funnel, candlesticks, and a chafing dish were commissioned before 1769. He also recorded occasional unusual requests such as putting silver handles on seashells, making a dish out of an ostrich egg, cutting a branding iron for his cousin William Hitchborn, and mending glass objects. Revere even worked on small gold objects such as buttons, rings, and bracelets. This diversity provided a steady source of income that helped him weather economic and political hardships. When silver scarcity became a concern during the postwar depression of the mid to late 1760's, Revere branched out into other services such as dentistry and false teeth construction (which used thin silver or gold wires to fasten the teeth) and copperplate engraving and printing.[41]

Engravers often allied themselves with printing establishments, and their work was always in great demand, particularly in the decade before independence. Originally an outgrowth of his ability to embellish silverware, engraving and printing played an important role throughout Revere's life. He made his first copperplate engravings around 1762, and quickly

[40] Ibid., p. 83.
[41] Ibid., pp. 65, 71, 72; Skerry, "Revolutionary Revere," p. 47.

learned to produce a variety of images and texts for portraits, church hymnals, political cartoons, advertising cards, bookplates, and many other media. Although he had to master the technical intricacies of this work, he also drew the illustrations that appeared in print.

Several aspects of his engraving work typify his lifelong career trajectory and operating methods. First, although he became quite proficient in reproducing images in a variety of formats, Revere was more of a borrower and adapter than a creative artist. Most of his political cartoons were direct copies of British illustrations, in accordance with the style of the times. But although he did not display a creative talent, he did have to reproduce these images freestyle, using engraving tools that required both strength and control. Second, he demonstrated a remarkable ability to master the many technological aspects of this job. Many entries in his silvershop daybooks contain prices for engravings, including charges for "cutting a copper plate," "smoothing plate," "to the copper for a plate," "to preparing plate for engraving," and "cash paid for 4 letters." Although he never described his engraving in more detail than this, the evidence suggests that at the very least he reshaped existing plates, and he very possibly made his own. He also carries charges for the printing of numerous copies of certain documents. Similarly, when he produced "metal cut" illustrations and mastheads for mass-produced newspapers and almanacs, he almost certainly made his own "type metal," a compound of lead, antimony, tin, and other metals. These skills would not have been taught during his apprenticeship.[42]

Luxury Items, Art, and Reputation

Contemporaries and historians primarily judge silversmiths on their ability to create elaborate luxury pieces. These expensive items were "bespoke," or made to order, to insure the buyer's satisfaction and to prevent the silversmith from wasting time and effort on something that might not quickly be purchased. Silver plate was a popular luxury and status symbol among the upper classes, who used it for ceremonial occasions, gifts, or display purposes. This was a further boon to silversmiths, who were often hired to melt down "old" silver and remake it in accordance with the most recent fashions.

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[42] Bridenbaugh, *The Colonial Craftsman*, p. 99; Clarence S. Brigham, *Paul Revere's Engravings*, (Worster: American Antiquarian Society, 1954), pp. 4, 133; Many entries in Volume 1 of the Revere family papers (RFP), Massachusetts Historical Society, Boston (see in particular May 3, 1774; July 9, 1774; May 2, 1781).

At the beginning of Revere's career, the highly ornamental rococo style of decorative artwork was moderately popular in Boston, and widespread in New York and Philadelphia. Skerry contends that Revere's rococo pieces were roughly equivalent to contemporary work in New York and Philadelphia, but exceptional "in their exuberant interpretation and technical execution" in comparison with other Boston rococo objects. Many other early Revere products display an above average to exceptional degree of workmanship, evidenced in terms of uniformity, artistic interpretation, and elegance.[43] Several types of item are worth mentioning.

He made his most famous creation, one of the most famous pieces of silver ever designed, for the growing patriot movement.[44] In June of 1768, the Massachusetts General Court disobeyed a direct order from Secretary of State Hillsborough by voting not to rescind a circular letter protesting the Townshend Act. Fifteen members of the Sons of Liberty who took part in this vote commissioned Revere to make a large engraved bowl commemorating the event. The result, called the Sons of Liberty Bowl (or merely "Liberty Bowl") is a punch bowl bursting with engraved patriotic slogans and images such as a liberty cap, the Magna Carta, and three images relating to British reformer John Wilkes.[45] As a complementary finishing touch to this political statement Revere designed and engraved "A Warm Place – Hell," a copperplate print depicting the 17 house members who voted to rescind as they sadly marched toward the gaping jaws of hell.[46]

Over half of Revere's total production of large silver items consisted of objects for drinking and dining, primarily on the tables of the wealthiest Bostonians. His output reflects changing social trends such as the growing popularity of tankards and teapots for social drinking rituals. Throughout the 18th century, tea drinking grew in importance until it became a vital ritual in the female-controlled domestic social world. Tea drinking accessories, as well as tea itself,

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[43] Skerry, "Revolutionary Revere," pp. 48-49.

[44] The liberty bowl is famous for its political, and not artistic significance.

[45] John Wilkes was a member of Parliament who also published a newspaper called the *North Briton.* Issue 45 of this newspaper contained a harsh criticism of royal policies and continued Wilkes' urgings for Constitutional reform. Within a week, a questionable warrant was issued, allowing authorities to imprison Wilkes and search his house. Correspondingly, the Liberty bowl contains the phrases "Wilkes and Liberty" and "No. 45," as well as a torn paper labeled "general Warrants." Wilkes was a hero in the colonies, who often tied his fate to theirs. Contained in "A Note on the Origin of the Paul Revere Liberty Bowl," Museum of Fine Arts pamphlet, by Edwin J. Hipkiss, February 16, 1949.

[46] Brigham, *Paul Revere's Engravings*, p. 136; Triber, *A True Republican*, pp. 64-65.

grew increasingly cheaper, eventually becoming available to some extent to all but the poorest members of society.[47]

Revere made one or two teapots a year prior to 1767, and a total of two between 1769 and 1775 when his shop output diminished during his patriotic activities. One of these two, in 1773, was part of a 45-piece tea service for loyalist Dr. William Paine.[48] Many Bostonians who boycotted tea during this period turned to coffee, and correspondingly, Revere's coffeepot output increased from a total of two in the years before 1767 to six in the year 1769 alone. One of these, made in 1772, is the only known marked three legged coffeepot made in America. Revere adapted the foreign form of the three-legged coffeepot, commonly made by French silversmiths, to his own design by adding three large legs (ornamented with shells and scrollwork in the rococo style) to a basic coffeepot body. Experts consider the end result quite successful.[49] As much as any other single piece, this coffeepot exemplifies Revere's combination of artistic and technical creativity.

Revere also engraved many of the silver items he produced. This embellishment was particularly prevalent in the colonies because the jurisdiction of the British College of Heralds did not cross the ocean. Families could basically design their own coat of arms (typically aided by advice books such as John Guillim's *A Display of Heraldry*) and silversmiths would add them to bookplates or salvers. He also engraved items that he did not make, reflecting the high esteem in which other silversmiths valued his abilities.[50] Revere's outstanding embellishment work was proof of his craft lineage to his father and Coney, who also specialized in engraving. Revere continued to perfect his engraving skill throughout his life, although his eye for geometric shapes, particularly when the federal style grew popular after the Revolution, might have been his greatest talent.

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[47] Although upper class women were fairly active in the pre-Revolutionary tea boycott, several letters of complaint written to colonial newspapers illustrate that this was no small sacrifice. If men were allowed to continue drinking imported rum, argued some women, why must they lose their own social ritual? Loyalist Peter Olivier joked that, although most ladies agreed to only drink the tea they already possessed, and only when they needed it to forestall sickness, "they were cautious enough to lay in large Stocks before they promised; & they could be sick just as suited their Convenience or inclination." Wolf, *As Various as their Land,* pp. 80-81, 85.

[48] This tea set was a gift from Dr. Paine to his new wife Lois Orne, a distant relative of Revere's wife Sarah Orne.

[49] Federhen, "Artisan to Entrepreneur," pp. 67-68; Skerry, "Revolutionary Revere," p. 51.

[50] Federhen, "Artisan to Entrepreneur," p. 70.

Historian Gordon Wood contends that most colonists were more aware of the people immediately above and below themselves in the social hierarchy than of those at their own level.[51] Revere's experiences indicate that, while he probably grouped his interactions by the social category of the recipients, all levels mattered to his business.

Although Revere and others recorded vast numbers of small sales to a wide range of clients, the best colonial silversmiths often depended less upon intermittent customers than upon loyal "patrons," wealthy members of the gentry who loyally ordered many items from their favorite craftsman over the years. Only the wealthiest five percent of the population owned numerous pieces of silver, and these members of society were also most concerned with their social standing.[52] Revere did not have specific patrons before the war, but he was tied to the merchant class in many ways. In preindustrial Boston, all endeavors either depended upon the natural cycles of agriculture or the commercial cycles of merchants.

Credit relationships and the type and manner of payment were of major importance to all colonists, allowing them to buy more goods. Most payments were made "in kind" via an exchange of goods and services that did not involve cash or coinage. Compensation rarely took place at the moment of exchange, as long creditor lists illustrate. Considering the often severe currency shortages, most colonists had to depend upon loans from local merchants or "moneyed" men, thereby extending personal networks of credit. In early colonial America, these personal exchange networks dominated all economic transactions and also solidified social relationships. In rural areas, debts were often tracked through oral agreements and personal memory, or perhaps in informal account books. New England led the way towards more rigid accounting methods, in which artisans (and eventually, farmers) converted all debts and credits of goods and services into monetary values in ledgers. Accounts were typically settled in March or April, at the beginning of the agricultural year, although many debts were maintained for years. The vast majority of these debts were interest free.[53]

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[51] Wood, *Radicalism of the American Revolution*, p. 23.

[52] Silver cups were indispensable status symbols in upper class households, often prominently displayed in sideboards, which were eventually known as cupboards. Clarke, "The Craft of Silversmith," p. 74.

[53] Wood, *Radicalism*, pp. 64, 66-67. Larkin, *Reshaping of Everyday Life*, p. 37, Jonathan Prude, *The Coming of Industrial Order* (Cambridge: Cambridge University Press, 1983) p. 11.

Revere maintained records of all his silvershop transactions beginning in 1761. This meticulous notation of all his activities shows that he did affix monetary values to all his items at the time of sale. But his ledgers are often confusing, especially at first, because of barter transactions and unexplained cash withdrawals. The records do reveal a fairly consistent seasonal business pattern of peaks and lulls. Sales surged each year between February and April, and then dropped off until a second surge between August and November. These busy periods corresponded to spring and fall merchant shipments of new British goods, which completely dominated the colonial economy. New goods shipments provided Revere with raw material and also increased the amount of specie in circulation, encouraging greater spending. Since merchants formed a large proportion of his customer base, his shop thrived when they completed lucrative transactions. Merchants also provided information about the latest British styles, which he quickly learned to produce, and close ties with merchants enabled him to import some objects that he preferred not to make. For example, he made very few silver forks or knives throughout his career, choosing instead to import them from Britain at relatively inexpensive prices.[54]

Revere depended heavily upon his peers, fellow silversmiths and other artisanal colleagues. He was well connected within the Massachusetts silversmith community, and recorded many sales to fellow silversmiths. Some of his surviving silver pieces are stamped with his mark and then overstruck by the mark of other masters, indicating subcontracting. Revere's pre-Revolutionary accounts indicate that he had transactions with at least thirteen silversmiths, as well as other craftsmen such as a jeweler and a turner. Other silversmiths often asked him to work on chasing, repoussé ornamentation, salvers (which required a flawlessly flat surface), and other difficult objects or tasks requiring advanced skill. Silversmiths also exchanged goods for services in an extensive barter system. For example, between 1760 and 1765, Revere received important shop supplies such as gold foil, saltpeter, files, and binding wire from John Welsh in exchange for engraving work and objects such as spoons and spectacles.[55]

Numerous friends and associates patronized Revere's shop and provided him with enormous sales. Revere joined the St. Andrew's Freemason lodge in 1760 and formed a number of ties that aided him throughout the rest of his life. His Freemason career brought him social entertainment, status in the eyes of the community, leadership responsibilities, and strong

[54] Federhen, "Artisan to Entrepreneur," pp. 69, 75. Revere probably chose to import forks and knives because they required more labor than spoons.
[55] Skerry, "Revolutionary Revere," p. 47; Federhen, "Artisan to Entrepreneur," p. 74.

business contacts that carried him through many difficult periods. The members of St. Andrew's lodge overwhelmingly belonged to the middle class, including lesser merchants and many artisans. Revere's growing network of friends, colleagues, and family members provided him with a major source of revenue. Many of his best clients were Hitchborns, freemasons, fellow artisans, or members of his revolutionary committees, although Revere also had prominent Tories and British officers among his most loyal clients.[56]

Finally, Revere received assistance from apprentices throughout his silverworking career. His first apprentice was his younger brother Thomas, whose services were transferred to Paul after their father's death. Thomas seems to have graduated to the status of journeyman in 1761 when Revere began charging him for board and clothing – items that would be provided free of charge to an apprentice who lived in the master's household. Another apprentice, the son of Josiah Collins of Newport, is identified in a letter from his father.[57] Two possible journeymen in his employ, Samuel Butts and Mathew Metcalf, appear in his account books when they paid him for board and shop supplies. He almost certainly employed other apprentices and journeymen in these early years, but they do not appear in the surviving records.

Success, and Looking Forward

In the absence of guilds, government regulatory agencies, or assaying offices to certify the quality of metal or workmanship, a silversmith's mark stamped on the bottom of all silver objects was often the only guarantee of quality. Therefore, a silversmith's reputation determined whether he succeeded or failed. This reputation depended upon the reputation of his mentor, his technical and artistic skill, versatility, the loyalty of his client base, and his perceived integrity.[58] Without an external assessment of Revere's skill or reputation, his financial records serve as a measure of his success.

Overall, Revere's colonial silver years were quite profitable. He recorded income between 11 and 294 pounds in the years between 1761 and 1775, with an average yearly income

[56] Triber, *A True Republican*, pp. 29-31; Federhen, "Artisan to Entrepreneur," pp. 74-75.
[57] The letter states "I Cannot pay you for the Board of my dr Child till my Returne or the Returne of the Vessel which will be about 3 Months ... This, I hope, will not be the means of my poor Childs Suffering." Josiah Collins to Paul Revere, November 22, 1774, RFP. This is a wonderful example of the risk involved in trade endeavors and the interconnectedness of personal credit relationships – one late payment or bad debt could easily ripple throughout society.
[58] McLean Ward, "Boston Goldsmiths," p. 130.

throughout this period of 85 pounds.[59] In comparison, successful colonial journeymen might earn 45 pounds a year, and full time manual laborers' maximum income was in the neighborhood of 30 pounds, with the median free white income throughout the 1770s staying around £10 to £12. Many of his income fluctuations reflect distractions minimizing his shop time and external economic conditions. His shop output and income took a dramatic plunge between 1767 and 1770, largely due to his political activities. However, his shop output increased in 1773-1774 due to prewar speculation, business from British officers, and help from at least two new apprentices, including his oldest son, Paul Junior. Because Paul Junior's apprenticeship bracketed the Revolutionary War, he provided his father with services above and beyond those of ordinary apprentices. As his father devoted more of his time to patriot activities, Paul Junior filled in wherever he was needed, occasionally looking after the entire shop while his father was away. Paul Junior never achieved the artistic or technical skill of his father, judging from the small number of his surviving silver pieces.[60]

In the midst of increasing financial security and prestige, Revere lost his wife Sarah in May of 1773. Within a few months he started courting 27-year-old Rachel Walker (1745-1813), whom he married in October of 1773. His marriage to Rachel undoubtedly helped his entire family. Revere had six surviving children from his first marriage, not counting the infant Isanna who died four months after Sarah. Rachel immediately took up the slack on the home front, in addition to giving birth to eight more children over the next 14 years.

Interludes from Silver

Revere's patriotic and military exploits are the subject of several excellent biographies, and will only briefly be discussed here.[61] Instead, the following analysis focuses on his technical activities during the Revolutionary War years, and how these experiences altered his goals and

[59] He earned a high of over £294 in 1762, and recorded an income of only £11 in 1770. However, this low figure is highly suspect – for example, he spent £214 on a North End house in 1770, implying confidence in his earning potential. Revere did not record income from dentistry and (presumably) other sources, and in general his records are incomplete, particularly when he was occupied with Revolutionary activities such as in 1770. Triber, *A True Republican*, p. 209.

[60] Edwin J. Perkins, *The Economy of Colonial America* (New York: Columbia University Press, 1990), p. x ; Triber, *A True Republican*, p. 35; Federhen, "Artisan to Entrepreneur," p. 69; Nash, *The Urban Crucible*, pp. 207-208.

[61] The defining work in this field is undoubtedly Triber, but Forbes, Fischer, and Goss all provide interesting perspectives and important information.

self-perception. His four-year military career divides his two distinct silverworking periods, and therefore represents some transition in his thinking and practice.

Patriot and Soldier

Prior to the Revolution, Revere's patriotic activities grew increasingly time consuming. His position as an artisan required him to interact frequently with both laborers and members of the gentry. As a result, he was highly qualified to serve as a liaison between the upper class patriot leaders and the "mobs" that carried out activities from protesting to boycotting to military service.[62] Although no evidence indicates that he acted as or was considered a revolutionary leader, his role as the primary message courier for the Committees of Safety and Correspondence, participation in groups such as the Sons of Liberty, North Caucus, and Long Room Club, and membership on the London "Enemies List" of prominent Whig rebels all illustrate the many ways he publicly aided the patriot cause. These activities did not yield direct or tangible economic benefits, but indirectly aided him by expanding his network of associates, exposing him to new fields and ideas, and increasing his organizational experience.

Revere did not realize at the time that his famous midnight ride would be the start of a five-year forced vacation from silverwork. Following the events of April 18, 1775, he began a period of exile from British-occupied Boston, which lasted until March of 1776 when the King's soldiers left the city. He earned money by continuing to serve as a courier for the Committee of Safety. The rest of his family joined him in a boarding house in Watertown by mid-May, with the exception of 15-year-old Paul Junior who remained behind in Boston to look after their property.[63]

Revere eventually satisfied one of his goals by serving in the army, although his request for a Continental Army officer commission was denied, in spite of a letter of recommendation from John Adams. In April of 1776 he entered the Massachusetts State militia with the rank of Major, and he rose to the rank of Lieutenant Colonel by the end of the year. He commanded an

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[62] Revere's patriotic activities were representative of the behavior of many artisans. Capitalizing on their position as well-off workingmen with upper class patronage, artisans played a large role in organizing independence gatherings and boycotts, which improved their reputation in the eyes of both gentry and common people. In addition, these political services increased the unity and organization of the artisan class, leading towards a collective artisan identity and the formation of numerous pre-war artisan associations. These organizations reappeared in the 1790's in the form of Democratic-Republican societies. Wood, *Radicalism*, pp. 244, 276.

[63] Triber, *A True Republican*, pp. 110-115.

artillery detachment in several local military expeditions, including the failed Penobscot campaign of 1779. A large force of Indians, militias, privateers, and warships laid siege to the British fort in Penobscot Bay in Maine. The American forces panicked and fled as soon as seven British warships appeared in the bay, and Revere and other officers were relieved of their command upon returning to Boston. The Board of Inquiry decided to censure and dismiss Revere in 1779 for contributing to the disaster. This represented a devastating blow to Revere's plans: not only would he never achieve a higher military rank, but his honor, the great possession that might help him enter the ranks of the gentry, was cast into doubt. He tirelessly petitioned the Massachusetts legislature to convene a court-martial hearing to rule on the charges against him, which finally took place in 1782. At this time he was formally acquitted of all the charges against him, but the war and his military career were over.[64]

Although his military service ended on a sour note, Revere's memoranda books reveal the effort he put into his command. His appointment to an artillery regiment refleced his interests and aptitudes. He had to use and maintain a variety of pieces, gunpowder, and ammunition that might have originated in France, Britain, or inexperienced colonial foundries. The commander who mastered the use of these pieces had to know how to improvise solutions to a variety of unpredictable problems, and had to educate his men to do the same. Although he probably enjoyed the prestige and authority of his command, his books reveal a painstaking attention to the technical details of artillery use. In particular, he included directions for making gunpowder, signal rockets, fireworks, smoke bombs, fuses, and charcoal. He also recorded his ideas on the optimal use of many of these items, such as the mechanics of firing behind parapets and the use of shells that have a delayed detonation. Without any relevant military education, Revere had the sensibilities and methodical approach of a military engineer, and acquired an impressive quantity of technical knowledge in the process.[65]

The Versatile Technician

Revere provided several unique Revolutionary services of far greater importance than military leadership. Almost immediately upon resettling in Watertown, he worked as an engraver and

[64] Patrick Leehey, *What Was the Name of Paul Revere's Horse?* (Paul Revere Memorial Association, 1997), pp. 15-16.
[65] Undated entries in *Journal and Commonplace Book, 1777-1801*, Roll 14 Volume 51.1, RFP.

printer for the Massachusetts Provincial Congress. This was a logical follow-up to all of the printing and engraving he performed before the war, and his patriotic political cartoons may have earned him particular attention from the patriot leaders. In fact, he engraved many currency notes on the back of his earlier copperplates such as his famous "Boston Massacre" plate (which had to be cut down to size). His work included large plates for Massachusetts's bills of credit, loan notes of unspecified amounts that were redeemable at certain fixed dates, as well as smaller currency notes for public circulation. This quickly proved an extremely lucrative commission. He received more than £240 in 1775 and over £81 in January of 1776 for printing 100,000 extra bills of credit. His engraving work continued at least to the end of 1776, when he was asked to replace the word "Colony" with "State." His desire to serve in the army must have been great if it could pull him away from such a profitable assignment. Revere and his family shared a crowded Watertown house with Henry Knox and his wife, which might have helped Revere receive contracts from Knox in the future.[66]

His engraving and printing work was interrupted several times for more pressing concerns. In November of 1775, the Continental Congress asked Revere to travel to Philadelphia and learn to manufacture gunpowder. Although he was armed with a letter of access intended to gain his passage through the plant, Oswell Eve, the suspicious and competitive plant owner, only allowed him a quick walking tour of the building. This, combined with plans provided by an unknown source as a favor to Samuel Adams, gave Revere enough information to help design and possibly build a powder mill in Canton.[67]

Revere was also asked to learn to cast cannon. The Massachusetts Board of War put Colonel Hugh Orr and Lewis Ansart, a skilled and innovative French foundryman, in charge of setting up and operating a state furnace at Titicut (Bridgewater Connecticut) in early 1777. The Massachusetts Board of War asked them to seek Revere's advice concerning the best manner of brass cannon casting.[68] This is a very peculiar request, considering that Revere had not previously cast any large copper objects, while Ansart's knowledge of metallurgy was virtually unequaled in America. Whether or not his silverworking experience was of any aid to the experimentation process is unknown, but Revere learned much from Ansart, and helped him cast

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[66] Brigham, *Paul Revere's Engravings,* p. 141, 143, 147; Triber, *A True Republican*, p. 115.
[67] E.H. Goss, *The Life of Colonel Paul Revere*, (Boston: Joseph G. Cupples, 1891), p. 404, and Triber, *A True Republican,* p. 119. Forbes and Goss imply that Revere helped to set up and possibly operate the mill, but Triber points out that the source materials do not credit Revere for any service other than designing it.
[68] Triber, *A True Republican*, p. 127.

and test four cannon by March. He would successfully duplicate this process in his own forge seventeen years later.

In addition to the specific skills Revere mastered and performed to help the patriot cause, his repeated services illustrate his great ability to learn new procedures. This facility was clearly recognized by others, since he seems to have been consulted whenever a technical task had to be quickly implemented.

Quest for Gentility: The Would-be Merchant

With the end of the War, Revere had to return to his former lifestyle. In October of 1781 he wrote to his cousin John Rivoire in France. As their correspondence had only recently begun, he brought his cousin up to date on his background, and revealed several clues about his self-image:

> My father was a Gold-smith. He died in the year 1754, he left no Estate but he left a good name and seven children, 3 sons & 4 daughters. I was the Eldest Son. I learned this trade of him and have carried on the business ever since till the year 1775 when the American Revolution began. From that time till May 1780 I have been in the Goverments service as the Lieu't Col of an Artillery Regt, the time for which that was raised then expired, I thought it best to go to my business again, which I now carry on.[69]

This letter found Revere at a crossroads in his silverworking career, as he had just returned to his old profession after a five-year absence. Much had changed in these five years, for his country as well as himself. He "thought it best" to return to silverworking when other opportunities ended; hardly an enthusiastic return to an interrupted lifestyle. His letter continues:

> I am in middling circumstances and very well off for a Tradesman. I am forty seven years old. I have a wife + 8 children alive, my Eldest daughter is married, my oldest son since has learned my trade. Since we left the army he is now in business for him self. I have one brother + two sisters alive.[70]

His large family, the fact that his oldest daughter was married, and his son's success and independence all pleased Revere and identified him as a fairly traditional patriarch, happy that his son could carry out his father's legacy. However, the happy tone of this passage is

[69] Paul Revere to John Rivoire (his cousin), October 6, 1781, in "Loose Manuscripts 1746-1801," Volume 1, RFP.
[70] Revere to John Rivoire, October 6, 1781, Volume 1, RFP.

undermined at several points. Two uses of the word "alive," even though they are meant positively, allude to the constant presence of death in the early American household: by 1781, Revere and three of his siblings were the only survivors of his father's 12 children, and he had already lost four of his own 12 children. Only five of his 16 children would outlive him. In addition, he qualified his success by claiming he was very well off "for a Tradesman." His circumstances were "middling," an accurate description. He would never be content with his status as a skilled laborer fixed in the middle of the social hierarchy. In the new America, he could be so much more.

Postrevolutionary America was a period of virtually unrivaled social, economic, and political change. The new economic landscape produced a tremendous upheaval, with vast amounts of new currency and constantly changing availability of credit enabling vast fortunes to be made – or lost. And with the removal of the political restraints that had been attacked so thoroughly in the Whig press, a new feeling of liberation inspired many new endeavors. The alteration of traditional privileges and institutions produced a complex, society-wide reconfiguration of individual status, property distribution, and financial opportunities, one that many ambitious colonists sought to exploit.

Societal attitudes towards elitism and labor changed dramatically after the Revolution. In keeping with revolutionary rhetoric, artisans, businessmen, and "common" people began to distrust and even condemn some of the trappings and attitudes of the gentry. Leisure was increasingly seen as corrupting and idle instead of distinguished or intellectual, while labor received a new moral value. Success through ambition, talent, and hard work became the birthright and badge of a new generation of Americans, clear proof of a person's superior qualities. Thus, old hereditary social classes gave way to a meritocracy, with wealth becoming the clearest gauge of one's skill and status.[71]

Ironically, Revere's desire to escape the artisan class further connected him with the majority of postrevolutionary artisans. In the words of Gordon Wood, Revolutionary-era artisans had difficulty "establishing their self-esteem and worth in the face of the age old scorn in which their mean occupations were held."[72] Gradual changes did take place, building upon Revolutionary War developments. Most master craftsmen, regardless of their discipline, desired

[71] Wood, *Radicalism*, pp. 227, 341; Drew R. McCoy, *The Elusive Republic,* (New York: W. W. Norton, 1980) p. 107, Wood, "The Enemy is Us," p. 301.
[72] Wood, *Radicalism,* p. 278.

to advance their economic and social position. The educational trajectory of artisans, through stages of apprenticeship and journeymen status, suggests a common class-wide desire for "independence," defined broadly. Each stage of an artisan's career ended with rites of passage inaugurating a new rank that accorded him greater respect, monetary rewards, responsibilities, and autonomy. Becoming a master craftsman owner of his own shop was often the pinnacle for these men. Revolutionary fervor ran strong in this group: after spending many years attaining their positions, they were highly reluctant to part with their income or have their decisions constrained by external authority. Similarly, artisans remained quite ambitious even after "succeeding," and often aspired toward even greater successes.[73]

Sensing the possibility for postwar social and economic advancement, Revere attempted to establish himself as a merchant and become a gentleman. He soon learned that this was stressful and risky under the best of conditions, and downright frightening after the war. Revere first entered the merchant profession on a small scale, using profits from his silver shop to set up a "hardware store" in the early 1780s to sell local and imported goods.[74] Once again, he was following a societal trend.

The growth of a colonial consumer society corresponded with the appearance of layers of middlemen eager to satisfy the full range of postwar material needs. Buying and selling became a way of life for many individuals, and specialized terminology soon divided them into different roles and classes. Merchants sat atop the heap, as international wholesalers often possessing enough capital to speculate in other commodities such as land. Shopkeepers were general retailers, buying from merchants and selling to local residents. Sub-categories of shopkeepers such as grocers, tobacconists, and ironmongers answered more specialized demands, while hucksters and peddlers were traveling salesmen in cities and rural areas respectively. Many craftsmen had always doubled as specialized shopkeepers in the daily process of selling their wares, but after the Revolution this often became their primary occupation.[75]

Although Revere imported occasional shipments of goods until his retirement, he never earned enough money as a merchant to support his family. This was at least in part caused by his inability to secure credit from overseas merchants and a lack of specie caused in part by many of

[73] Bridenbaugh, *The Colonial Craftsman*, pp. 165-173; Gilje, "Identity and Independence," p. xii.
[74] Between 1783 and 1789, he withdrew hundreds of pounds of cash from the silversmith shop as he experimented in new trades. Leehey, "Reconstructing Paul Revere," p. 30; Federhen, "Artisan to Entrepreneur," p. 85.
[75] Wolf, *As Various as their Land*, p. 190.

his funds being tied up in irretrievable government securities. Revere already had many ties with Britain from his silversmith operations, which he hoped would help him become a merchant. But these contacts were not willing to extend him credit, probably because he lacked large amounts of capital. He tried using the steady income produced by his silvershop to secure credit, as illustrated in a letter to a London purchaser:

> You may depend that I shall pay the strictest attention to making you remittance and flatter my self, I shall be able to give you full satisfaction, as my dependance for a living will chiefly depend on the Goldsmith business, which will be carried on by my son, under my inspection ...[76]

This and other attempts would prove fruitless. One interesting detail is Revere's description of his role in the shop with respect to his son. He increasingly saw himself as an owner and manager, and his son as the on-site superintendent. This trend will be discussed further.

Revere could certainly blame the economy for some of his difficulties. After the Revolution, the Continental Congress and state governments issued massive quantities of paper money, largely in the form of bills of credit, in order to pay their creditors and soldiers. Governments eventually issued over $400 million, and inflation had reduced $167 in colonial currency to the value of one dollar of specie by 1781. This tremendous quantity of circulating currency helped America to shift from the barter to a market economy amidst widespread economic turbulence. But after the war, a combination of conditions such as the contraction of foreign credit and a glut of cheap foreign goods produced a crippling depression. This was a terrible time to request a loan or attempt to sell merchandise.

Revere's inexperience also hindered his success. Some of his letters indicate a lack of specific instructions for his London buyers:

> I could wish that the goods may be fashionable, tho' at the same time I should not prefer the extremes of fashion, as a medium will best answer here... Where I have not mentioned the number and peices of articles but the amounts of what I wish to have purchased, I must beg your kind advice; as your aquaintance with the business of this Town will enable you to give better directions than I am able to.[77]

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[76] June 30, 1783 letter to Frederick Geyer, RFP Volume 53.1.

[77] Leehey, "Reconstructing Paul Revere," p. 30, June 30, 1783 letter to Frederick Geyer, RFP Volume 53.1.

Despite failing to realize great profits as a merchant, Revere still continued to drift away from the activities of the "typical" American artisan. For example, many artisans, although fewer in New England, joined the Jeffersonian Republicans near the turn of the century in support of its appeal to democracy and social equality. Revere remained a lifelong Federalist, partly because he identified with the upper classes more than the mechanic class. After 1787, he stopped calling himself a goldsmith on official documents and instead referred to himself as "Esquire," a gentleman's title.[78] At around this same time his role in the silvershop was about to change dramatically, and new technological endeavors lay just around the corner.

The Postwar Revere Silvershop

Revere's second silverworking period lasted from 1779 to approximately 1800, occupying him from age 44 into his early 60s. While his first period clearly began with his entry into the business and ended when he devoted his attention to patriot activities, this second phase is more nebulous. He resumed management of his silver shop in late 1779 while concluding his tenure in the Massachusetts militia, but his personal involvement in the shop is harder to delineate. He initially divided his time between silverworking and attempting to succeed as a merchant. When his hardware store failed to produce great profits, he shifted his attention to iron work in his forge, and soon experimented with copper casting. In spite of these distractions, he continued to work personally on some silver objects at least until 1795 and supervised the production of many others. During this period Revere exemplified a societal trend by increasing his emphasis upon wage labor, moving towards standardization, and using new technical methods and equipment such as his flatting mill.

From Master to Manager

In the late 1700's, increased prosperity enabled many master craftsmen to upgrade their income and status by expanding into new positions such as quality control inspectors, merchandisers,

[78] Federhen, "Artisan to Entrepreneur," p. 85.

speculators, and factory supervisors.[79] This society-wide redefinition of craft labor was neither smooth nor painless.

The Revolutionary War produced permanent changes in the master-apprentice relationship.[80] Societal upheavals overturned centuries of tradition and challenged masters' authority. For example, increased literacy and publicly available sources of scientific and technical knowledge (such as "how-to" books) enabled ambitious newcomers to learn trades without needing to "waste" seven years in servitude. In addition, revolutionary republican rhetoric produced, in the words of contemporary Charles Janson, a "loss of subordination in society" that further encouraged independence.[81] Although the government's initial actions attempted to support the rights of masters, for example, by implementing new procedures to efficiently return runaway apprentices to their master, the law was incapable of saving the master's authority when society no longer valued the complete authority of masters.[82]

The interests of masters and journeymen also began to diverge. By the 19th century, large-scale strikes became more common as journeymen looked to each other when craft masters no longer took their needs into account. The previous patriarchal relationship was gone, replaced by an employer-employee conflict that led both sides to complain; masters about the migratory nature of journeymen, and journeymen about low wages.[83] Prior to 1750, many craft shops served as extended households for both journeymen and apprentices, treating them as part of the family. Even transients were often taken in when times were hard. The wage system put an end to these practices. Workers were less frequently confined by the paternalistic control of their masters, but at the same time had to live at the mercy of economic cycles, often losing their jobs when times were rough.[84]

Although Revere supervised the training and output of apprentices and journeymen throughout his career, only after the War did he truly began to think of himself primarily as a manager. He shared his managerial duties with his oldest son, Paul Jr., thereby freeing more of his time for other projects. After guarding the family property during the British occupation of

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[79] Wolf, *As Various as their Land,* p. 184.
[80] The heavy demand for soldiers led to an interesting legal conflict between masters' rights to their apprentices' labor and the need to enlist soldiers to repel the British. Rorabaugh, *Craft Apprentice,* pp. 16, 20; McCoy, *The Elusive Republic,* p. 92.
[81] Quoted in Rorabaugh, *Craft Apprentice,* p. 36.
[82] Ibid. p. 55.
[83] Wood, *Radicalism,* p. 185.
[84] Wolf, *As Various as their Land,* p. 185.

Boston, Paul Jr. served in the army until 1782 and then briefly went into business for himself. Unfortunately, he never equaled his father's skill, judging from his own surviving silver pieces. By 1783 he returned to his father's shop, where he quickly assumed a managerial position. By November 1793 the business was known as "Paul Revere & Son."[85]

The Shift Toward Standardization

The Revere silvershop's workforce increased considerably in the years after the revolution, although the rank of the different assistants there is unclear. Revere certainly continued to train apprentices, but an increase in wage payments reveals that he also hired employees, probably journeymen. He also hired master craftsmen to perform work for him, and paid with cash, goods, or services. Throughout this period he adapted his labor practices and production methods to fit the changing conditions, and steadily increased his output as a result.[86]

Although Revere's postrevolutionary production of unique luxury items decreased, his overall output exploded: he produced over 4,000 objects between 1779 and 1797. To maintain this level of output, Revere experimented with the division of labor and standardized production methods, important elements of mass production.[87] For example, he increased his use of sheet silver, which he could quickly produce with his new flatting mill, described below. He experimented with different methods of seaming these silver sheets and finally settled on soldering, partly because it required very little training and experience. Revere also realized the need to advertise his standardized products. After reopening his silver shop and starting his hardware store in 1783, he produced over £117 of representative standardized items such as buckles, buttons, and spoons for display in the shop window. This impressive investment of material and labor would help create a demand for pre-designed items.[88]

As he devoted more effort to merchant and iron endeavors, Revere took steps to decrease his personal involvement in the production of each silver piece. By the late 1780s his products almost exclusively relied upon standardized patterns and procedures, allowing him to delegate

[85] Leehey, "Reconstructing Paul Revere," p. 26; Federhen, "Artisan to Entrepreneur," p. 86.
[86] Federhen, p. 88.
[87] Other craftsmen joined him in this shift: in colonial woodworking, for example, many cabinetmakers assembled products from essentially mass-produced components. Wolf, *As Various as their Land,* p. 179.
[88] Federhen, "Artisan to Entrepreneur," p. 81; Undated entry (between August 30 and September 17, 1783), RFP Boston Wastebook 1783-1797.

more of his work to his apprentices and other employees. Variations in his shop output throughout the 1780's and 1790's indicate that many workers had a hand in the production of different objects. These differences are noticeable in different engraving styles, silver thickness inconsistencies, and variations in seamings.[89] Of course, Revere's stamp appears on all these products, obscuring the extent of his personal effort in each case.

The Rolling Mill

Although surviving records do not provide details of Revere's techniques or tools, he started using one particular piece of equipment that greatly altered his shop's production methods and output. Starting in or after the mid-1780's, nearly all of his products benefited from the highly uniform output of a silver sheet rolling mill, also known as a flatting mill. Flatting mills were present in the colonies at least as early as 1733, and were initially most common in Philadelphia. Revere purchased one in 1785, and hired a carpenter to install a platform for it.[90] This mill probably had a wooden frame, iron rollers that had to be imported from Britain, and iron screws to regulate the separation of the rollers.[91]

At this early point, Revere began to exploit the distinction between tools and machines. This division would soon define much of the transition that would take place in his life and in American work culture. A tool is inherently versatile but limited by the skill and knowledge of its user. Tools are usually hand-held, and therefore depend upon their wielder's physical activity and coordination. A machine is usually a more specialized device, producing more standardized output. While skill may still be required in the operation of a machine, the skill need not relate to knowledge of the product – such knowledge is only required in the machine's maker. The flatting mill, and all the machines Revere would later employ, allowed him to de-emphasize the role of craftsmen in his operations. This gave him greater control over the final product.

Rolled sheet silver could easily be cut to shape and seamed, eliminating the time consuming process of "raising hollowware." This older process involved painstaking hammering, smoothing, and measurement. Truly uniform sheets were extremely difficult to

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[89] Federhen, "Artisan to Entrepreneur," p. 75, 86.
[90] Skerry, "Revolutionary Revere," p. 53. A 16-foot joist was used in this construction, suggesting that the mill was fairly large.
[91] Federhen, "Artisan to Entrepreneur," p. 77.

produce. Historian Henry Kauffman in *The Colonial Silversmith* suggests that many "old-fashioned" silversmiths resisted the use of prefabricated silver or silver-rolling technology, preferring to continue relying upon manual processes that required large amounts of effort and skill. Revere did not fall in this category. He started using sheet silver for the spouts and handle sockets of his cylindrical teapots in the mid 1780s, a sign that he still lacked the confidence to form a complete object from sheet silver. He gradually expanded his use of rolled silver.[92]

In addition to tea-oriented silver, Revere also produced a large quantity of silver-plated harnesses along with an assortment of harness fittings, such as bridles, saddle nails, and stirrups. He imported some of these objects from Britain, but substantial evidence indicates that he also made his own plated objects. This implies that his flatting mill was in fact a plating mill. A plating mill can easily serve as a flatting mill to produce sheet silver, but can also be used to produce silver plated objects by heating the rollers and fusing sheets of silver and copper together with heat and pressure. After 1786, Revere began producing thousands of small plated objects.[93]

The Federal Style and Artistic Mastery

In the decades after independence, a new artistic style gained popularity in America. Called the neoclassic or federal style, it represented a return to simplicity after the ostentation of the Rococo period. The federal style's emphasis on ordered, streamlined, geometric forms supposedly represented a return to scientific principles, which might partially explain its popularity in America during the pragmatic self-improvement era after the Revolution.

In spite of the emphasis upon standardized production, the Revere shop achieved its greatest artistic results under this new style. He was able to master the technical aspects of silver production without sacrificing aesthetic beauty. The federal style also might have lent itself to standardization more than earlier, more elaborate silverwork. In one sense, Revere's own skills seem to fit federal silver better than earlier types: a methodical, measured approach was necessary to integrate and balance the different forms. According to craft specialist Graham Hood, "Paul Revere's finest work ... was done in the last decade of the eighteenth century."

[92] Ibid.
[93] Ibid. p. 80.

Unlike New York and Philadelphia, which featured a large number of competitive and equally skilled silversmiths, Revere completely dominated the Boston postwar silver scene and truly mastered the federal style. For example, Hood considers Revere's fluted teapot "brilliant" and "pristine," adding "In its sophistication and purity of form, it is one of the masterpieces of design in the classical period." Other experts echo this praise. The fluted teapot was one of the signature pieces of the Revere shop, an item only produced by three American silversmiths (including Revere) at this time, all of whom lived in Boston. These objects required less labor than ornate objects such as fluted sugar urns and creampots and made use of the flatting mill's uniform sheet output. The fluted teapot consistently sold well and had an enduring appeal.[94]

The Making of an Entrepreneur: Looking Ahead to Post-Craftsmanship

By the end of the 18th century, many factors undermined the artisan's traditional socioeconomic position. The expansion of a market economy corresponded with many developments: a much greater demand for goods; the extension of transportation networks; increasing numbers of corporations, banks, and factories; increased quantities of money in circulation (largely in the form of bank notes); and larger businesses in all fields.[95] Craft masters participated in these changes by emphasizing production quantity over quality, replacing barter and personal trade networks with monetary transactions, and introducing machinery and wage labor to cut costs.[96]

The proximity of these changes to the Revolution is not coincidental. The Revolution created new practical and ideological opportunities for nearly all members of society, which helped unveil the age of capitalism. Old-fashioned concepts of sacrifice for the greater good and remaining within one's preordained societal role changed under the influence of liberal Republican ideology. Merit, and not birthright, would determine rank in the new nation. Individual citizens now believed they had the right to act in their own commercial interests, and

[94] Hood, *History of Style,* pp. 162, 166; Skerry, "Revolutionary Revere," p. 53.
[95] The specific time and mechanism of the origin and spread of a market economy in America is a fascinating and complex topic that is still a matter of some scholarly debate. Many of the capitalist conditions listed above appeared haltingly or in unusual ways. For example, paper money first appeared during the War, but vanished after the passage of the new Constitution. By this point, bank notes (greatly in excess of the assets of the issuing banks) had become quite prominent. This subject is covered in great detail throughout the Summer 1996 issue of the Journal of the Early Republic (volume 16:2).
[96] Gilje, "Identity and Independence," p. xiv; Larkin, *Reshaping of Everyday Life,* p. 53; Paul A. Gilje, "The Rise of Capitalism in the Early Republic," *Journal of the Early Republic,* Volume 16:2 (Summer, 1996), p. 162.

those who succeeded in amassing a fortune could then use their wealth and corresponding prestige to acquire a public office and help their country as well. The new wartime and post-wartime market opportunities furthered these beliefs by rewarding some of the most prominent speculators and risk-takers.[97]

The expansion of the market economy paved the way for industrialization, a type of manufacturing oriented toward the production of numerous inexpensive goods for widespread market distribution. Although the term "industrialization" conjures images of factories and widespread use of machinery, increased division of labor often played a more vital role in the onset and spread of industrialization than the use of technology. The division of production into smaller subtasks enabled manufacturers to decrease their costs and increase output and standardization. As illustrated by Revere's example, some artisans already had extensive experience with these concepts by the Revolution, and further expanded their production after the War. Indeed, self-reinforcing cycles of production and demand led to the expansion of industrialization at incredible levels after 1789.[98]

Many aspects of the new society were inimical to the craft tradition. For example, apprenticeships no longer represented the only way to learn production methods and technologies because innovation was also located elsewhere, in factories and machine shops. The prominence of cash wages in these factories made apprenticeships appear less rewarding to young men and their families: why spend up to seven years working for free when one could earn wages while learning on the job? As a result, the apprentice tradition began to change, coming into closer alignment with the more market-based society. Ideals of individual enterprise and the universal drive to increase one's capital gradually edged out the former paternalistic family-oriented mutuality of craft shops. Masters no longer considered apprentices and journeymen extended members of the family or household, preferring to treat them as business associates who would receive cash wages for their services. One consequence of these changes was the beginning of labor movements in America. Apprentices and journeymen who previously categorized themselves "vertically" according to their crafts now began to organize "horizontally" with other apprentices or journeymen in different trades. And master craftsmen would also feel the impact of these changes, as they struggled to keep up with their changing

[97] Wood, "The Enemy is Us," p. 304, Gilje, "The Rise of Capitalism," pp. 172-5.
[98] Jonathan Prude, "Capitalism, Industrialization, and the Factory in Post-revolutionary America," *Journal of the Early Republic,* Volume 16:2 (Summer 1996), pp. 242-245.

society. Many craftsmen would become wage laborers, others continued operating their small shops despite the erosion of craft traditions, and an elite few made the transition to the world of manufacturing and business ownership. Many factors, including access to capital, entrepreneurial skill, and the ability to master new machines and technical processes determined the fate of master craftsmen in this new regime.[99]

Despite this fragmentation of master artisans, many cities experienced a proliferation of craft-oriented libraries and mechanics' associations. These groups soon reflected the changes to craft institutions. The Boston Mechanic Association (later renamed the Massachusetts Charitable Mechanic Association) was one of the most prominent artisan groups.[100] The 82 founding members, representing a wide cross-section of artisans, unanimously elected Paul Revere their first president. Although the association initially intended to serve as a quasi-guild to regulate apprenticeships, it had trouble collecting dues and enforcing its requirements. Massachusetts eventually granted it an act of incorporation and passed a law to regulate apprenticeships in 1805, but by this time the age of artisan traditions in most trades was drawing to a close. Apprentices were becoming paid employees, and master craftsmen had bigger problems to worry about than their continued loyalty. The Charitable Mechanics Society expanded its mission statement to include goals such as "the diffusion of benevolence" and "the encouragement of improvements in the mechanic arts and manufactures," and eventually consisted of well-educated businessmen.[101]

The evolution of the goals and status of the membership of the Charitable Mechanics Society in many ways mirrors the development of its first President, because Revere always aspired to more than craftsmanship. During his silver years, his abilities and goals never seemed

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[99] The decrease of paternal, family-oriented businesses and the widespread availability of currency also affected relationships between shop owners and their customers. Old-fashioned networks of trade exchange, barter, and personal credit gave way to modern commerce when shopowners asked customers to settle all transactions with cash at the time of purchase. Rorabaugh, *Craft Apprentice,* pp. 24, 59, 63-65; Larkin, *Reshaping of Everyday Life,* pp. 53, 59; Gilje, "The Rise of Capitalism," p. 170; Wood, *Radicalism,* p. 185; Wood, "The Enemy is Us," p. 301; Bruce Laurie, "'Spavined Ministers, Lying Toothpullers, and Buggering Priests': Third-Partyism and the Search for Security in the Antebellum North," in *American Artisans: Crafting Social Identity,* ed. by Howard B. Rock, Paul A. Gilje, and Robert Asher (Baltimore: Johns Hopkins University Press, 1995), pp. 99, 105-6.

[100] In 1794 the mechanics of Boston petitioned the Massachusetts legislature to charter a corporation to license apprentices and prevent masters from hiring runaway apprentices. The merchant interests feared that this measure would increase labor costs and defeated the measure in the legislature. The petitioners organized themselves into the Boston Mechanic Association, a voluntary organization with coercive powers. Quimby, "Some Observations on the Craftsman in Early America," pp. 7-9; Oscar Handlin and Mary Flug Handlin, *Commonwealth,* (Cambridge, Massachusetts: Harvard University Press, 1947), p. 132.

[101] Quimby, "Some Observations on the Craftsman in Early America," pp. 9, 13; Handlin, *Commonwealth,* p. 132.

to converge. Ironically, the very skills and practices that enabled him to succeed at innumerable technical and entrepreneurial challenges had barred him from the colonial gentry. Even after societal expectations shifted toward the appreciation of diligent labor, Revere's standards and goals remained unchanged. He wanted to become a gentleman. Throughout this period he came to view silverworking as the means to this end, and he worked hard to improve his shop's income and prestige through the adoption of proto-industrial practices such as subcontracting, the division of labor, mechanization, and standardization, with his own role changing from artisan to manager and owner. Although he failed to redefine his societal position, the recipe for success originated in this early period. The answer lay in changing the rules. The means had to become the end.

CHAPTER TWO: TO RUN A "FURNASS"

Iron, Bell, and Cannon Casting (1788-1795)

November 3, 1788 was a good day for Paul Revere. In a letter to Messrs. Brown and Benson the proprietors of the Rhode Island Hope furnace, he announced "We have got our furnass a going & find that it answers our expectation & have no doubt the business will do exceedingly well in the Town of Boston."[1] This furnace represented the culmination of years of research, inquiry, and experimentation. Revere could now enter a new field and try to achieve the wealth and status toward which he had always aspired, while leaving his profitable silvershop in the capable hands of his oldest son, Paul Junior. This would be a new beginning.

New beginnings in technical fields were neither cheap nor simple during the late 18th century. The two commodities vital for establishing a manufactory, capital and technical expertise, were extremely scarce. By November 3, Revere had succeeded at the difficult first step of building the furnace. He still had to make this investment pay off by recruiting knowledgeable laborers, mastering casting processes, arranging dependable supplies of raw materials, and insuring that his goods would find buyers. He truly had a lot to learn.

Between 1788 and 1795, Revere learned not one but three applications for his furnace: iron, bell, and cannon casting. Each of these fields exposed him to a new network of practitioners, suppliers, and customers. By repeatedly interacting with these communities and learning their practices, Revere participated in America's ongoing technological transfer from Europe. Between independence and Jay's treaty of 1794, the industrial and economic relationship between Britain and America is best described by the term "colonialism." America's postwar economic position was, in many ways, one of weakness and dependence. Scarce labor supplies, older technologies, and the falling value of export goods combined to produce a trade imbalance and American vulnerability to British mercantile tactics such as credit retraction and product dumping. Many

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[1] Paul Revere to Messrs. Brown and Benson, November 3, 1788, Revere Family Papers (RFP) Volume 53.1.

entrepreneurs like Revere identified the potential local market for manufactured goods, and searched for help with technical processes. They found this help, often without crossing the Atlantic.

This aspect of technology transfer, the spread of knowledge between shops in the same country and the application of information from one field to another, receives little attention in most historical studies, which invariably highlight the immigration of skilled laborers and the foundation of the "pilot" plants that first reproduce machinery and processes. The actual technology transfer process is far more complex. Historian of technology David Jeremy divides the diffusion of technology into four steps: demonstration of the potential of a new technology, the establishment of a pilot manufactory, the internal diffusion of similar facilities using the new technology, and the modification of the technology by different operators to suit local conditions.[2] Revere's experiences, beginning with his ironworking, illustrate the mechanisms of internal diffusion and (to a lesser degree) modification of technology. In particular, his interactions portray a fairly open technological community in turn of the century America, with free exchange of advice even among potential competitors. Revere's example also demonstrates the importance of technological transfer across disciplinary lines, through channels other than hiring skilled laborers. Although he greatly benefited from discussions with skilled practitioners, he also availed himself of information sources such as books, correspondence with scientists, ongoing experimentation, and his silverworking knowledge and tools. Revere's self-education also included on-the-job training in different managerial techniques. This was every bit as important as the technical challenges of the job, and Revere's silverworking background once again served him well.

Revere's casting endeavors provide an excellent study of domestic turn-of-the-century technological transfer mechanisms. Revere's career shifts offer three opportunities to study his startup procedures. This is necessarily at the expense of the longer-term operations of his furnace. Much of this bias is unavoidable because Revere emphasized these transitions when recording costs and expenses or writing letters. At some point after mastering each casting application, he turned it over to one of his sons

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[2] David Jeremy *Artists, Entrepreneurs, and Machines* (Brookfield: Ashgate Publishing, 1991), p. 5.

so he could focus on the next one, at which point his documentation of the older enterprise grows sparse. This pattern reiterates several lessons from his silverworking career. Revere loved technical procedures and greatly enjoyed corresponding about metallurgy and metalworking in his free time, but did not want to do this for a living. His casting endeavors were still a means to an end: he was searching for income and prestige, and not a new craft practice. However, this perspective began to change as his operations and payroll grew, particularly after the government became an important client.

The Making of a Founder

Revere's entrance into the ironworking field constituted one of the great challenges of his life, and his exact reasons for undertaking this new field are unknown. His unsuccessful career as a hardware merchant failed to provide him with wealth or prestige, but did allow him to assess the buying habits of Bostonians and identify potentially lucrative product lines. In particular, his hardware store operations taught him much about the local iron market and local iron producers. He must have been favorably impressed.

Revere consulted different ironworkers throughout his startup process, notably the ironmasters at the Hope Furnace in Providence, Rhode Island. While this phase of his education focused upon the practical aspects of designing his foundry, he would have also learned some of the recent history of the ironworking field, particularly as it related to his upcoming role in the larger community.

Direct versus Indirect Ironworking: Bloomeries and Blast Furnaces

Revere's research familiarized him with different iron products and the techniques used to make them. Colonial ironworkers employed two general ironworking strategies to convert iron ore into usable metal. The direct or blooming process was the original form of iron production, which took place in facilities called bloomeries. This process was simple: a single operator placed a small quantity of iron ore over a stone hearth and heated it with a powerful charcoal fire fanned with bellows to reach higher temperatures.

This separated iron and waste products both chemically and physically: some impurities combined with carbon monoxide from the fire and escaped as gases, while others solidified into slag. Most of the slag melted and drained off, and the rest became hard, brittle lumps throughout the iron. The operator shattered the brittle slag by hammering the iron while it cooled.[3]

The bloomery process directly produced bar iron, the most versatile type of iron in use during the colonial period. Bar iron is a fairly pure form of iron containing a small percentage of slag particles. Also called wrought iron, it is tough and malleable, easily worked into different shapes by a simple heating and hammering process. It also resists rust better than other types of iron because the slag particles inhibit the rusting process.[4] Early ironworkers understood the advantages of bar iron over most other metals, but attempted to discover an alternate production method that would allow them to produce it faster, cheaper, and more efficiently. The solution to this dilemma involved the use of a technological and managerial innovation known as the blast furnace.

Blast furnaces were larger and more complicated than bloomeries and eventually replaced them. The blast furnace process was also known as the "indirect" process because it required two steps to produce bar iron. The first step converted iron ore into an intermediate substance called pig or cast iron. Workers shoveled alternate layers of charcoal fuel, iron ore, and flux (calcium-rich materials such as limestone that chemically combined with slag and separated it from iron) into a gigantic stone chimney 20 or more feet high. Once ignited, this mixture burned for days at a time, fueled by a constant stream of air pumped via water-driven bellows. Dense molten iron pooled in a crucible at the bottom of the furnace, and workers periodically poured it into sand molds where it would harden into pig iron.[5]

Unlike bar iron, pig iron was slag-free, but contained small amounts of carbon and silicon (typically 2-4 percent) as a result of its proximity to charcoal and other substances in the stack. The presence of these and other less-desirable impurities

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[3] David Lewis, *Iron and Steel in America* (Delaware: Hagley Museum, 1976), p. 10; Robert B. Gordon, *American Iron, 1607-1900* (Baltimore: Johns Hopkins University Press, 1996), p. 14.
[4] Gordon, *American Iron,* pp. 7, 12-13.
[5] Ibid. p. 14; Peter Temin, *Iron and Steel in Nineteenth-Century America, an Economic Inquiry* (Cambridge, MIT Press, 1964), p. 10.

determined the quality and final properties of the output. Although casting was an inexact and non-uniform process, all pig iron was heat resistant, hard, and brittle, useful for large hollow objects such as cauldrons or cannon, but not for tools. Pig iron lacked malleability even when it was hot, and once it left its molten state it could only be reshaped by being re-melted, which took place in foundries under the supervision of casters, technically called founders, such as Paul Revere. Skilled founders could design intricate molds to produce detailed objects that most smiths would have trouble matching.[6]

Blast furnaces were only the first half of the indirect ironmaking process. Because of the limitations of pig iron, blast furnaces often formed symbiotic links with other ironworking institutions called fineries or forges. Skilled finery ironworkers (or "finers") converted pig iron into bar iron by heating the cast iron in a fanned charcoal fire. This melted the pig iron and oxidized the carbon and silicon impurities, which escaped as gases. The finer then removed the lump of metal and hammered it to separate the purer bar iron from the impurities. Most fineries contained between two and four hearths, each requiring the full attention of a skilled laborer and a waterpower-driven hammer.[7]

Blast furnace operation required managerial as well as technical skill. By contemporary standards, ironworks required large quantities of skilled, coordinated labor. In blast furnaces, the largest ironworks, 12 or more workers regularly fed and tapped the furnace all day and all night, every day, for months at a time.[8] This required vast organization and discipline, since one missed task could cause costly setbacks and injuries. This fostered the separation of a manager or supervisor task from the work of

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[6] Gordon, *American Iron,* pp. 4-5, 10-11

[7] Ibid. p. 14; Robert B. Gordon and Patrick M. Malone, *The Texture of Industry* (New York: Oxford University Press, 1994), pp. 79-80.

[8] An even larger variant of the blast furnace is the "iron plantation," a popular late 18th century innovation in the mid Atlantic states. Plantations heralded modern industrial organizations in many ways, such as large-scale use of wage labor, collection of all aspects of production (blast furnace, forge, finery, slitting mill) in one facility, advanced transportation networks, and complicated market analysis and accounting systems. However, the plantations also retained old-fashioned elements such as communal on site housing, integrated agricultural and industrial work for the laborers, and paternal family-based ownership. James A. Mulholland, *A History of Metals in Colonial America* (Alabama: University of Alabama Press, 1981), pp. 64-66, 70-72; Charles B. Dew, *Bond of Iron: Master and Slave at Buffalo Forge*, (New York: W.W. Norton & Company, 1994).

the skilled labor pool. Skilled ironworkers needed intelligence, experience, perceptiveness, and stamina to interpret subtle clues and gauge complex and invisible chemical transformations for long shifts under trying conditions. Knowing when to draw off and work the material depended on one's knowledge of the heating process and ability to judge the changing color of the iron. Competent managers ideally possessed technical skills as well as the organizational and leadership abilities needed to coordinate the workers.[9]

After studying the different aspects of ironworking Revere chose to enter the field as a founder. It was a very sensible decision. Bloomeries were extremely small and only made sense in frontier areas that were close to iron ore sources and far from competing sources of iron products. Blast furnaces required extremely large capital investments, enormous amounts of iron ore, charcoal, and water power, and knowledge of several complex processes. While fineries required less starting capital and involved procedures probably within Revere's grasp, waterpower would simplify the hammering process, and he did not have access to any. A foundry depended upon a process he had already learned, the art of heating and casting metal into molds.

The Importance of Timing: American Iron History

By the time Revere entered the foundry business, American iron had experienced a long cycle of booms and busts, largely determined by interactions with Britain. Britain supported colonial ironworking as long as it fit into its mercantilist doctrine, which defined the colonies' role as a source of raw materials and a market for the mother country's goods. When colonial iron seemed to grow dangerously competitive, Parliament passed the Iron Act of 1750. This act encouraged colonial production of unworked pig and bar iron by removing all duties on them, but prohibited the construction of new slitting and rolling mills, plating and triphammer forges, and other advanced processing works. The Iron Act was rarely obeyed, and almost never enforced in the colonies: no American was ever prosecuted despite repeated violations. The growth of the colonial market for iron continued inspiring the construction of new iron facilities

[9] Gordon and Malone, *Texture of Industry,* p. 242.

until the Revolutionary War. American ironworks in the 1770's employed around 8,000 men and produced 30,000 tons of pig and bar iron a year, approximately 15 percent of the world's output.[10]

War between the colonies and Britain both helped and hindered the iron industry. Wartime demands engendered large ordnance contracts from Confederation and state governments. However, some ironworks were destroyed in the war, while many others were crippled by manpower shortages. In 1785, visiting Swedish engineer Samuel Gustav Hermelin observed that many American furnaces were idle, facilities had been destroyed, and skilled labor had been either dispersed or killed. Lord Sheffield, a spokesman for British commercial interests, concurred with Hermelin, reporting that Britain would face no American competition whatsoever on a list of articles including copper sheets and utensils, bar steel, and "iron and steel manufacture of every kind."[11]

The postwar period was initially a time of great duress for the iron field. Ironworkers suffered the effects of harsh foreign competition and unfavorable economic conditions. In contrast with American iron's decline during the war, British ironworks thrived, increasing their efficiency and overall output by converting to coke and coal fuels, as well as steam power. The postwar influx of cheap, high quality British iron forced Americans to cut their prices and profits accordingly. Also, a postwar recession compounded by inflation and the lack of currency affected all business ventures in America. These conditions improved in the late 1780's, when new protective tariffs and a booming economy enabled ironworks to prosper.[12] And whether by coincidence or design, this was exactly when Revere chose to enter the field.

The Importance of Experience: Revere's Background and Learning Process

Despite the extremely different properties of silver and iron, Revere's silverworking knowledge enabled him to master the iron casting process rapidly. Revere's craft

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[10] Mulholland, *History of Metals in Colonial America,* pp. 104-109, Lewis, *Iron and Steel in America,* p. 22; Margaret H. Hazen and Robert M. Hazen, *Wealth Inexhaustible* (New York: Van Nostrand Reinhold, 1985), pp. 196-7.
[11] Mulholland, *A History of Metals in Colonial America,* p. 146.
[12] Ibid. pp. 145-8.

upbringing gave him a general understanding of metallurgy and the specific ability to melt silver uniformly in a furnace, prepare molds, cast silver into molds, verify the consistency and homogeneity of metal products, prepare alloys of different metals, and use heat and hammering to reshape metal objects. All he needed to do was replace his understanding of silver's properties – in particular, its melting point, malleability, and cooling rate – with an equal understanding of iron. Revere could also draw upon the casting work he performed for the Massachusetts government during the Revolutionary War when he helped Lewis Ansart build the Titicut forge in 1777. He also worked with Ansart on the casting and testing of four brass cannon. Although the records do not indicate whether Revere ever worked with iron at Titicut, he certainly received extensive practice operating a large furnace, preparing large molds, and designing and building a complete working facility.

Well-established ironworkers were clearly the most relevant information source for anyone trying to enter the field. Every detail from the moisture content of the sand molds to the type of clay used to line the furnace had some impact upon the final product. Although Revere drew upon a wider array of sources when entering bell and cannon casting fields, he focused upon communication with experts for this first casting venture.

Fortunately, ironworkers in America freely shared knowledge with each other. This may have been something of a shock for Revere, whose artisanal education and membership in the Freemasons emphasized the need to hide valuable trade mysteries and secrets. The artisan attitude descended from British traditions, which treated human skill and knowledge like tools and blueprints, valuable commodities to be hoarded for the future well being of the empire. The British ironmaking industry was equally secretive. Parliament passed a law in 1785 prohibiting the export of ironmaking tools as well as the "seducing" of workers in these industries. A detailed list of non-exportable items included "all forms of rolls, anvils hammers, molds, presses, or models or plans of such equipment."[13] These new restrictions continued earlier policies, such as a law of 1718 prohibiting the emigration of skilled artisans from Britain.

American ironworks for the most part presented a different picture, one in which owners "let neighbors and children stop by their smithies, forges, and furnaces to watch

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[13] Ibid. p. 148.

and learn." This open, community-based field encouraged information exchange and cross-fertilization from other fields.[14] Such fluidity had far reaching implications for Revere, who would not have succeeded as an ironworker without advice from current practitioners. Revere adopted a similar attitude in the years to come, although his letters also reveal an underlying patriotic sentiment: he viewed the discovery and dissemination of new procedures as a benefit to his country. This was illustrated in a letter he received from Stephen Rochefontaine in 1795:

> Mr. [name missing] a French Gentleman who will deliver you this, is charged by government to make use of a new method for casting iron guns ... will you be so kind to help him in doing it yourself or by providing him all the workmen and assistance in your power? I am so well acquainted with your fondness for scientific discoveries that I am persuaded that it is enough to point out the Gentleman who may be useful in enlarging the knowledge of this country to be certain that you will afford him all sort of assistance and meet him with a hearty welcome.[15]

Rochefontaine was a former French military engineer who emigrated to the United States during the French Revolution. He represented an invaluable stockpile of technical and military experience in the new republic, and served as an inspector of ordnance for the United States army. Although his degree of interaction with Revere is unknown, he represented a potential ally.

One must not exaggerate the quantity of information exchange in the young republic. Different firms certainly competed with each other and guarded their most important secrets, and Revere's patriotism would never convince him to jeopardize his profit margin. The theoretical background of patent law as well as personal and political rhetoric reveals the prevailing belief that technical and scientific advancement should simultaneously aid the individual as well as the nation: patents enabled inventors to profit from their ideas, but after a time the new invention entered the public domain for widespread use. More pragmatically, metalworkers in general and Revere in particular seldom suffered from excessive competition, while they often had to endure

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[14] Gordon, *American Iron,* p. 2. America's comparatively open technical exchange policy is also discussed in Merritt Roe Smith, "Eli Whitney and the American System of Manufacturing," in *Technology in America*, ed. by Carroll W. Pursell Jr. (Cambridge: MIT Press, 1981), pp. 57-59.

[15] June 22, 1795 letter from Stephen Rochefontaine, RFP Roll 1: Loose Manuscripts.

inexperienced labor, equipment breakdowns, and external threats such as cheap British imports. In America's industrial infancy, practitioners gained more by sharing, cooperating, and educating each other than they would lose.

Nicholas Brown was the closest Revere would ever come to having an ironworking mentor. Brown was a member of the Rhode Island Browns, an influential family of merchants and, to a lesser degree, manufacturers that included Moses Brown, the investor who financed Samuel Slater's textile mills. They built the Hope blast furnace on the Pawtuxet River in the 1760s and employed up to 75 men, although at least half of them were wood gatherers. They considered building a forge but restricted themselves to pig iron production and sold their output to a wide range of New England forges.[16] Revere often contacted Brown for advice, or included a question when arranging iron shipments from the Hope furnace. For example, in a November 3, 1788 letter, Revere asked Brown to send a copy of Richard Watson's *Chemical Essays* as soon as possible. These essays were published between 1781 and 1787 and written for people with minimal experience with chemistry.[17] Brown eventually helped him learn the bell making process as well.

Revere also talked to Dr. Benjamin Waterhouse, a physician who was the Harvard University professor of minerology and had contacts in Britain. Although the actual interactions between them have not been recorded, Dr. Waterhouse later commented that Revere was "the only man in America who appears to know anything of the discrimination between ores and the seven metals."[18] Revere started his own correspondence with one of these British experts in 1791, to prepare for his bellmaking career.

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[16] Edwin J. Perkins, *The Economy of Colonial America* (New York: Columbia University Press, 1980), p. 128.
[17] Paul Revere to Messrs. Brown and Benson, November 3, 1788, Volume 53.1 RFP; and Renee Lynn Ernay, "The Revere Furnace", (Master's Thesis, University of Delaware, 1989), p. 12.
[18] Margaret Green, *Paul Revere: The Man Behind the Legend*, pp. 172-3.

Revere's lucrative silvershop financed his foundry construction and startup costs. Some of the finances of the period pertaining to the foundry's inception (the mid and late 1780s) are obscured by vague record keeping practices: numerous withdrawals "To Cash" certainly account for some of the furnace's funding costs, although Revere also used this heading for personal cash withdrawals. His Hitchborn cousins also provided him with funds. Samuel Hitchborn, the Harvard-trained lawyer and gentleman, allowed Revere to use some of his Lynn street property for the foundry, possibly charging rent that may have been paid in the various "To Cash" withdrawals from the silvershop books. He eventually sold this land to Revere on June 28, 1792, commenting "I have this day executed a Deed of a certain piece of Land situate in Boston on which there is an air furnace to Paul Revere of said Boston Esq."[19] Samuel Hitchborn also paid for coal and carting on two occasions (totaling £9 2s 8p), and for iron on three occasions (totaling £37 4s) between November 10, 1787 and March 10, 1788. Revere always recorded the purpose of each payment, such as "By Cash from Sam'l Hichborn to pay Wm Little for Iron." In contrast, whenever Revere recorded a transaction with silversmith Benjamin Hitchborn, another cousin who might have served as Revere's apprentice years earlier, it simply read "By Cash from Benj. Hichborn Esq." Benjamin made nine cash payments to Revere throughout this same period for a total of £66 6s. Although the full relevance of these terminologies is unknown, it does imply that Samuel's payments were loans to the shop to help defray operating expenses, while Benjamin's cash payments might have been repayments of old debts (both Hitchborns made numerous large silver purchases throughout the late 1780s). Samuel and Benjamin might have served as silent partners as well. On a November 28, 1787 receipt, Revere instructed Benjamin to pay a carting expense and charge it to the furnace, implying some form of working partnership.[20]

Revere started listing furnace expenses in March of 1787. Some of these early charges include labor fees, raw materials, research trips, and miscellaneous costs. Since

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[19] Deed, June 28. 1792, Revere Family Papers. Please note that Revere's cousin refers to him as "Esquire."
[20] Ledger titled "1787 The Iron Furnace D. to Stock," Volume 9 Part 2, RFP; Boston Wastebook 1783-1797, Volume 2 RFP; November 28, 1787 note/receipt from Revere to Benjamin Hitchborn, RFP Roll 1: Loose Manuscripts.

his foundry was up and running by November of 1788, the startup period covers approximately 21 months. Major categories of startup costs are raw material purchases, labor, and research trips.

Revere's accounts contain numerous purchases of the different raw materials needed to construct a furnace. One ledger covers the expenses incurred from March 18, 1787 through March 20, 1788.[21] Revere purchased most of his construction supplies from local merchants, shopowners, and landowners whom he lists by name, in contrast to the wider array of distant merchants who provided raw materials once the furnace started operating. He bought sand, stones (up to 20 tons at a time), nails, clay, and wood, and also paid transportation charges for many of the larger shipments.[22] Revere billed a total of more than £102 to his furnace account, although this does not include purchases paid by the Hitchborns, which might add as much as £112 to the startup cost. Of course, Revere may have incurred additional expenses not recorded on this list, particularly if he purchased items for his silver shop or hardware store and then used them for the furnace. But in general he thought of his different business endeavors as independent entities, and recorded many sales between his shops in his account books. He was also very meticulous about the smallest expenses, often recording charges of one shilling or less.

In addition to raw material costs, another primary startup expense was wages for nine part time employees. The records do not always specify the tasks performed by each person, and it is often unclear whether Revere's workers spent their time constructing, repairing, modifying, or operating the furnace. A spurt of activity took place in April of 1787 in which three of the men whom Revere classifies as "labourers" performed all their work, and another in July when the majority of the brickwork took place under the supervision of Mr. Richmond, the highest paid employee, listed as a "brick maker." Revere paid for brick molds, labor, as well as four and a half weeks of Mr. Richmond's board (the only instance in which he paid board) in July of 1787. To aid the July construction spurt, Revere rented a windlass, a crank-operated machine used to lift heavy weights, as well as four different purchases of "Drink" costing slightly over a pound.

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[21] This ledger is a four-page section of Volume 9, Part 2 of the Revere Papers. The Volume is titled "Account Book, Boston, 1783-1804," and it contains many unrelated entries. This section is labeled "The Iron Furnace D. to Stock," referring to the list of expenses charged to his furnace account.
[22] Ledger titled "1787 The Iron Furnace D. to Stock," Volume 9 Part 2, RFP.

Revere's class views affect the way he referred to his workers. Some of his workers are listed as "Labourer Simmons" or "Joseph Brown, Labourer" while others receive a first and last name, such as Paul Reed. He uses "Mr." to address most merchants and property owners, while a select few, such as his Hitchborn cousins, are known as "Esquire."[23]

Revere made four furnace-related business trips between April 11, 1787 and March 20, 1788. Since his furnace had not yet begun operating, these trips were part of his initial research. His first trip to Menotomy (now Arlington, Massachusetts) almost certainly concerned the search for reliable raw material supplies, as he specified in several later records that he purchased sand from there. He traveled to Providence on July 28 to visit the Hope furnace and speak to Brown. The purpose of his third trip to Halifax on August 9 is unknown, and his fourth trip to Marblehead in March of 1788 involved the purchase of cannon since he included a bill for weighing cannon on the same day.[24] Marblehead was also the port used by Brown and Benson for their iron shipments.

By the time Revere was ready to start casting iron he had at his disposal a casting oven that could and would serve a variety of purposes. In the short term he would use it to produce large utilitarian iron objects for local households and metalworking shops, as he initially intended. But the effort he devoted to learning and constructing the foundry would save him a great deal of time when he branched into other operations years later.

Running the Iron Foundry

Revere's library research, rewarding visits to forges and ironworks, Revolutionary War and silverworking expertise, and innate mechanical aptitude compensated for his lack of a formal metallurgical education. Casting became a permanent component of Revere's industrial processes, and he used his furnace for many applications for years to come. The following analysis explores five primary aspects of Revere's iron operations: equipment and production techniques, raw material usage and environmental impacts,

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[23] Ledger titled "1787 The Iron Furnace D. to Stock," Volume 9 Part 2, RFP.
[24] Ibid.

labor policies, managerial techniques, and his product line and income. This analysis is limited by gaps in his records: Revere made one list of expenses from 1787 to 1788, and the next ledger details his sales and expenses from 1792 to 1794.[25]

Equipment and Production Methods

Revere never explicitly described his actual ironworking procedures, but his techniques can be inferred from common contemporary practices alluded to in his correspondence. The most important item in Revere's foundry was the large oven (which he confusingly called a furnace) used to melt the pig iron.[26] This oven included a large central hearth, lined with bricks and clay, and was heated with charcoal that was probably fanned by a hand or foot powered bellows.[27] The size of this furnace is unknown, but if it was the same furnace he used to prepare a sample copper sheet for Benjamin Stoddert in 1800, it would be capable (according to Revere's estimate) of holding and refining 1,800 pounds of copper at a time. Revere eventually cast several bells in this foundry that weighed over 2,000 pounds.

The interior of the furnace had to reach the melting point of pig iron, around 1150 degrees Celsius. A small tap at the bottom of the furnace allowed the founder to draw small amounts of molten pig iron out, and a spigot or canal enabled him to direct the iron flow into different molds or receptacles prepared in advance. In some cases he used a ladle to pour small amounts of iron into the mold. These molds had to be prepared from a special mixture of sand or clay, usually pressed tightly in a two-part wooden frame that could be opened or closed.[28] After the item cooled it could be touched up with a file,

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[25] The furnace records are far from complete: one ledger covers expenses incurred until 1788, and the next available records detail his ongoing production after August of 1792.

[26] Technically, what Revere called a "furnass" should be called a foundry, although many contemporaries used "furnace" and "forge" interchangeably to describe any large heating oven. More common usage throughout the 18th century referred to blast furnaces as "furnaces," and foundries as "air furnaces."

[27] Many bellows were water powered, but this would not be an option in downtown Boston. Steam powered bellows were not used in America until almost the mid-19th century.

[28] The founder prepared the mold by pressing a wooden model of the desired iron object into the sand, forming an exact indentation. The founder carefully opened the mold (hopefully the packed sand would retain the shape of the model), removed the model, re-sealed the mold, and poured iron into it. Robert B. Gordon, *American Iron, 1607-1900*, p. 195.

although skilled founders could prepare incredibly detailed and elegant items directly from the casting.

When casting larger objects that did not require as much detail, the founder prepared a pit of sand on the ground and pressed a model into the sand to create an indentation that would receive the molten iron. The finished item would be detailed on the face in contact with the molded sand and flat on the top. This casting process was used for the casting of stove backs, iron plates placed in the back of fireplaces or hearths to reflect heat into the room and protect the brickwork of the chimney. The stove back usually had a design on the surface facing the room, and could be rough on the surface facing the bricks.[29]

Many problems could ruin a casting. If dissolved gases were not allowed to escape as the iron cooled, the bubbles remained in the iron and made the metal porous. Iron shrank as it cooled, so the mold had to be larger than the final object. However, the cooling rate was uneven, fastest where the metal came in contact with the colder mold, and a cavity could form in the center of the object. Slag, graphite flakes, or dirt contained in the iron or gathering in cracks in the mold also entered the iron and weakened it.[30]

Many of Revere's expenses concerned ongoing improvements to his furnace operations, an understandable activity considering his ever-expanding production and product line. For example, purchases of lumber, nails, and carpentry work on September 1, 1792 probably involved cosmetic changes to his building. He also bought a new bellows on August 14, 1793 and invested in new patterns that would allow him to expand his range of products. Revere recorded one expense for "Altering patterns," several fees for the transport of patterns, one for "pewter for patterns," one mention of "iron plate & hooks for mould," and five purchases of "patterns for stoves and bells" between 1792 and 1794.[31] And he continued making trips, to Hanover, Norton, Providence, and possibly Watertown as well. The purpose of these trips is not listed, but the Providence trip certainly involved a visit to the Hope furnace. Revere's eleven purchases of sand were used for the making of molds, but might have met other needs as well. Similarly, two

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[29] Ibid.
[30] Ibid.
[31] Some of these patterns might have been intended for bells.

purchases of clay could have been used for construction or repairs to the furnace or for making clay models to be used in casting.[32]

The casting process lent itself to standardization, in its rarely achieved ideal form. If a founder obtained high quality and durable models, he could produce virtually identical sand molds, and meticulous attention to the heating and pouring of the metal would minimize or prevent the different casting errors. The final ingredient of standardized output, consistent raw material inputs, was the hardest to control, considering the state of blast furnace technology and frequent iron shortages.

Raw Materials and Environmental Impacts

Revere purchased coal, limestone, and clay for his furnace, but the lion's share of his raw material efforts and expenses centered upon iron. In a pattern that would be duplicated when he shifted to copperworking, Revere and his purchasing agents cast a wide net in search of cast, bar, and "old" recycled iron, often making purchases in Rhode Island and New Jersey as well as Massachusetts. The different types of iron met different needs. Pig iron directly fed the furnace, and was the optimal purchase for Revere, although other blast furnaces often ran out of stock. Bar iron was more expensive because it had been refined at a finery. It was stronger and tougher, suitable for a wide variety of tools and common household products. The fact that Revere purchased bar iron implies that he performed or subcontracted blacksmith operations in addition to his casting. Old iron was the term for a variety of recycled iron goods Revere purchased from merchants or accepted from customers as a credit. This was the least desirable type of iron, because its quality and purity were unknown, and usually poor. Revere spent a total of £53 17s 1p on iron between November 28, 1788 and March 10, 1788, and frequently relied on Samuel Hitchborn to make these payments. He purchased a much larger quantity and variety of raw materials between 1792 and 1794 than in his early years, including £32

[32] Ledger titled "1787 The Iron Furnace D. to Stock," 1792-1794 furnace records, Volume 9 Part 2, RFP.

spent on coal, 11 shillings for arsenic, £36 12s for copper, £29 on tin, and an unknown amount on iron that probably exceeded £50.[33]

With the exception of silverworking, all of Revere's endeavors repeatedly had to slow or stop their operations because of raw material shortages. A lengthy correspondence record illustrates Revere's endless quest for iron. He started the search over a year before announcing his foundry's operation. J. Blagge, his purchasing agent, quoted pig iron prices at the Alsion and Batson furnaces (£10 and £9 10s per ton, respectively) in November of 1787, but reported that both furnaces had ended their yearly production and would restart in the spring. Brown and Benson wrote Revere in April of 1788, offering six tons of pig iron at $28 per ton, although they had trouble shipping it to Boston and asked if Revere could pick it up in Marblehead.[34] Revere tried his best to procure a regular supply in the November 3, 1788 letter to Brown and Benson:

> Mr. John Brown when in Boston informed me your Furnace was to go soon. I should be glad that you would ship as soon as possible ten tons of Pigs ... We are desirous to have a constant & regular supply of Piggs from your furnace, & in order to do it we think there cannot be a more effectual way than by interesting you, or some of your gentlemen owners of the Hope furnace, in our furnace, for that end we are willing to sell either one quarter or one third of it...[35]

Revere would not offer to relinquish a third of his newly finished furnace for anything less than a critical component of his operations. The Hope furnace produced fairly consistent, high quality output. Had this offer been accepted his iron supply would be permanently secured, but it was not. Revere wrote another letter to Brown and Benson in September of 1789, repeating many of the details and more formally requesting up to 100 tons of pig iron a year, a staggering quantity of metal in a time when most blast furnaces output seven or fewer tons a week.[36]

Revere had an interesting early transaction with the Massachusetts government in 1789. He received 14 cannon from Massachusetts in Marblehead valued at over £314.

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[33] Ibid., and March 8, 1788 receipt from Mr. Little, RFP Roll 1: Loose Manuscripts. The iron ambiguity is caused by charges to merchants that do not explain the product.
[34] November 1, 1787 letter from J. Blagge; April 11, 1788 letter from Brown and Benson, RFP Roll 1: Loose Manuscripts.
[35] November 3, 1788 letter to Messrs. Brown and Benson, RFP Volume 53.1.
[36] September 3, 1789 letter to Messrs. Brown and Benson, RFP Volume 53.1.

The receipt for these cannon does not list their weights, their composition, or the date of this transaction. He transferred five of these cannon to Bridgewater on April 17, 1789, and moved the remaining nine cannon to Boston on March 6.[37] Since he would not have had any interest in such an enormous quantity of brass, it is reasonable to assume that these were damaged or obsolete iron cannon he could melt down and reuse. This was hardly a reliable metal supply, but he would greatly benefit from this early windfall. He would have frequent contact with state and federal government officials five years later, but apparently he was sufficiently connected to the government network at this earlier point to enable him to identify metal supplies. These cannon, like the large iron shipments from furnaces, enabled Revere to maintain a steady production run with a good degree of confidence in his raw material quality.

Revere repeatedly altered his operations to optimize his use of raw materials. But this is only half of the interaction between his foundry and the natural environment. Like all manufacturing operations, the foundry impacted its natural environment in numerous, complex ways largely involving raw materials and pollutants that entered and exited the premises. The "regular supply" of pig iron from Brown and Benson and other suppliers, as well as charcoal, stone, sand, and wood purchases all affected the local ecosystems and landscapes from which they were taken. And Revere affected his immediate environment in at least one documented way, by producing a large plume of smoke from his burning charcoal. J. Callendar's 1788 copper plate engraving of Boston specifically includes (and almost highlights) a plume of smoke emanating from Revere's foundry.[38] In a very real sense he was changing the Boston landscape.

Even though the foundry's raw material usage can be estimated from Revere's records, these figures cannot be associated with any specific environmental consequence. Revere's foundry was only one of thousands of manufacturing operations in the Boston area. And the combination of all of these impacts, while significant and measurable, was only one of several competing uses of New England's then-abundant natural resources, particularly the forests that were shrinking with each year as a result of fuel use and

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[37] March 6, 1789 receipts from Thomas Losrick (sp?) and Peter Green, and April 17, 1789 receipt from Thomas Good, RFP Roll 1: Loose Manuscripts.

[38] Goss, E.H. *The Life of Colonel Paul Revere*, (Boston, Joseph G. Cupples, 1891), p. 534.

agricultural land clearing. Revere contributed to deforestation, air pollution, and the depletion of local and distant ore supplies, but his direct impact upon the environment cannot be quantified.

Direct impacts are not the whole story. Even though Revere did not work with large quantities of iron ore, his continual orders of pig iron and the orders of other founders like himself provided a reliable local market for blast furnace owners. Local markets were preferable to regional or overseas shipping because of low local transportation costs, the unreliability and delays of overseas shipping, and competition from British furnaces in distant markets. Revere's presence in the network of blast furnaces, foundries, fineries, blacksmiths, and other local metalworkers enabled the entire community to supply the needs of the growing American market more efficiently.

Of all the colonial uses of wood, blast furnaces were the most damaging to the environment. Blast furnaces used about an acre of old growth wood or a larger amount of sub-optimal secondary growth wood each day to make charcoal. If the ironworks included a finery, the total wood usage doubled. Since owners could not relocate furnaces when local wood supplies thinned, the removal of wood was often widespread and absolute.[39]

Despite the seemingly wasteful wood practices and attitudes of blast furnace operators, evidence indicates that they recognized some of the perils of deforestation to the extent that they affected operations. Most operators attempted to procure 20,000 acres (31.25 square miles) of timber per furnace, assuming that 1,000 acres would be used each year. This would allow every harvested portion of the forest to regrow for 20 years before it was needed again. Erosion and other problems occasionally prevented the second growth from appearing, and if it did appear it often contained smaller amounts of poorer quality wood. Some ironworks instituted rudimentary forest management policies. Notations in a small number of ironwork ledgers indicate that some owners paid to fence, protect, and transplant ``sprouts,'' or new saplings that started to re-grow

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[39] Charles F. Carroll, *The Timber Economy of Puritan New England*, (Providence: Brown University Press, 1973) p. 10. Theodore Wertime, *The Coming of the Age of Steel* (Leiden: E.J. Brill, 1961) p. 110; and Paul F. Paskoff, *Industrial Evolution: Organization, Structure, and Growth of the Pennsylvania Iron Industry* (Maryland: Johns Hopkins Press, 1983), p. 21.

from an area that was previously cut down. This is not surprising: if a blast furnace ran out of wood, it ran out of business.[40]

Although he did not operate a blast furnace, Revere's general impact upon the environment was to expand the growth of the metalworking community and increase its use of natural resources. But how did environmental limitations affect him? Raw material scarcity played a much greater role in his foundry activities than in his silverworking trade. As a silversmith, he purchased silver from overseas merchants or local customers, and used small amounts of wood, charcoal, and other materials. His production depended more upon the affluence of the local population than upon the availability of materials. The opposite circumstances applied to ironworking. Revere never alluded to any problems obtaining sufficient fuel for his operations (although fuel prices rose steadily), but iron shortages proved a continual impediment. Seasonal patterns of iron production forced Revere to stop his production during the winter months, and he constantly asked merchants and purchasing agents to locate new sources. He often resorted to purchases of "old iron," which he would melt down and reuse in spite of its questionable quality. Customers and large clients paid some of their bills in old metal, a practice that expanded dramatically when Revere shifted to copperworking.

The switch from silver to iron brought Revere into contact with a very different set of customers, suppliers, and raw materials. While a silversmith dealt with merchants, other silversmiths, and upper-class clients, a foundryman dealt with blast furnace operators, colliers, other metalworkers, and anyone who needed iron goods. The price of silver depended upon a host of tariff, mercantile, and political factors, while the price of iron and charcoal primarily depended upon their local abundance. In an attempt to find a lucrative field of work, Revere studied different metallurgical sciences and investigated the quantity and quality of different ores in his vicinity while continuing to operate his forge. Throughout this period, Revere increasingly acted in a capitalist-industrialist manner, treating the environment as a commodity and limitation. This trend accelerated when he operated a small mill complex in Canton years later.

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[40] John R. Stilgoe, *Common Landscape of America* (New Haven: Yale University Press, 1982), p. 293; Joseph E. Walker, *Hopewell Village* (Philadelphia: University of Pennsylvania Press, 1966), pp. 121, 136.

Labor

Revere increased his departure from the artisan apprentice tradition by employing between six and ten full time wage laborers, paid according to the number of days they worked, although he occasionally continued his earlier practice of paying board in addition to wages. Incomplete records obscure the exact number of employees Revere had at any one time and the tasks performed by each worker: in addition to furnace operators, he hired people to build and repair equipment on the facility, carry materials, or perform related activities such as blacksmith work.

As part of the transition from artisan to industrial managerial practices, Revere gradually evolved new methods of tracking his employees' wages and hours. Three different record keeping methods apply to employee labor. The expense ledger includes numerous cash payments to employees along with occasional memoranda about their rates of pay or days worked. This is supplemented with assorted receipts that by this point were organized in a receipt book, and not merely thrown together with other loose papers. These receipts contained more detail than the ledger, including pay rates, number of days worked, occasional descriptions about the type of work, and tallies of the total pay owed to the employee before and after each salary payment. The third employee record is a one-page labor list describing each laborer's comings and goings.

The ledger is the most complete and fundamental of the records, although it is almost certainly incomplete. Solomon Oliver was by far Revere's most frequently paid employee, with 29 entries in Revere's ledger. Revere paid him nearly every week between May and October of 1793, implying that he might have worked as a caster when the furnace was operating. Oliver's salary started at 3 shillings a day, and increased to 4 shillings a day on September 1, 1793. Other employees listed in the ledger include John Freelove, Henry "a black man", Stanley Carter, Nelson Miller, Whitney, William Story, and Cap. White.[41] Revere paid most of his employees at the end of each working season, indicating that, like most early manufacturers, he served as a form of bank during the interim. On September 13, 1792, he paid Miller, Story, and Stanley Carter for eight to sixteen days of "air furnace work." Story and Carter earned five shillings a day each. All

[41] Ledger titled "1787 The Iron Furnace D. to Stock," 1792-1794 furnace records, Volume 9 Part 2, RFP.

three of these men chose to receive £1, and let Revere hold the remainder of their earnings. Miller eventually received 95 days pay (for "work at times since May") on December 2, of 1793.[42] Zebulon White's receipts (possibly the same person as the "Cap. White" listed in the ledger) were more complicated. On November 14, 1793 Revere paid him for two types of work: "77 days work at the furnace for my self" at a rate of six shillings and eight pence per day; and "95 days work at [furnace] for John Freelove" at five shillings per day.[43] The former charge is the highest rate paid to any of Revere's employees, probably indicating that White was the most skilled laborer. The second memorandum implies a relationship between White and Freelove, in which White received or managed Freelove's wages.

Although Revere's employment patterns approached a regular work schedule, the expectations of late 18th century skilled laborers required many concessions. His records include one extremely dense page of attendance and absentee information in paragraph form:

> Mr Miller came Thursday the 23 at night. Mr White & Mr Story came Saturday the 25 at night. Freelove came Monday night 27.
> Capt White Mr Miller Mr Story went home Saturday mor'g June 15. Mr Miller came back Tuesday 18 at night Capt White & Mr. Story came back Saturday 22d @ night. Mr Carter came Friday morning 28, went home 29 @ night – Capt White & Mr Story went home Saturd 29 at night...[44]

Unlike the careful spreadsheet-like lists of expenses or cash receipts, Revere used a free narrative for this first attempt to track employee attendance. The attendance page describes the work habits of Captain White, Mr. Story, Mr. Miller, Mr. Carter, Stephen Metcalf, Mathew Metcalf, and Freelove, who is listed without any title.[45] The workers started and stopped working at seemingly random dates and times, occasionally beginning at night or on a Saturday, and ending in the morning or on a weekday. Revere also charged seven rum payments (two of them for "6 days"), two beer payments, and

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[42] September 13, 1792 and December 2, 1793 receipts from Nelson Miller; September 13, 1792 receipt to William Story, and September 13, 1792 receipt to Stanley Caster; RFP Roll 1: Loose Manuscripts.
[43] November 14, 1793 receipt from Zebulon White, RFP Roll 1: Loose Manuscripts.
[44] 1793 Memoranda Book entry dated May 23, Volume 51.11 RFP.
[45] According to Revere scholar Deborah Federhen, Mathew Metcalf might have been one of Revere's prewar silvershop apprentices or journeymen. Federhen, "From Artisan to Entrepreneur," p. 73.

one payment for "Liquor – 7 days" to his furnace expenses. This notation implies some form of steady liquor allowance for his workers, a common procedure in early craft and manufacturing shops whose skilled workers expected certain privileges in exchange for their services.[46]

Rough labor estimates and general attendance patterns are definitely visible. Of the seven recurring laborers, Miller, White, and Freelove worked the most, approximately 70 to 75 days out of the 146-day period between May 23 and October 15. Story worked approximately 48 days, and Carter and the Metcalfs worked between 20 and 25 days. When the furnace was operating, Revere employed between one and five workers, usually three or more. The furnace operated in three to five week shifts, which were always followed by at least a week of rest. This is reminiscent of the work habits of a blast furnace, despite the fact that Revere's operation was not limited by waterpower shortages and would not benefit from extended periods of activity. The overall employment picture combines elements of discipline and freedom: for the most part the employees all arrived at the beginning of one of these work periods and all left at the end, but they definitely had some freedom to alter their schedule. At least one worker (Freelove) took occasional days off to go fishing, and all the workers adjusted their arrival and departure times by a few days whenever the furnace started or stopped.[47]

New Managerial Techniques

Revere learned many of his new marketing, managerial, and accounting skills from his mercantile experience. Starting in 1783, his "workshop" functioned as an all-purpose hardware and general goods store. His workshop sales included metal items such as brass candlesticks, kettles, saws, files, window weights, hinges, iron nails, locks, and buckles, as well as items that would be used in a metalworking shop, such as bellows, melting pots, and "moulding sand." Although he probably did not make many of these items at first, the retail business placed him in contact with merchants, local blacksmiths and coppersmiths knowledgeable in their arts, and the local clientele. Indeed, his

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[46] Ledger titled "1787 The Iron Furnace D. to Stock," 1792-1794 furnace records, Volume 9 Part 2, RFP.
[47] 1793 Memoranda Book entry dated May 23, Volume 51.11 RFP.

transactions with local producers were lengthy and complex, involving a two-way exchange of goods, services, cash, and debt. As a result, he gained an intimate awareness of the local demand for different items, the range of available products, typical wholesale and retail prices, and the practices of the metalworking community. This experience also allowed him to inspect the construction details of different items and chat with their makers, which must have helped him learn the technical processes as well. He also knew about metalworking tools, and where to buy them.

The foundry represented another step in Revere's progression from informal barter and credit exchanges to monetary accounting. His silvershop began as an 18th-century craft operation, and like most American businesses in this period it started to adopt advanced capitalist aspects reflecting the expansion of the market economy. Revere's workshop and early foundry operations involved an even greater reliance upon cash, wage labor, and written contractual agreements. He started writing receipts for many services, and these receipts invariably included the monetary value of all services rendered. Also, he changed his accounting and record keeping technique upon opening his furnace. His early silvershop and workshop records are far more confusing than the surviving furnace records. In the silver shop records, for example, credit and debit accounts were freely commingled. Expenses and sales often followed each other on the same list, only sorted out when Revere transferred the entries into separate ledgers.[48] He listed many withdrawals only as "to cash," although he frequently provided more information in later years. With the beginning of the furnace, Revere clearly separated his expenses from his sales and income via a double entry bookkeeping system.

Product Line and Profits

Revere's sales information is extremely hard to tabulate with any certainty. The approximate lower estimate of cash he received for the 1793 furnace run is slightly over

[48] Revere's wastebooks were lists of all transactions that took place, arranged chronologically. His ledgers were account books sorted by client. Periodically, he transcribed the entries from wastebooks into the proper section of the ledger, allowing him to determine how much each client owed.

£393. If all of the 1793 expenses are tallied, the result is slightly over £311, yielding Revere an £82 profit for the year.[49]

His furnace records illustrate the seasonal nature of his production and sales. The working year began with slow sales in March, which increased by the end of April. The high production season extended from May through September. Business dropped off in October, November was extremely slow, and operations ceased until the following spring. Incomplete customer cash payment records reveal a lag of several months (averaging around 60 days) between product sale and payment. Customers started paying their bills in June and July, the cash inflow picked up in August, and the largest number of payments arrived in September and October.[50] This cycle reveals the close ties between Revere and different constituencies. His production cycle relates to that of a blast furnace, which would cease operations in winter when the river froze and in summer when the river ran low. And the payment cycle coincides with a typical harvest season, since most farmers would sell their crops at some point in the fall and use the proceeds to pay their debts and make purchases for the next season.

Revere's records up to 1788 reveal that he sold pig iron window weights, grates, fire backs, and stoves during the early period of his furnace operation. By 1792-1794, he produced a fairly wide range of products. The five most common items recorded in sales were iron boxes, chimney backs, stoves, "coggs," and window and sash weights. All of these items were pig iron, although it is possible that the cogs were made from bar iron. The records contain various descriptions of stoves and related stove products, including Franklin stoves, large and small stoves, ovens, frames for ovens, stove backs, and "dogs," which probably referred to andirons.[51] Not surprisingly, these most commonly produced items were highly standardized, involving simple molds that could quickly be pressed into casting sand.

Revere's other furnace sales represented less popular items, often intended for highly specific uses. Some items, such as pig iron bars, blocks, and plates, appear to be

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[49] This comparison of costs and expenses might not be fair: his cash receipts end prematurely on November 12 of 1793, and his post-November 25 cash expenses include close to £100 of copper, tin, iron, coal, and one unlisted purchase, clearly not used in the 1793 production.

[50] Ledger titled "1787 The Iron Furnace D. to Stock," 1792-1794 furnace records, Volume 9 Part 2, RFP.

[51] This entire section is derived from an analysis of Revere's untitled 1792-1794 wastebook, contained in Volume 9 Part 2, RFP.

resold raw materials. Revere may have melted pigs into smaller and more usable shapes for resale, or may have once again acted as a merchant, buying from the blast furnaces and selling for a profit. Other sales, such as forge hammers, anvils, iron or friction wheels, cabooses, swages, press plates, iron molds, gudgeons, and furnace covers, illustrate that Revere was still supplied the rest of the Boston metalworking community. In preparing these items, Revere learned more about the tools of the trade.

Beyond Iron

By the time Revere added bellmaking to his technical repertoire his foundry operations had become fairly routine. This was a major accomplishment.

Revere's quick iron casting success resulted from innate technical aptitude, thorough research, and the casting experience he gained from silverworking. Learning to cast high quality items was only the first step. The foundry oven had some characteristics of both tools and machines: it required skilled labor and could use different inputs to produce different products, but the basic casting process remained the same. Revere's job during his iron casting career was to teach himself and his employees to use the foundry oven in a machinelike way, optimizing its use until they produced standardized output. He succeeded at this goal, as far as the technical challenges were concerned.

Revere could not control the managerial aspects of standardized output at this time, nor could anyone. The iron network, while strong, had a long way to go before iron production took place with any regularity. Pig iron quality was fairly consistent by this point but the quantity was not, forcing him to turn to undependable old iron. And even if he had arranged a reliable iron supply, his laborers still expected to be treated as craftsmen, with control over their work schedules.

These complications did not particularly concern Revere because standardization did not yet exist in the technical vocabulary. His version of standardization would enable his shop to produce more objects cheaper and faster, without requiring his own labor. In this sense he succeeded. For his next endeavor, standardization was not even a possibility.

Becoming a Bellmaker: An Art and a Science

Revere needed an excuse to begin his bellmaking career. In 1792 he volunteered to learn the trade to cast a replacement bell for his parish, the Second Church in Boston, after their old bell cracked. Although his church's need might possibly have inspired him to begin the next phase of his career ahead of schedule, in fact he had been researching the field at least informally for several years. Despite the complexities of bellmaking and the lack of a supporting network such as the ironworking community, Revere's broad range of skills prepared him quite well for this new task. Most important of all, he did not need to modify his furnace for this new trade.

History of an Art: Bellmaking

Although bells were made for many different purposes, the church bell played the largest role in early American society. Bells were often used to wake members of the parish, summon them to church services, and announce the death of a community member. They also served as important instruments of general communication, used for fire alarms or to proclaim momentous news. In some cases, bell ropes were left hanging outside of churches to allow any community member to ring them in emergencies.[52]

Bellmaking is often described as both an art and a science, partly because minor variations in every aspect of the bellmaking process enable workers to produce a nearly infinite range of final products. The quality of a bell's sound primarily depends on factors such as the type, quality, and proportion of metals and the shape and size of the mold. Bellmaking required an understanding of geometry and general mathematics, to enable the bellmaker to scale a general pattern to different sizes without altering the acoustical properties. In fact, bells could be pitched in different musical keys, based upon their size and dimensions.[53] Revere would embrace the many intricacies of bellmaking, recording different drawings and recipes in his drive to unravel the optimal process.

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[52] Edward and Evelyn Stickney, *The Bells of Paul Revere* (Bedford: n.p., 1976), p. 4.
[53] Henry J. Kauffman, *American Copper and Brass*, (Camden: T. Nelson Publishers, 1968), p. 170.

Different metals were used to make bells in Revere's time. With the exception of a small number of iron bells, most bells were made from copper alloys. Copper readily combines with tin or zinc to form bronze or brass, respectively, although the proportions of different metals, heating times, and temperatures used to make these alloys varied. Contemporary descriptions of the casting process were purposely vague, either to guard trade secrets or acknowledge the wide range of practices and preferences.[54] Although modern experts define bell metal as a variant of bronze consisting of 75% copper and 25% tin, many bell makers experimented with small additions of other metals to improve the bell's sound, with silver a common choice. A study of fragments of a Revere bell shattered by lightning illustrate that he followed the prevailing wisdom concerning bell composition: his bell was approximately 77% copper and 21% tin, with small amounts of lead, arsenic, zinc, nickel, and silicon, and a trace of silver. The lesser ingredients were probably the result of impurities in the copper, although the silver might have been intentional.[55]

Bell metal and gun metal (which is 90% copper and 10% tin) were also considered interchangeable, which is why innumerable invading armies appropriated the church bells of conquered cities for the construction of new cannon. Founders such as Revere often used old bells and cannon as raw materials. Bell casting certainly prepared him well for his later cannon endeavors, and he could purchase raw materials for both processes at the same time.

Bronze alloys had many intrinsic advantages that made them the preferred metal for casting the largest bells and cannon. Bronze is a very tough metal, able to withstand the shocks and impacts cannon and bells would receive throughout their lives. It also melts at a relatively low temperature, which allowed the caster to insure that it melted in a uniform manner, not hardening until all the metal had time to fill the mold. It is fairly soft, especially in comparison to iron, which makes it much easier to bore. This is related to its elasticity, which allowed the bell's vibrations to last a long time and propagate over

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[54] One definition stated that "Bell-metal is a composition of tin and copper in due proportion; which has the property, that it is more sonorous than any of its ingredients taken apart." *A Supplement to Chambers' Cyclopedia or Universal Dictionary of Arts and Sciences*, London 1753, quoted in Henry J. Kauffman, *American Copper and Brass*, p. 169.

[55] Ibid. p. 169; Edward and Evelyn Stickney, *The Bells of Paul Revere*, p. 7.

great distances. Finally, bronze resists corrosion and is lighter than iron-made goods, essential qualities for items exposed to the elements or carried into battle.[56]

The bellmaking process involved many steps. Bell makers first created an inner "core" that modeled the inside diameter of the bell. They accomplished this by digging a hole in the ground, building a hollow pile of bricks in the center, covering them in a special mud, and using a pattern to pack the mud into the shape of the interior of the bell. Second, they applied a mixture of tallow and wax to the outside of the core, creating a perfect wax model of the bell. Workmen added any lettering or designs to the wax at this point, until it exactly resembled the desired final product. Third, workers applied numerous thick coatings of "bell mud" on top of the wax, creating the "shell," which was a model of the outer surface of the bell. When the shell hardened, a workman lit a fire inside the hollow brick structure at the center of the core, which melted the wax and allowed it to drain off, hardening the core in the process. At this point the core and the shell represented the inner and outer surfaces of the bell, and they were separated only by air. The shell was then hardened with additional fire, and covered in sand or loose soil to prevent it from bursting. Finally, molten metal was poured into the space between the core and the shell. After it cooled, the bell was removed and workmen trimmed any casting irregularities. Holes, pockets of air, or cracks in the core or shell could ruin the bell at any stage of this process.[57]

Although Revere and his workers grew more proficient with practice, the bellmaking procedure clearly did not lend itself to standardization. Each bell required its own mold that would be destroyed in the casting process, and every step of the mold-forming and casting process needed careful attention and adjustment. Even though this technical process favored the use of skilled craftsmen, Revere continued his departure from his artisan roots by adopting new pricing and warrantee policies, as will be discussed later.

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[56] Margaret and Robert Hazen, *Wealth Inexhaustible*, p. 92.
[57] Kauffman, *American Copper and Brass*, pp. 171-2.

Several secondary sources imply that Revere learned many of the details of bell casting from Aaron Hobart of Arlington, Massachusetts, one of the few American bell founders operating in the early 1790s.[58] Upon receiving the contract to cast a new bell for his church, Revere certainly would have attempted to contact anyone who could offer any pertinent advice, especially someone in a nearby community. However, Revere's bellmaking preparations predate his 1792 contract.

Once again, Revere's prior experience was directly relevant. The iron foundry work that occupied his time since 1788 would be extremely similar to this new task. Armed with his iron casting knowledge, he would need to learn how bronze differed from iron throughout the heating and cooling process; practice the casting of larger objects, acquire some bell molds, and experiment with acoustics. He even had a head start, because his silverworking career would have taught him much about the casting of copper alloys. Copper and silver have some elements in common, while iron is fundamentally different. For example, iron hardens when it cools quickly, and copper and silver soften. An additional problem with casting copper is the fact that copper takes on oxygen when it is melted, making it viscous and hard to mold. Founders often overcame this difficulty by adding lead to the melt.[59]

Revere had first investigated the possibility of casting bells, at least briefly, several years earlier. Nicholas Brown wrote to him in October of 1789, responding to an earlier letter in which Revere asked many questions about bellmaking. Brown had witnessed the bell casting process at his furnace, although he was not an expert in the process. Revere asked about the cost and proper proportion of metals in a recently cast bell and Brown responded that it cost over £60 and consisted of 60 pounds of copper and 35 pounds of block tin, somewhat of a deviation from current and 18th century metal proportions. This letter makes repeated mention of Brown's papers on the subject of

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[58] Arthur H. Nichols, *The Bells of Paul and Joseph W. Revere,* (Boston: Newcomb & Gauss Press, 1911) p. 1. The first bell cast in America was also the most famous, the Liberty Bell cast by Philadelphia's Pass & Stowe foundry in the 1750s. The number of early bellmakers, while undoubtedly small, is hidden by the fact that several foundries (such as Revere and Son) probably cast a small number of bells in addition to their normal activities.

[59] Mulholland, *A History of Metals in Colonial America*, p 93.

bellmaking, such as "I set to overhauling the file of papers about recasting our meeting bell," and "I found authors differed about the loss & proportion of metal," providing another illustration of the research that all metalworkers commonly performed and the importance of any source of expertise.[60] Even without Revere's original letter to Brown, it seems clear that he had been toying with the idea of bellmaking since 1789. Bellmaking might even have been a motivation for building the foundry.

In late 1791, Revere's interest in metallurgy took on a heightened and more scientific intensity. He began a correspondence with Doctor Lettsom (which he misspelled "Lestrom"), a London scholar. Revere's questions to Dr. Lettsom illustrate his advanced knowledge on many aspects of metallurgy, and his practical and abstract curiosity concerning related topics. Before writing Dr. Lettsom, Revere tested a sample of tin from a recently discovered Massachusetts source. Because the sample was "1/32" heavier than his sample of Cornwall block tin, Revere theorized that his ore sample was not "divested of the crude minerals which it is commonly mixed with," possibly implying that it was what the miners call stream tin. He requested Dr. Lettsom's opinion, as well as samples of "shade, stream, and mine tin" from Cornwall or Devon "in their crude state." Revere sent Dr. Lettsom some samples of minerals found in the area and promised to continue doing this every spring and fall "for I am realy selfish in the cause, for I doubt my abilities in chemistree, and am sensible that I shall git a true estimate of all that I shall send you." Dr. Lettsom responded in August of 1792, and sent Revere the tin ores he requested. He also identified Revere's samples and mused about the establishment of a minerology school at Harvard. In March of 1793, Dr. Lettsom responded to a new letter and identified a new batch of minerals sent to him.[61] This research might have been too abstract to be directly relevant to Revere – after all, he needed to cast the copper and tin, and not learn to identify different ores. It does undeniably illustrate his interest in the field, and increased his overall understanding of metallurgical processes.

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[60] December 7, 1789 letter from Nicholas Brown, RFP Roll 1: Loose Manuscripts.
[61] Dec. 3, 1791 letter to Dr. Lestrom (sic), August 20, 1792 letter from Dr. Lettsom, and March 29, 1793 letter from Dr. Lettsom, RFP Volume 53.1.

Revere's furnace records also provide evidence of his research. An undated page in his 1793 Memoranda book contains a recipe for "The mud for thickness of Bell one part horse dung one Sand & one part Clay For Navel & Cope 6 parts horse dung 4 Sand & 4 Clay & some Cow Horn." The acquisition of molds and patterns was his highest priority and is reflected in several fees for "core moulds," "patterns of crown of 3 small bell," and "patterns of crown of large bell." He also purchased sand and clay and other patterns that might have applied to either iron casting or bellmaking.[62]

Operations and Feedback

Revere made three types of bells. Church bells were by far the largest and most complicated, weighing more than 500 pounds. Schoolhouse bells weighed between 100 and 500 pounds (but usually under 300 pounds) and ship bells weighed less than 100 pounds. Revere's records illustrate the difficulty in scaling a bell mold to a different sizes. A 700-pound Revere bell (exact location unknown) measured 32 inches diameter across the bottom, 27 inches high, and 17 inches across the top. In comparison, the 2,437-pound bell at King's Chapel in Boston measured 49 inches across the bottom, 36 inches high, and 27 inches across the top.[63] The ratios of these dimensions are displayed in Figure 2.1:

Figure 2.1: Bell Size and Shape Ratios

Measurement	King's Chapel Bell	Small Bell	Ratio
Height	36 inches	27 inches	1.3
Weight	2437 pounds	700 pounds	3.5
Top Diameter	27 inches	17 inches	1.6
Bottom Diameter	49 inches	32 inches	1.5

[62] 1792-1794 furnace records, Volume 9 Part 2, RFP.
[63] Edward and Evelyn Stickney, *The Bells of Paul Revere*, p. 5.

Revere had problems with bell shapes and weights throughout his career, as illustrated by occasional complaints about his bells or severe miscalculations of some bells' final weights.

Revere sold his first bell in 1792, and it still rings twice a year, on Good Friday and Christmas Eve, in the St. James Episcopal Church in Cambridge. It is singular among his surviving bells because of its visible creases and imperfections, a sign of his inexperience.[64] Figure 2.2 presents the church bells made by Revere's foundry until 1810, the last full year of his employment. He probably ended his personal involvement in the bellmaking process much earlier than that, but the entire production line is presented for comparative purposes. Lighter and more numerous ship and school bells are not included.

Figure 2.2: Bell Production and Weights

YEAR	NUMBER OF BELLS	TOTAL WEIGHT OF BELLS	AVERAGE BELL WEIGHT
1792	1	912 (pounds)	912 (pounds)
1793	5	1643	329
1794	1	673	673
1795	5	3096	619
1796	4	3481	870
1797	5	2799	560
1798	10	5302	530
1799	2	1199	600
1800	8	6691	836
1801	7	6011	859
1802	9	9153	1017
1803	6	5276	879
1804	4	3517	879

[64] Ibid. p. 5.

1805	3	2640	880
1806	12	12553	1046
1807	5	5379	1076
1808	9	6736	748
1809	5	5975	1195
1810	2	2086	1043
TOTAL	**103**	**85122**	**826**

This chart reveals a general trend of increasing bell weights and quantities, although this trend is shattered by repeated fluctuations. The lack of continuity illustrates changing internal and external conditions affecting Revere's ability to produce bells. The low output in 1794 and 1799 (2 bells) probably reflects Revere's preoccupation with federal contracts for cannon, bolts, and sheeting, while the 1804-5 lull was probably caused by an economic recession. Bellmaking often brought in good money, but he could not count on a steady income.

In addition to improving his technical skills, Revere's marketing savvy increased. One sign of this is his one-year warranty offer, initially made on all church bells:

> This bell is warranted for twelve months accidents & improper usage excepted; and unless it shall be rung or struck before it is placed in the belfry, or tolled by pulling or forcing the tongue against the bell, by a string or otherwise.[65]

Revere's specific mention of common bell ringing errors was a careful attempt to limit his liability and insure that his bells were treated properly. A second notation elaborates several of his pricing policies:

> Price of Bells
> All bells of 300 lbs and over are to be warranted as Church Bells, and the same discount made for cash. All under 300 lbs, or all sums less than one hundred dollars, 60 days credit or one pr cent to be discounted for cash.[66]

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[65] Undated entry on page 1 of Volume 40 ("Stock Book 1793-1828") of the Revere Family Papers.

Revere extended a warranty and cash discount only to church bells or the largest school bells. The cash discount may appear trivial by modern standards, but represented a new step for Revere, as he realized that the continued extension of credit could hurt his business. Departing from complex silvershop dealings in credit, barter, and cash, he was trying his best to move to a fully cash system.

Revere the Cannon Founder

Of all the technological leaps Revere made in his lifetime, the shift from bell to cannon casting was the easiest. Cannon casting used almost identical raw materials and equipment. Even cannon-specific techniques and tools such as cannon molds were familiar to Revere, since he had worked with them on at least one earlier occasion in 1777 when he helped Louis Ansart at the Titicut furnace. Revere also had a working familiarity with the use of different types of cannon from his service as an artillery officer in the French and Indian and Revolutionary Wars. Revere's correspondence and records contain less information about how he learned to cast cannon than about his iron and bell casting experiences. Presumably, he consulted several of his knowledgeable colleagues, obtained some molds, and experimented until he mastered the process.

Another similarity between bell and cannon casting lay in their histories, or more accurately, their lack of histories in America. Neither trade had existed long enough to enable a large or connected community to form, forcing Revere to learn complex processes largely through trial and error. He was far from the first American to learn the trade in this manner.

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[66] Ibid. Although this is undated, the reference to dollars instead of pounds and shillings implies that it took place after 1795.

In June of 1776, then-Colonel Henry Knox proclaimed that "The business of casting Cannon and making fire arms is of infinite importance to this Continent and cannot be too much encourag'd."[67] Although colonial American gunsmiths developed impressive skills in the art of making and repairing muskets and rifles, cannon casting remained an unknown technology until the Revolutionary War. By the start of the war, Americans lacked cannon as well as the means or knowledge to make them. Large British cannon stockpiles were carefully guarded by British troops, and the only other cannons were privately owned by merchants for their ships. Different colonies, beginning with Massachusetts in 1774, sought to purchase cannon for defense against British attacks. Early purchases and captured stockpiles succeeded in arming some colonial forts and militias, but various colonies realized they had to learn to make cannon and ammunition if they wanted to have any hope of mounting an effective defense. Numerous ironworks had the capacity to produce massive cannon, provided they could learn how.[68]

During the War, various founders learned to make cannon. Beginning with the Hope Furnace in Rhode Island, the Salisbury furnace in Connecticut, and the Reading and Warwick furnaces in Pennsylvania, American foundrymen began with iron cannon. They were forced to use iron by the lack of copper as well as their unfamiliarity with copper casting. But iron had many disadvantages. Because iron was less elastic than bronze or brass, iron cannon were made larger, to prevent them from bursting. Therefore, iron cannon were heavier and harder to move, more suitable for coastal defense than battlefield action.[69] Although early American cannon had an unfortunate tendency to burst during testing or use, often with fatal results,[70] by the end of the war many hundreds of American-made cannon had been used or placed in fortifications. Colonial ironworkers borrowed from existing casting technology, occasional European experience

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[67] Quoted in Mulholland, *A History of Metals in Colonial America*, p. 118.
[68] Ibid. pp. 122-123.
[69] The colonists also sought brass cannon suitable for field action, but the lack of copper forced them to buy most of their field pieces from France rather than make them. Ibid. pp. 124-127; Margaret and Robert Hazen, *Wealth Inexhaustible*, p. 204.
[70] At one point George Washington commented, "It is a melancholy Consideration that in these cases we suffer more from our own Artillery than the Enemy." Quoted in Mulholland, *A History of Metals in Colonial America*, p. 129.

(whether acquired through published "shot tables" or from European foundrymen such as Louis Ansart), and trial and error experimentation, much as Revere would do in 1794.

The Casting Process

Although cast metal (whether iron or bronze gunmetal) is brittle and non-resilient, the great thickness of cannon barrels compensated for this. Bronze remained the preferred material for cannon casting because of its lower melting point (castings were more reliably uniform), immunity to rusting, and ease of boring. The ease of casting and greater elasticity of bronze also made bronze cannon less likely to burst than iron cannon, and when they did burst the gun tubes usually split without hurling metal shards into the gun crew.[71] American founders often substituted brass for bronze until a special form of gunmetal consisting of 85 percent copper and 5 percent tin, zinc, and lead, eventually supplanted all other casting metals.

Cannon casting closely resembled other forms of metal casting, and the actual three-step process changed little between the Middle Ages and postcolonial America. First, the founder created a mold from baked clay. This mold contained three parts: the cannon's exterior, including decorations; the breech, or closed back portion of the barrel; and the core, or hollow middle portion. Some founders reinforced their molds with iron bars to better withstand the stresses of casting. Second, the mold was secured in a pit and filled with molten metal. After the metal cooled, the mold was removed from the casting by breaking it. Third, the center had to be bored out. Even though one portion of the mold prepared a hollow area in the core of the cannon, this could not be performed with sufficient precision for a final product, so the hollow area was enlarged via boring.

The boring process described above was replaced at some point in the 1770s by the solid-bore practice, in which the cast cannon did not contain a hollow cavity and workers used a machine to bore the entire core. Boring devices made use of water or

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[71] Ibid. p. 7.

steam power and hardened iron shafts and bits. Revere eventually adopted this process, and subcontracted the boring portion of his work at first.[72]

The high failure rate of colonial and Revolutionary cannon, both during the proving process and under battle conditions, illustrates the incomplete American mastery of the casting process. As late as December of 1795, Secretary of War Pickering complained, "The casting of cannon has not been attended hitherto with the expected success." He also stated that a "French gentleman" had been hired to overhaul the casting and boring process, and further efforts were underway to hire a "complete cannon founder" from Europe.[73] This may refer to the same French gentleman Stephen Rochefontaine directed to Revere, quoted earlier.

Revere 's Early Cannon Transactions

Revere quickly learned to cast cannon, but his early attempts reveal the need for continued practice and learning. As with the bellmaking process, cannon casting required an enormous component of skilled labor and personal judgment. Even experienced cannon founders had trouble getting the metal to solidify in a uniform manner, and unless the boring of the shaft was centered exactly the cannon would burst or misfire. Revere and his workers undoubtedly had to practice before perfecting their methods, as illustrated by the large amount of wasted metal and loss of several cannon during proving on his first contract.[74] Later contracts make no mention of similar waste or losses.

Revere had four clients between 1794 and 1800. The federal government gave him his first contract in July of 1794 to cast ten howitzers, large army field pieces that fired six-pound cannonballs. Both the War and Treasury departments corresponded with him, reflecting the unclear division of authority and responsibility in the early executive department. Government officials divided the howitzer contract between Revere and James Byers, a supervisor at the federal armory in Springfield, Massachusetts. Although

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[72] T.K. Derry and Trevor Williams, *A Short History of Technology* (New York: Oxford University Press, 1960), pp. 150, 350.
[73] Clyde Sanders and Dudley Gould, *History Cast in Metal* (Illinois: Cast Metals Institute, 1976), p. 152.
[74] Ledger beginning with "Boston New England 1794, Aug 16, Furnace for Brass Howitzers," and ledger six pages later, titled "1794 The United States," Volume 9 (part 2) of RFP.

Revere and Byers might have begun as rivals, they quickly learned that they had much in common, including challenging technical and bureaucratic hurdles. They chose to cooperate, exchanged molds and advice, and eventually became close friends.[75] Revere finished his howitzers by January of 1795, although he used much more metal than he initially estimated. One of his cannon burst during the testing process, requiring him to recast it and use even more metal. The government questioned his excess metal usage, and delayed paying his contract until different departments convinced themselves he had been honest.[76]

Revere's second federal contract involved the first American attempt to cast carronades, light, short-range naval cannons that splintered ship hulls in an attempt to kill enemy sailors. General Henry Knox of the War Department asked Revere to board the French Frigate Concorde while it was docked in the Boston harbor, and had him sketch these weapons. Revere took his research seriously and wrote Knox:

> By post I send you the draft of the Charonade. I have endeavored to make it as plain as possible, as in several things it differs from other guns. I enclose directions translated from a French printed paper. For the use of the seaman, the officers speak very much in favor of the Charonade.[77]

Revere had to lobby the government for years until they agreed to fund his project in 1798, requesting ten carronades for the U.S.S. Constitution.[78]

The Massachusetts state government was his most frequent client. He won his first contract to cast twelve brass "three-pounder" cannon for Massachusetts in April of 1794. "Three-pounders" were small cannons frequently used by infantry regiments, so named because they fired three-pound cannonballs. Revere completed this first job in October of 1794, and by June of 1795 he claimed to have made a total of more than 30 three-pounders for Massachusetts, with pending orders for ten more. His records do not

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[75] Tench Coxe contract with Paul Revere, July 23, 1794, RFP Roll 1, "Loose Manuscripts."
[76] Undated 1796 entry in Volume 9 (part 2) of the RFP. Ledger dates usually correspond to the first entry in the ledger, as Revere often does not date the final transaction of each contract.
[77] Revere letter to General Knox, November 3, 1794, RFP Volume 53.1.
[78] April 1, 1798 ledger titled "Henry Jackson Esqu," Volume 9b, RFP.

confirm that he completed 30 cannon by 1795, but he cast at least 68 cannon for Massachusetts between 1794 and 1800, and continued into the 1800s.[79]

Revere's reputation quickly extended to different states. James Lawrason of the Alexandria Artillery Company in Virginia wrote Revere in July of 1794 upon Samuel Hodgson's (the Superintendent of Stores in Philadelphia) recommendation, and ordered one six-pounder, two three-pounders, and three carriages.[80] And on May 10, 1798, William Rhodes and Nathaniel Fischer of Rhode Island contacted Revere about his brass artillery after hearing him highly recommended:

> We the undersigned being appointed by the Honorable House of Representatives of the State of Rhode Island for the purpose of seeing whether Brass Field Artillery can be procured in this country and to report the expense, we understand by Col. Corliss [sp] that you have cast some at your foundry which is equal to any imported.[81]

The letter then requested Revere's prices and terms of payment for 12 four-pounders. Revere responded on May 16, advising that Rhode Island buy three-pounders instead of four, since four-pounders had been largely discontinued because their ammunition was too similar to three pound balls causing "very great dificultys in time of action" when artillery suppliers confused the two.[82] The Rhode Island delegation wisely took his advice: by this time he was a skilled founder with more experience in artillery matters than most non-military people.

Revere's total ordnance production is summarized in Figure 2.3:

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[79] Revere to James Lawrason, June 14, 1795, Volume 53.1 RFP, and ledgers beginning with "Boston April 16 1795," Volume 9 (part 2) of the RFP.
[80] James Lawrason to Paul Revere, undated letter (date given as July 9, 1794 in following letter cited here), Lawrason to Paul Revere, May 28, 1795, Revere to Lawrason, June 14, 1795, and Lawrason to Paul Revere July 17, 1795, Roll 1 and Volume 53.1, RFP.
[81] William Rhodes and Nathaniel Fisher to Revere, May 10, 1798, Roll 1 RFP.
[82] Revere to Rhodes and Fisher, May 16, 1798, Volume 53.1, RFP.

Figure 2.3: Total Ordnance Production[83]

Year	Ordnance Type	Client	Quantity
1794	Three-Pounders	Massachusetts	12
1795	Howitzers	United States	10
	Three-Pounders	Massachusetts	12
	Three-Pounders	Alexandria Artillery Co. (Virginia)	2
	Six-Pounder	Alexandria Artillery Co. (Virginia)	1
1796	Three-Pounders	Massachusetts	8
1797	Three-Pounders	Massachusetts	8
1798	Three-Pounders	Massachusetts	12
	Carronades	United States	10
	Three-Pounders	Rhode Island	6
1799	Three-Pounders	Massachusetts	2
	Twelve-Pounders	Massachusetts	6
1800	Three-Pounders	Massachusetts	8
TOTAL			97

Raw Materials

Revere initially bought raw materials with a specific product in mind, the same process used during his early bell castings. As his shop grew, his raw material purchases became more regular, subject to merchant prices and availability. His shop maintained a stock of metal that he could apply to any project. His ledgers contain one inventory performed by two of his sons in 1799. This is presented in Figure 2.4:

[83] Ledgers beginning with "Boston April 16 1795," Volume 9 (part 2) of the RFP.

Figure 2.4: May 1799 Furnace Inventory[84]

Item	Quantity (in pounds)
Gun & Brace Mettal	4209
Copper	2114
New Spikes & Nails	180
Bell Mettal	410
Coarse Brass	1284
Fine Brass	556
India Tin	1912
Worn Tin Melted	3115
Brass Wire	574

By 1799, Revere had ceased his iron casting and focused exclusively upon copper products. Gunmetal was his highest priority at this time.

These new raw material practices represented a logical response to the increasing quantities of metal he had to deal with. In 1995, Revere tallied all his metal expenditures for his federal howitzer contract at the government's request. He bought 38,032 pounds of copper and 4,712 pounds of tin for 10 howitzers, of which he sent 15,473 pounds of copper and approximately 1,800 pounds of tin to Byers in Springfield. Revere's final howitzers weighed 16,917 pounds, and although he had some leftover copper and tin when the contract was completed, he still wasted as much as 8,200 pounds of metal, an enormous percentage.[85] Revere's wasted metal greatly concerned the government. Raw material purchases were initially the responsibility of the buyer. The War Department's first contract with Revere agreed to provide him with all needed metal, but government

[84] Ledger entry beginning "Memorandum of Stock in Furnace May 1799 as taken by Joshua & Jos. W. Revere," Roll 6 Volume 9b, RFP.

[85] Revere did not know the amount of leftover copper that he sent to Byers, so he wasted approximately 8,200 pounds of metal minus whatever he sent.

officials quickly asked Revere to do this. Since Revere was reimbursed for all the metal he bought, any metal he wasted would be the government's loss.[86]

Revere's large initial percentage of waste reflected the quality of his metal as well as his inexperience. The government limited him to a price of one shilling and two pence per pound of copper, which forced him to buy inferior material. Because of limitations on the money he could spend on shipping copper to Springfield, he had to send away the highest quality copper because it was densest and cheapest to transport. In contrast, the bulkier recycled copper and brass implements that had to be melted and recast were left for Revere. This reused copper (primarily from the West Indies) contained small pieces of iron that either accumulated in the furnace or entered the final product as imperfections. In justifying his larger waste percentages in comparison with Springfield, he felt the need to defend his honor and judgment: "I was as carefull and as prudent as if the metal belonged to my self & what is deficient was wasted."[87] Revere received his complete fee by May of 1796. He grew more efficient as he mastered the casting process and wasted far less in future contracts.

Clients other than the federal government did not even attempt to provide Revere with copper. The search for raw materials was usually the responsibility of the founder, which cost Revere an enormous amount of time and effort. Revere's final bill listed the weight of his finished products, a charge per pound for the metals used, and a charge per pound for his labor. Wasted metal did not appear in this expense list, implying that Revere paid for it.

Labor

All of Revere's expense reports compute a "labor" fee, usually listed as "for casting," that is based on the weight of the finished product. This simple calculation obscures all the labor expenses and other charges (depreciation, shipping insurance, etc.) that Revere incurred throughout a project, thereby preventing the determination of Revere's net profit. For his first federal contract, Revere computed a labor fee of $2875.89, or 17

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[86] Tench Coxe to Paul Revere, July 21, 1794, Roll 1, RFP.
[87] Revere to Nathaniel Gorham, January 27, 1796, Volume 53.1 RFP.

cents a pound for 16,917 pounds of ordnance (the ten howitzers weighed between 1,633 and 1,750 pounds each). He added charges of $22.50 for the engraving of the United States coat of arms on all the finished pieces, for a final fee of $2897.39.[88] Revere gradually raised his rate over the years, to 20, 22, and finally 25 cents per pound. Revere's labor fee constituted between 45 and 60 percent of finished contract prices for different small contracts with the Massachusetts government.[89]

Two receipts shed a little light on labor practices concerning his two most highly skilled employees. Nelson Miller acknowledged receiving $24 for 12 days of work for himself and his son ending on June 1, 1795, an extremely high rate reflecting the faith Revere had in him. During his federal howitzer contract Revere asked his "Friend Miller" to return to Boston and help him recast the cannon that burst during testing. Later receipts indicate that Miller continued working for Revere for at least two more years and remained one of the highest paid employees. Revere paid a larger sum of money to Elib Faxon in August of 1795, broken down by task and not by the amount of time he worked. Revere subcontracted some of his tasks, such as the artillery boring process, to Faxon, who must have owned his own equipment. According to this receipt, presented in Figure 2.5 below, Revere paid Faxon for a variety of services. This receipt does not date each portion of Faxon's work, but covers the time from August of 1795 to April 2, 1796.

[88] Undated 1796 entry in Volume 9 (part 2) of the RFP. Ledger dates usually correspond to the first entry in the ledger, as Revere often does not date the final transaction of each contract.
[89] Ledgers beginning with "Boston April 16 1795," Volume 9 (part 2) of the RFP.

Figure 2.5: April 1796 Payments to Faxon[90]

1795 Paul Revere to Elib Faxon	Debit
To boring, turning, & filing 10 howitzers @ £7 10s	75 – 0 – 0
10 Howitzers	
To cutting of 3 Sprues	1 – 16 – 0
To cleaning 5 Howitz's @ 12	3 – 0 – 0
To turning & boring a Cillinder	4 – 10 – 0
Aug. To Turning & boring boring & filing 12 pieces of cannon @	36 – 0 – 0
£3 each	
To finishing a Mortar	0 – 18 – 0
To Carting a Cillinder	0 – 7 – 6
(subtotal)	£ 121 – 11 – 6
To drawing copper bolts (detailed numbers hard to read)	430 – 2 – 9
(total)	£ 551 – 14 – 3
Credit By his account of this date	281 – 16 – 4
Ballance	£269 – 17 – 11
Boston April 2, 1796 Rec'd ballance in full	

The tasks listed above the first subtotal all required large equipment and specialized skills. Since Revere had just entered the cannon-casting field, he had not yet purchased bulky and expensive cannon turning and boring devices. The two largest charges above the first subtotal correspond to the boring and turning work on Revere's first two contracts, the ten howitzers for the federal government, and 12 smaller cannon for Massachusetts. The second subtotal includes an additional charge of over £430 for drawing copper bolts. Faxon and Miller were two of Revere's favorite assistants because they could be trusted to perform a range of tasks competently, with minimal supervision,

[90] Elib Faxon receipt dated April 2, 1796, RFP Roll 1, "Loose Manuscripts." Please note that some of Revere's superscript notations have been removed from this table, and parenthetical comments were added by the author.

and in Miller's case, on short notice. As Revere grew older and more experienced, he continued changing his role from skilled worker to manager and overseer.

Managerial Advances and Contractual Difficulties

Other than his lengthy business relationship with his home state, Revere encountered difficulty with every contract he accepted. After he first discovered the harm that could be caused by payment delays, Revere implemented a generous credit policy and explicitly stated his terms at the start of each new contract. No solution seemed equal to this task, however, and two of his later jobs also led to major misunderstandings about each party's obligations.

Revere's first federal contract reveals the inexperience present on both sides. Revere took on too many responsibilities, and accepted constraints that excessively limited his operations. He could not procure high quality metal at the price the government set, and wasted time and money working with inferior old copper. He also, understandably, had not mastered the casting process as quickly as he expected. His burst cannon and high amount of wasted metal triggered a government review process that delayed his reimbursement almost a year. The government's division of authority between the War and Treasury departments also complicated all transactions, as Revere often received two sets of identical questions, and no response to his own concerns. By the time he finally received his payment, his profit had been reduced by the extra labor for the burst cannon as well as the lost use of his money during the long delay.

Revere's interactions with the Alexandria Artillery Company's contract quickly became even more problematic. James Lawrason expressed interest in buying one six-pounder, two three-pounders, and three carriages from Revere in early 1795. He submitted this order before hearing the prices, and Revere started work at once. By July of 1795, Lawrason asked to remove the six-pounder from his order because he had trouble collecting his subscription money. Revere had already finished and engraved all the cannon, making them hard to re-sell. Furthermore, he complained that some of his associates, "The Carriage maker & Blacksmith," demanded their fees for the work they had performed. Lawrason countered that he never definitively asked for the six-pounder,

that he assumed Revere would not start without an advance, and that he would not have ordered any cannon if he knew he needed to pay so quickly. Lawrason attempted to satisfy Revere with partial payments, and eventually paid in full, after a long delay.[91]

Aware of this potential ambiguity, Revere clearly summarized his terms and policies at the start of his correspondence on the Rhode Island contract:

> The lowest price I can cast & finish them for is fifty cents @ pound, & if the State Arms are put on them, that will be an extra sixpence. I am willing that they be proved by any person who understands the business; the proving is at the expense of the purchaser. Those three pounders I have cast for this State weigh from 412 to 420 lb. each. ... My terms of payment will be one half down when delivered & the other in ninety days. I believe the carriages +c may be procured upon the same terms. I am not certain that I have copper sufficient for twelve pieces should therefore be glad to have some copper procured for which I will allow twenty cents pr pound.[92]

These conditions attempted to pass some unpleasant tasks to the client. For example, Revere would gladly credit the account for the copper cost if this would allow him to avoid the hassle of buying it. Proving would also be the buyer's responsibility. And the 50% payment upon delivery followed by 90 days credit seemed a fair compromise, protecting Revere from complete payment delay while allowing the customer some time to raise funds.

Unfortunately, these terms did not lead to a smooth contract. William Rhodes and Nathan Fisher, the Rhode Island purchasing agents, asked Revere to cast six howitzers in May of 1798, including state arms. By August, Fisher announced he would only require four, and once again, Revere already cast six and placed the Rhode Island arms upon them. Revere won this argument, but the terms of one half down and the other half within 90 days did not materialize. Of the $1292 price tag, Revere received only $450 upon delivery at the end of August. The rest was due on November 30, but he was still owed $492 as of February 13, which he might never have received. This dispute reiterates the vagueness and lack of commitment in early work agreements, when

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[91] James Lawrason to Paul Revere, undated letter (date given as July 9, 1794 in following letter cited here), Lawrason to Paul Revere, May 28, 1795, Revere to Lawrason, June 14, 1795, and Lawrason to Paul Revere July 17, 1795, Roll 1 and Volume 53.1 RFP.

[92] Revere to Rhodes and Fisher, May 16, 1798, Volume 53.1 RFP.

contractual obligations (such as Rhode Island's inability to reduce the size of the order after it was finished) remained unclear, and even Revere's 90 day credit policy seemed too strict for a state government to meet.[93]

Transition and Growth

Between independence and Jay's treaty of 1795, the commercial and industrial relationship between Britain and America is best described by the term "colonialism." America's postwar economic position was, in many ways, one of weakness and dependence. Scarce labor supplies, older technologies, and the falling value of export goods combined to produce a severe trade imbalance that was only corrected after the growth of a market economy accompanied the increase of federal power under the Federalists. While America was undergoing this transition from postcolonial economy to independent producer and trading power, many artisans such as Revere continued their own transformations. By 1795, his operations had already changed and expanded dramatically in areas such as technical advancement and production style, managerial finesse, and financing.

Technically, Revere learned the many differences between iron and bronze casting and his earlier silverwork. One such lesson involved the concept of uniformity. As a silversmith, the majority of Revere's work involved bespoke work made for each individual customer. Although silverwork styles imposed certain common forms and conventions on all pieces, many items were prized because of their uniqueness. This began to change with the spread of fairly standardized utensils and common items, but the highest calling of all silversmiths was still the production of unique silver plate. Ironworking imposed entirely new values and goals upon the producer. From the blast furnace operators to the founders and finers, the measure of a skilled ironworker was his ability to produce completely uniform metal and absolutely standardized objects. The use of molds and patterns imposed an ideal upon the founder in particular: the best

[93] Revere to Nathan Fisher, August 23, 1798; Revere to Nathan Fisher February 7, 1799; Ledger titled "William Rhodes & Nathan Fischer," August 30, 1798, Roll 6 Volume 9b of the Revere Family Papers.

objects duplicated the model used in casting, and all deviations from it decreased the item's value and perfection. Bellmaking forced Revere to continue his use of skilled labor and unique output, but still employed advanced technology and a more advanced managerial framework.

Managerially, Revere observed the practices and cultures of different ironmaking establishments, the largest of the technical communities, both intentionally and inadvertently throughout his ironworking career. These surveys provided interesting counterpoints to his artisanal silverworking experiences. He gained familiarity with the operations of different ironworks, which were among the largest managerial operations in America. Ironworks introduced many managerial innovations as well as some of the first rigid labor expectations for the workers who increasingly polarized towards skilled supervisors and unskilled laborers. Historian Robert P. Gordon contends that early ironworkers "already accepted the industrial discipline we commonly ascribe to the textile mills started a hundred and fifty years later."[94] This overlay of individual skilled labor and rigorous supervised discipline was common throughout this period, and would grow increasingly prevalent in Revere's own shop. Of course, the attendance patterns of his own workers indicate that Revere still allowed his men to enjoy many of the privileges and freedoms of skilled laborers.

Revere's shift from iron to copper alloy products was extremely clever, and possibly resulted from an assessment of his location and a growing emphasis upon his raw material needs and limitations. New England's iron sources paled in comparison to sources in the rest of the country, particularly in the mid-Atlantic states. Small New England furnaces could not supply his needs, necessitating expensive transportation fees. In contrast, copper was in short supply throughout America. The ideal site for a copper manufactory was a location near a major port city, which could provide supply and demand, in a region containing surplus labor and mechanical expertise. Boston was one of the three best locations in the nation.

Perhaps the major difference between bell and cannon casting involved managing the operations. Bell casting took place on a much smaller scale, and Revere could afford to wait for a contract before searching for metal. Cannon casting had more in common

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[94] Gordon, *American Iron,* p. 1.

with Revere's iron work because it took place on a larger scale and required more raw materials. Fortunately, he had begun teaching and coordinating his skilled laborers while still concentrating on iron. Likewise, he had some experience developing reliable supply sources and tracking his income and expenditures.

Finally, Revere's example illustrates how some artisans managed to become managers and owners instead of skilled employees. Revere's success in a number of endeavors, starting with silverworking, iron founding, and bell and cannon casting, provided him with both fixed and liquid capital that allowed him to continue trying new applications. His furnace, his property, and intangible assets such as experience, workers, supply networks, and a solid reputation allowed him to experiment in new fields without excessive risk or delay. And his steady income from already-mastered occupations gave him the freedom he needed to survive the startup of each new operation. During this early federal period, entrance requirements for new endeavors were high enough to discourage the bulk of the population, but low enough to allow members of the middle class to take a chance. In his later endeavors, Revere would require help to overcome higher startup costs. As his experience and ambitions continued to grow, Revere broadened his influence and increased his profits by selling ship fittings and other products to the largest client possible – the federal government.

CHAPTER THREE: THE ROAD TO ROLLING COPPER

Government Contracting and Malleable Copperworking (1795-1802)

On New Year's Eve of 1798, Revere wrote his first letter to Benjamin Stoddert, America's first Secretary of the Navy:

> I understand you have advised the Committee for building the Frigate in Boston, not to send abroad for any thing they can git manufactured in this Country; these sentiments, have induced me to trouble you with this letter. I can manufactor old or New Copper, into Bolts, Spikes, Staples, Nails &c &c or any thing that is wanted in Ship building; that is cast the Copper into Pigs, draw the pigs into Barrs under the Forge hammer, and then manufactor the Barrs into Bolts, Spikes, Nails, &c &c. I supplyed the Constitution with Dovetails, Staples, Nails &c &c. The Frigate Building here has upwards of 5000 lb. of Bolts, & Spikes, allready in her, of my manufactor, & I have supplyed Jacob Sheafe Esq., Naval Agent at Portsmouth with 600 lb. of Spikes for the Frigate building there. – My greatest difficulty is to git old Copper. Could I git a sufficient supply of Copper I would undertake to roll sheet Copper for Sheathing Ships.[1]

Revere's contacts had informed him correctly. Stoddert wanted to build a strong navy from domestically produced components and was actively seeking manufacturers able to produce bolts, spikes, and sheeting from malleable copper. This fit perfectly into Revere's plans. He had spent the prior three years perfecting his ability to work copper into a malleable state and then draw it into various shapes such as bolts and spikes. The long list of products in the above paragraph reveals his growing technical proficiency. This letter also displays his confidence, and his eagerness to learn to roll copper as long as Stoddert helped him find enough raw materials. In spite of this seemingly perfect match between Stoddert's needs and Revere's skills, this letter was quickly shelved and forgotten. A quick consultation with Colonel Joshua Humphreys suggested that Revere's claims were ludicrous. Joshua Humphries was America's foremost turn of the century naval architect and also served as "chief technical advisor" to the Navy Department. His knowledge about both the science of ship design as well as the technical details

[1] Paul Revere to Benjamin Stoddard (sic) Esq., December 31, 1798, Revere Family Papers (RFP) Volume 53.1, Letterbook 1783-1800.

underlying different ship components made him eminently qualified to assess the nation's technological limitations.[2] Humphreys assured Stoddert that no American could produce malleable copper. Humphreys was wrong.

Revere started experimenting with malleable copper in the mid-1790s. After learning to produce and modify bolts and spikes he investigated the possibility of making sheathing copper for ships' hulls. This road to rolling copper consists of two intertwining narrative pathways: Revere's technological progress and the government's evolving goals. These threads converged when he finally made contact with Stoddert, and remained connected until his retirement. Revere's technical accomplishments continued the self-education and occupational expansion that characterized his foundry endeavors. Malleable copper items such as bolts, spikes, and sheets caused Revere to change his methods and expectations in an attempt to standardize output. This was only possible because of his technical and managerial flexibility, which allowed him to combine relevant aspects of all his endeavors. Also, Revere's education in this period differed from all his previous studies, because he was trying to learn a British process that was very rare, and possibly nonexistent, in America. This moved him up David Jeremy's technology transfer ladder, from the "internal diffusion" stage to the "pilot plant." Revere did not travel to Britain or consult British workers, but relied on other methods closer at hand.

Revere's last ride cannot be properly understood without also following the federal government's early development, which in 1800 was still young and inexperienced yet embroiled in several intense ideological and diplomatic struggles. In addition to serving as the single largest customer for American businesses, the government also represented the only entity truly interested in the source of its products. A strong market and market mentality developed in large port towns by the 1790s and the laws of supply and demand encouraged private buyers to seek the highest quality at the lowest price, which usually led to British goods. Certain individuals within the federal government, particularly Benjamin Stoddert, realized they had to think of the future and prepare for a time when volatile international relations might lead to blockades, the

[2] Leonard D. White, *The Federalists: A Study in Administrative History* (New York: MacMillan, 1948), p. 159. Humphries is also remembered for designing the U.S.S. Constitution and five other frigates. Revere and Humphries eventually became close friends.

cessation of foreign imports, or war. A well equipped, domestically supplied navy would protect against this scenario. Politics had always fascinated Revere, as his Revolutionary activities amply illustrate, but both local and international events had a bearing on his professional success or failure.

Malleable Copper: Bolts, Spikes, and Naval Contracting

Revere's transition from bell and ordnance casting to drawing malleable copper bolts and spikes represented the largest technical hurdle of his career, as it departed from anything he had previously learned and did not engage a helpful technological network. Later, his copper rolling work depended completely on the technical skills he learned while trying to produce strong copper spikes by a hammering and annealing process. This learning experience forced him to develop new contacts, new financial and managerial techniques, and a much larger scope of operations.

American Copperworking and the "Secret" of Malleable Copper

From their earliest years, the British colonies of North America were far more committed to ironworking than copperworking. Usable iron ore was plentiful in many of the colonies, but copper was rare and much harder to smelt.[3] Dutch, French, and British colonists all initially searched for copper ore, with minimal success. The first sustained copper mining in the American colonies took place in the early eighteenth century using labor from Germany and, to a lesser degree, Britain. Although several refineries

[3] Unlike iron, copper must be virtually free of contamination before it can be worked. Therefore, the rise of copperworking has always been inextricably linked to the ability of copper smelters to remove impurities. The first copper ore removed from a mine is of unusually high quality because it has already been partially purified through the atmospheric oxidation of impurities. American mine operators learned to perform relatively simple smelting processes to make these ores usable. Once the surface ores were exhausted, other contaminants such as sulfur appeared, requiring the far more complex, costly, and time consuming pyretic ore smelting process which remained a highly guarded British secret. As a result, Cornish miners and Swansea smelters held a virtual monopoly on copper production until the 1830s, and American miners primarily focused upon extracting ore from the ground and shipping it to Britain for processing. Otis E. Young Jr. "Origins of the American Copper Industry," in *Journal of the Early Republic*, Volume 3, Summer 1983, p. 118; Charles K. Hyde, *Copper for America* (Tucson, University of Arizona Press, 1998) p. 9.

functioned briefly in the colonies to satisfy local copper needs, operating costs were too high and demand too low for these ventures to be profitable. Early copper refining in America borrowed heavily from iron refining, which led to major errors and frequent imperfections in the final product. Therefore, colonial copper mines shipped nearly all their copper ore to Britain for smelting and fabrication, and Britain shipped finished products back to America.[4] Mines at Simsbury Connecticut produced copper ore from 1720 to 1788 and the Schuyler mine in New Jersey had the most output when it operated between 1715 and 1773. Different investors opened several other mines in New Jersey and Maryland, but failed to find large quantities of copper. By the Revolution, most colonial copper mining activities had been discontinued.[5] Thomas Cooper discussed America's lack of copper smelting knowledge and equipment in 1814, lamenting that for all its importance, "we have no smelting work for copper, or any copper mine worked in the United States."[6]

American copper demand grew steadily with population growth, and Americans depended on British imports to meet their needs. Copper imports, usually of pots and cooking utensils, increased from under 20 tons a year in the beginning of the 18th century to a peak of 350 tons in 1760. Copper items are superior to iron for many cooking tasks because of their heat transmission and imperviousness to rust, but iron was still used for the majority of pots and other utensils in the early colonial period because copper was too expensive.[7] Colonial coppersmiths were few and far between, itinerant laborers who performed a variety of simple patching or tinkering services. These smiths usually required a second trade to meet their meager operating expenses, and might double as

[4] Copper could also be profitably shipped to Britain because of the high metal content of copper ore, which reached and exceed 50% usable metal. Iron ore, in contrast, typically contains less than 10% usable metal, partially explaining why iron was typically worked close to its source. Of course, demand for iron was also much higher than copper demand. James A. Mulholland, *A History of Metals in Colonial America* (Alabama: University of Alabama Press, 1981), pp. 49, 53, 91, 166; Edwin Tunis, *Colonial Craftsmen* (Baltimore: Johns Hopkins University Press, 1965), pp. 76-77.

[5] Actual copper mine output is difficult to establish due to unreliable record keeping. The highest output took place in the 1720s and 1730s, at possibly one to two hundred tons of metallic copper a year. The Simsbury and Shuyler mines produced most of this copper, and American output plunged when they slowed or shut down,. By the 1750s the colonies produced less than a hundred tons a year, and by 1770 this had declined to 41 tons. Mulholland, *A History of Metals in Colonial America,* pp. 21, 43-47, 53; Hyde, *Copper for America,* pp. 4-6; Otis E. Young Jr., "Origins of the American Copper Industry," pp. 118-123.

[6] Thomas Cooper, in *The Emporium of Arts and Sciences*, June 1814. Quoted in Charles Hyde, *Copper for America*, p. 3.

[7] Hyde, *Copper for America,* pp. 7, 10; Mulholland, *A History of Metals in Colonial America*, pp. 91-2.

tinsmiths and braziers who performed other metalwork. Nearly all copper objects at this time were made from sheet copper, which furnaces produced by casting copper into long and thin molds. Therefore, most coppersmith knowledge centered on shaping copper sheets to produce and modify pots, stills, funnels, and utensils.[8]

The shipbuilding boom of the late 1780s produced new demands for different items and technologies. A variety of metal fasteners, such as bolts, spikes, and staples, held together the timbers of a ship. The demand for bolts and spikes increased dramatically when ship makers started fastening copper sheets to the outside of ship hulls at this time to prolong hull life. The ocean environment subjected these fasteners to salt water, necessitating a rustproof metal.[9] However, the metal also had to withstand the constant strain of the ship's weight and motion pulling it in different directions. This required a metal that was "strong," or able to resist being pulled apart. And the shipbuilding process also subjected these fasteners to savage impacts as the shipwrights hammered them into cured wood, requiring "toughness," which is the combination of "hardness" (resistance to penetration) and a lack of brittleness. To avoid frequent overhauls, an all-purpose metal was needed.

Cast copper was not the solution to this need. As with cast iron, cast copper is brittle, and breaks or shatters under impact. Cast copper can be "cold-worked," or reshaped (plastically deformed) by the application of external force such as hammering. However, cold working increases the amount of strain within the metal, making it increasingly hard and brittle. In short, cast bolts and spikes would begin as fairly brittle fasteners subject to cracking under great strain, such as the process of hammering them into the ship hull. If these bolts were ever cold-worked to change their diameter or length, they would become even more brittle.

By 1783, the British copperworking industry had developed a rolling process to produce "malleable" copper bolts and spikes that were much stronger than regular copper. The proper combination of heating and hammering produces fundamental changes in the molecular structure of cast copper. Annealing is the process of heating the

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[8] Tunis, *Colonial Craftsmen*, pp. 76-77.

[9] Rusting was exacerbated by a chemical reaction known as galvanic action between the iron fasteners and copper sheets. J.R. Harris, *Industrial Espionage and Technology Transfer*, (Brookfield: Ashgate Publishing, 1998), p. 263.

metal above its recrystallization temperature but below its melting point. This releases some of the metal's strain and brittleness and restores its ductility, allowing it to behave in a plastic manner again. Hot working is the procedure of reshaping a metal after it has been heated to the temperature range that restores ductility. However, if the metal remains at the high temperature for too long it becomes soft. Malleable copper is produced by a combination of hot and cold-working processes. The coppersmith alternately had to heat, cool, and hammer the copper until the desired blend of qualities was produced. In this manner, copper could become both strong and tough (i.e., hard and non-brittle).[10]

This process was not widely used or understood in Revere's time. Even with respect to iron, a metal that was used and understood far more than copper, skilled workers did not fully comprehend the ramifications of their procedures or the different characteristics of metal. According to Robert Gordon, "Throughout most of the nineteenth century, mechanics thought that the stronger iron was, the better it was. They failed to appreciate the relationship between strength and toughness."[11] The artisan mentality and training placed a high premium upon tradition and the preservation of secret knowledge, but the new technological demands required a more experimental approach. And this was where Revere excelled.

Technical Experimentation and Improvement

Revere's surviving records do not explain how he learned to hammer and anneal bolts without weakening them. He repeatedly refers to the magnitude of this achievement, for example, describing the "considerable labour & expense" he exerted.[12] He would not highlight his difficulty learning this skill if it represented a commonplace product or simple process. Revere also repeatedly compared his product quality to that of British-made bolts and spikes. It went without saying that if his copper was equal to that of the British, it was excellent. Although Revere might have received advice or assistance from

[10] Harris, *Industrial Espionage and Technology Transfer*, p. 264.
[11] Robert B. Gordon, *American Iron, 1607-1900* (Baltimore: Johns Hopkins University Press, 1996), p. 13.
[12] April 24, 1797 letter to John Brown Esq., RFP Volume 53.1.

skilled British laborers, no mention of this ever appears in his records. He probably practiced in his foundry until he could produce items similar to British ones.

One clue hinting at Revere's technical processes lies in his use of the word "drawn" in his letter to Portsmouth Naval Agent Jacob Sheafe. As a silversmith, Revere was familiar with the wire drawing process, which closely approximated several nuances of malleable copperworking: too little heating would not restore flexibility to silver wire, and too much would soften or even melt it.

Revere learned a related technical skill during this period. In a January of 1800, Revere reported his first successful copper rolling experiment (discussed below). In explaining the difficulties he overcame, he mentioned that he had a hard time smelting 400 pounds of copper ore in a furnace that he usually used to refine 1800 pounds of copper at a time.[13] Copper refining represented an extremely complex technology when done properly. Different copper ores could easily become contaminated with other chemicals such as sulfur or oxygen, and the metalworker used an arsenal of techniques to separate pure copper from other elements. In Britain, refineries carried out a many-stage process that gradually removed larger and larger quantities of contaminants. Revere almost certainly did not possess the knowledge or equipment to carry out such a complex operation, but he might have imperfectly refined the metal by heating it in a reducing (i.e., oxygen-lacking) environment, which would remove oxygen but not other contaminants. Although this would produce second-rate copper, any version of copper refining technology represented a milestone in postrevolutionary America. Revere's bolt and spike "drawing" process, therefore, probably involved a combination of refining cast copper into a purer state, forming it into bar shapes, and hammering and annealing them until they were bolt-sized.

Additional information about Revere's processes and errors appear in his correspondence. He discussed his first contract in an October 28, 1795 letter to Paul Sheaf that also exhibited his growing metallurgical knowledge and access to information about current naval construction. Revere told Sheaf that he just delivered 15 tons of copper bolts to naval agent General Jackson, who hired him to resize British bolts

[13] Revere to Edward Edwards, January 20, 1800, RFP Volume 53.1.

without weakening them. In his letter to Sheaf, Revere proved that he understood the technical nuances of this work:

> ... should they [copper bolts] be cast, they will not answer for the use they came for, for when that metal is cast in sand, it looses a very great part of its ~~Mallibillity~~ ~~Malleable~~ Mallebility and is very easily broken. But those which are drawn retain their Mallebility and are as tough as iron.[14]

This is relevant because Sheaf (according to Revere's informer, "a Gentleman from Portsmouth") planned to reduce the size of his spikes by casting them – a move that would make them brittle. Revere also singled out "casting in sand" as part of the problem. By this point Revere had learned the process, although not perfectly.

Revere initially had unrealistic expectations regarding his products. In a February 7, 1796 letter to an unknown recipient, he claimed his bolts "acted under the hammer as tough as Iron," adding "I will risque my reputation, that you shall take one of those bolts and place it across two blocks of Iron and strike with a large Black smith sledge, backwards and forwards, three hundred times, before you can break them."[15] This is a bet Revere could not win. He chose this imagery to demonstrate his bolts' toughness, but later complaints reveal that his bolts were not indestructible.

Revere's rapidly increasing workload testified to the good reputation of his products and justified at least some of his self-promotion, but he also had to deal with complaints. He wrote a letter to Jacob Sheafe on January 7, 1799 in which he defended his spikes and rejected a request to take back a shipment. Sheafe reported that he could not use the 616 pounds of composition spikes Revere recently sent him because the heads were too large and one side was uneven. Revere's two-part response reveals much about his view of his products.

Concerning the issue of the spike heads and unevenness, Revere noted "that all the English ones have large heads & the French ones have still larger & ar square." In a lengthy full-page letter, this was the only direct response Revere made to the charge that his spike heads were too large. He did not discuss their unevenness at all. Instead, Revere used this letter to defend the workmanship and quality of his spikes in general,

[14] Revere to Paule Sheaf, October 28, 1795, RFP Volume 53.1.
[15] February 7 1796 letter to unknown recipient, Ibid.

and discuss the different types of metal used in spikes. He took a historical approach to the subject:

> I wish to mention, when the Brittish Nation first began to [word missing] other than Iron bolts & spikes into their Ships, they were made of a composition of Copper & Tin, but they soon found that it would not Answer, by reason it was too brittle. They then found they could harden copper; they now make use of no Composition Bolts or Spikes, but clear copper. – If you wish to distinguish between Copper & Composition bolts or spikes, lay them across two pieces of Iron, bend them backwards & forwards, & you will soon find which breaks first, then look at the grain.[16]

Revere also pointed out that Sheafe was wrong to describe the spikes as "composition" metal, since he sent only spikes made from "clear copper, drawn from barrs of copper under the hammer in the same manner as iron spikes are made." In Revere's terminology, composition copper referred to bronze alloys, and clear, pure, or malleable copper referred to homogeneous metal. He added that these were exactly the same spikes as the 1500 pounds of spikes recently used in the USS Constitution, and "The work men that drove them [the spikes] told me they were equal to the English ones. And what is more no man but my self in the four New England States, can melt the Copper & draw it in to spikes but my self." The bolts were also "such as the Sec'y for the Naval department ordered to be drove into every Vessell building for the United States." He frequently resorted to this tactic of defending a specific item or product by citing his body of work and overall experience.[17]

Revere wrote a second letter to Sheafe on February 13 in response to Sheafe's follow-up letter, and did a better job of addressing the actual topic. In this letter, Revere admitted that this shipment of spikes had been rushed to insure they all arrived in one package. Therefore, "some of them might not be quite so even as others & their heads a little larger." For a second time, he devoted the majority of his letter to the charge that his bolts were too soft to penetrate the hull of a ship. This time, he contended that some woods, particularly the prized live oak used on naval vessels, were hard enough to break even British spikes. The shipbuilders of the Constitution had a similar problem, and

[16] Revere to Jacob Sheafe, January 7, 1799, Ibid..
[17] Paul Revere to Jacob Sheafe Esq., January 7, 1799, Ibid.

overcame it by boring holes before driving each spike. In conclusion, Revere mentioned that he could draw the spikes to a smaller size for five dollars per hundred spikes, and make them strong enough to drive "near as well as iron."[18]

Although Revere held his technical prowess in high esteem, his self-praise carried a large element of truth. His achievement was a milestone for America. In a letter he wrote to Harrison G. Otis in March of 1800, Revere presented a "Short History of that valuable & necessary Metal in this Country," a history of copper that was really a history of his own copperworking career. This letter confirms some of Revere's statements concerning the rarity of copper working knowledge in America:

> [Colonel Joshua Humphries] asured Mr. Stoddard that there were no person in America that could make Copper maleable so that it could be drawn in to Bolts & Spikes. I have shewn him, and he acknowledges that He was mistaken and gave me leave to make use of His Name.[19]

If an expert as qualified as Humphries believed that no American possessed the knowledge and experience required to make malleable copper bolts and spikes, then Revere's achievement truly separated him from most, if not all, American metalworkers. Several years later, Revere's accomplishments were the subject of public praise. An article titled "the Launch," printed in the May 21, 1799 issue of the *Massachusetts Mercury*, pointed out that the Frigate Boston was the first ship whose bolts and spikes were exclusively manufactured in the United States: "We think the publick are under obligation to PAUL REVERE, Esq., for his indefatigable attention to this Branch of Naval Architecture, especially at a time when the British Government has prohibited the exportation of that valuable Article."[20] The use of "Esquire," a gentleman's title, would not have been lost upon Revere. Many Americans recognized the importance of Revere's accomplishment even though he only duplicated an existing British process. Being first was not as important as being in the race at all.

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[18] Revere to Jacob Sheafe, February 13, 1799, Ibid..
[19] Revere to Harrison G. Otis, March 11, 1800, H.G. Otis Papers, Massachusetts Historical Society.
[20] United States. Office of Naval Records and Library, *Naval Documents Related to the Quasi-war Between the United States and France* (Washington: U.S. Government Printing Office, 1935-1938), Volume 3, p. 223.

Malleable Copper Contracts and Profits

After entering the malleable copper business in October of 1795, Revere received more contracts than he had ever undertaken in any prior endeavor. He was now positioned to provide a technically elusive resource to a country that needed it desperately. Although Revere was years away from rolling copper sheets, he initially produced a number of ancillary materials that otherwise would have been imported from Britain.

Revere first mentioned his work with malleable copper in an October 14, 1795 ledger entry, charging the United States government $2756 for 15 tons of bolts. He also recorded a cash payment for the same amount on March 10 of 1796, settling the contract in full. This entry is unusual because it does not break down Revere's expenses in any way. Also, his surviving correspondence does not explain how he heard about this contract and convinced General Jackson to hire him.[21]

Revere charged different prices for different types of bolts. In an August 31, 1798 letter to "the Committee building the ship at Mr. Hartt's yard," he offered to prepare spikes, rudder bands, chain for the rudder, bolts, and cogs for 37 cents per pound for cast copper or 41 cents a pound for malleable copper. In this case he was responding to an earlier request for his prices and terms, indicating that his reputation had preceded him.[22] By December of the same year his price for copper bolts and spikes (probably malleable copper, but this is not stated) rose to 50 cents per pound, and he expressed concern that he could not accept a new contract from Jacob Sheafe at Portsmouth because he could not find enough copper to finish his current contract. Raw material shortages affected his price as well as his ability to accept new work.[23]

A single ledger contained all of Revere's bolt, spike, and staple orders for the USS Constitution. This ledger began in September of 1798 and ended on April 2, 1799, and is unusual because Revere recorded all items in terms of their weight, and not their value. At the end of the contract, he computed a total of 8116.25 pounds of copper, but

[21] Ledger beginning with "1795 Octo 14 United States," Volume 9 (part 2) of RFP. Because the ship in question was constructed at Portsmouth, Revere probably conducted the negotiations in person.
[22] Revere to Naval Committee building the ship at Mr. Hartt's yard, August 31, 1798, RFP Volume 53.1.
[23] Revere to Jacob Sheafe, December 7, 1798, Ibid.

did not include an equivalent dollar amount. We can assume that he computed a final charge for the contract based on an overall price per pound that included labor and raw material costs. He clearly ignored any differences between bolts, spikes, staples, and other products by this point because they were all combined and their weights totaled.[24]

Revere's ledger records also contain smaller orders from merchant ships and miscellaneous goods for other naval vessels throughout this period. These orders range in value from $100 to Salem naval agent Joseph Waters to $876 for David Sears' ship "Indus." These small contracts reveal that Revere accepted payment in "old sheathing copper" and "old copper braces" in addition to cash, and that his product line continued to increase as he offered braces, various nails (including copper nails, sheathing nails, flat point nails), pintles, dove tails, composition cleats, braces, eye bolts, chambers for pumps, cast rollers, and chains.[25] If his prior experiences serve as a guide, Revere could reproduce nearly any item after observing how it was used and practicing for a bit. This period of product expansion and experimentation exposed him to the technology surrounding sheathing copper, and probably gave him the idea to attempt to produce that commodity as well.

Most of Revere's ledgers throughout his malleable copper production period are sketchy and incomplete, presenting the net fee from each contract and the status of the outstanding bills. One ledger provides information that would be helpful to Revere's overall business apart from any specific job. He maintained a fairly comprehensive ledger between May 1, 1799 and February 28, 1801 describing all his expenses and income. The vast majority of these activities involved the production of bolts and spikes. The debit column covers a variety of expenses, and the credit column lists payments received from different sources. Figure 3.1 outlines Revere's major expense categories.

[24] Ledger entry beginning "The Committee for building the 32 Gun Frigate at Harts Yard," Roll 6 Volume 9b, RFP.
[25] Miscellaneous ledger entries in Roll 6, Volume 9b, RFP.

Figure 3.1: Furnace Expenditures, 1799-1801

Expense	Cost (Dollars)	Percent of Total
Metal Purchases	14,989.58	70.02%
Fuel Costs	903.80	4.22%
Labor Costs	1,096.40	5.12%
Transportation (Shipping)	83.81	0.39%
Miscellaneous	4,333.91	20.24%
Total	$21,407.50	100%

Although most of Revere's costs are listed as a payment to an individual "for copper" or "for 6 weeks work," some are unlabeled, rendering them "miscellaneous." The miscellaneous costs primarily consist of ambiguous payments to individuals that probably represent additional raw material purchases and, to a lesser degree, wages. Other miscellaneous expenses include purchases of bricks, wire, and sand, and numerous small withdrawals labeled only as "cash."

Several patterns emerge from Revere's expense list. The constant need for copper (and iron, brass, bell metal, and tin, to lesser extents) dominated his operations and expenses. He recorded metal purchases ranging from seven dollars to over a thousand. He listed several purchases of old copper, cannon, and bells, indicating the need to recycle in order to meet demands. His supply network also reached a diverse level as he patronized at least 46 different metal suppliers (probably more than 50 after the unlabeled entries are considered), and numerous suppliers of coal, wood, charcoal, and other goods.

Revere's income is listed in a credit column that is far less comprehensive than the expenses ledger due to missing pages. Fortunately, he computed subtotals of his income at several times, and these subtotals cover the missing entries. He received $26,450.17 throughout this period. Although some of the 61 recorded payments are as small as two dollars, the average was over $430 thanks to twelve large payments of $500 or more (seven for a thousand dollars or more). Most of the payments merely record the name of the payee, but he did mention that five payments corresponded to bell purchases.

Stephen Higginson and Amasa Davis account for the four largest payments, all for Revere's work on federal government contracts.

Revere's gross revenues exceeded his expenses by $5042.67, yielding an approximation of his profit. Of course, this figure cannot be treated with any confidence or precision, because it depends upon Revere's subtotals and assumes that the beginning and ending of the debit and credit lists correspond to the same transactions. It also fails to include any hidden expenses such as his depreciation on tools and machinery, or the rent he paid for his property. With these disclaimers in mind, if the "profit" is compared to gross revenues, every dollar of sales yielded 19 cents income for Revere. This income, while not hurling him into the uppermost social or economic class, enabled him to continue amassing capital for future endeavors.

Management, Networking, and Adaptation

In the extremely fluid economic climate of postrevolutionary America, flexibility, adaptation, and innovation paved the way for great success. The 1790's saw a revival of commerce, and America's growing market economy created large demands for a wide range of products at a time when few domestic producers could compete with British goods. Britain's dominance of most manufacturing fields was an established fact, rarely questioned and in some cases appreciated for its impact upon America. But because of the hazards and costs of international transport, British goods were often surprisingly vulnerable in American markets. All that was needed was the initiative and capital required to master the process and establish a production system capable of meeting local needs at accepted prices.

By the end of the 1790's, Revere exploited these favorable conditions by filling the huge demand for malleable copper products. His position as a manufactory owner and supervisor enabled him to use his talents in a way that separated him decisively from the different laborers in his shop. The majority of his responsibilities fell into two categories: technical adaptation and networking.

Revere personally pioneered all technical processes employed in his shop. His adaptability is more evident at this point than at any other time in his life. Between 1792

and 1796, he learned to cast bells and cannon and draw malleable copper fasteners, all without any formal instruction. Revere was exceptional, repeatedly proving his ready intellect and creativity. In many ways he embodied the ideal of an adaptive American society struggling to emerge from Britain's shadow.

Revere also mastered the art of generating work for his shop. His location near the docks of a major port city and his numerous public and private contacts helped him identify lucrative projects and offer his services at the right time, usually before the work actually materialized. Of course, discovering the work was only half the job. No longer a newcomer to the metallurgical field, Revere's vast confidence was matched by an external reputation that accurately described his capabilities. He was becoming a respected manufacturer.

Revere marketed himself to the government during a period of federalist dominance, marked by international tension and domestic ambition. What the government lacked in competence and experience it made up for in ambition. Indeed, its ambitions were probably aided by the inability of most officeholders to recognize the funding limitations of the young bureaucracy. Revere corrected some of the government's deficiencies by boldly proposing new products or methods. He did this with two goals in mind. On one hand, he served his own interests with his extremely zealous work by making a profit and establishing a reputation for himself. However, he also wanted to do a good job to help his country. Although this is hard to prove (indeed, if Revere ever professed his patriotism, one would question his real motives), he did go to great lengths in his correspondence with key governmental figures such as Byers, Knox, and Coxe, offering free advice and other assistance. His government interactions employed a more respectful tone than his letters to private clients, and in spite of frequent delays and errors, he never considered ending the collaboration.

The curiosity and flexibility characterizing this period also propelled Revere into his next endeavor. Changing times called for new products. An advantageous location, his growing reputation, and a vast stockpile of experience helped him open the door to the greatest challenge of his life – rolling copper. All he needed now was government support.

The Early Federal Government: Problems and Promise

The United States government of the 1790s possessed three characteristics that complicated all its regular processes. First and foremost, it was completely inexperienced: every aspect of the federal government was new and its employees and officeholders had little or no administrative experience. Lawmakers often focused upon the theoretical underpinnings of the Constitution rather than the practical details of daily policy execution, rendering detailed transactions haphazard at best. Revere quickly learned that most government officials knew little about the products they asked him to produce, and knew even less about the funding mechanisms that would insure that he was paid. Second, the government was very small, and therefore limited in its budget and goals. This was partly an effect of the ongoing debate concerning strict versus loose construction, which forced all officials to carefully justify and even defend their actions. The government's small size affected Revere in several ways, by causing all of his contracts to undergo extensive review (usually after he provided his products but before he received his fee) and by plunging all operations into chaos every time any officeholder retired. Third, the government was intensely partisan, and many newspapers implied the very future of the nation seemed to hover on the possibility that the conflicting party might win a majority. Although the partisan nature of government helped Revere win some contracts in the 1790s, it would play a major role after 1800 when the majority party actively opposed his federalist ideology.

The federal government's activities shaped Revere's malleable copper contracts in the mid to late 1790s and wholly dominated his early copper rolling experiences. Fortunately for him, the government's reaction to changing international alliances and events provided large long-term contracts that balanced the frustrating delays and errors of the inexperienced bureaucracy. All of these impacts, good and bad, had their roots in the early years of the republic.

The government's deficit of administrative experience owed much to America's colonial status during much of the 18th century. Local and colonial governments operated on small and informal scales, and colonists rarely participated in the customs service, the largest colonial bureaucracy. Some Americans received administrative or managerial education in businesses or the army, but this was still haphazard.[26] The weak government created by the Articles of Confederation created a federal bureaucracy, but it was severely understaffed and overworked. Some government departments began to establish their own systems and traditions, but few of these administrators continued in office under the new Constitution, with Henry Knox as a key exception.[27] The new Constitution established a much stronger central government than that under the Articles of Confederation. The federal government now had the authority to borrow and coin money, tax, and regulate commerce, and the states were barred from usurping federal prerogatives such as issuing money or levying tariffs. Countless details remained to be defined, either by legislation or precedents set by the first generations of elected officials and civil servants. In the absence of clear Constitutional authority, many government officials hesitated before taking any action.

As the largest organizations in America and ones that had lengthy interactions with Revere, the army and navy merit special attention. After Congress demobilized the Revolutionary army, the War Department was reorganized and strengthened in 1791, and the new standing army reached a size of 12,000 men by 1798 in response to fears of a French invasion. Financing and supply problems plagued the army from the start. The administrative record of the early War Department provides repeated evidence of mismanagement, waste, the breakdown of supply lines, and an inability to delegate authority. The quartermaster's department and private contractors were singled out for particular criticism in a 1791 report. Alexander Hamilton described the prevailing situation in a colorful 1799 letter to the Secretary of War: "...the management of your Agents, as to the affair of supplies, is ridiculously bad. Besides the extreme delay, which

[26] White. *The Federalists,* pp. 470-474.
[27] Merrill Jensen, *The New Nation*, (Boston, Northeastern University Press, 1981), pp. 360-364, 373.

attends every operation, articles go forward in the most incomplete manner."[28] The government's chronic inefficiency had many sources. The Constitution did not specify whether the War or Treasury department should purchase and pay for supplies.[29] The Comptroller of the Treasury had to approve all federal funding claims personally, and even small errors in the application process led to rejection. Accounts were often submitted late, and the postal service was unreliable. In addition to a variety of specific factors and errors leading to delay, the overall youth and small size of the early American government must be emphasized: it was still learning how to function. Revere ran afoul of these pitfalls repeatedly in his manufacturing career – his papers contain many letters reminding different branches of the federal government that he had been waiting months for his payment.[30]

Unlike the American army, which dealt primarily with Indian issues until the War of 1812, America's navy was created and developed in order to address ever-changing international relations with various European powers. Although the department of the navy was only two years old when it contacted Revere in 1800, its origins stretch back to the creation of the new federal government and the mercantile and diplomatic policies of the early republic.

Benjamin Stoddert and the American Navy

Naval history presents an unusual paradox. The early navy was a vital component of national diplomacy and defense, and its existence and operations engendered continual partisan debate at all levels of government and throughout most American cities and town. At the same time, it was small enough to be almost completely managed by a

[28] White, *The Federalists,* p. 363; Russell F. Weigley *History of the United States Army* (New York: MacMillan Company, 1967) pp. 82-84; Richard H. Kohn, *Eagle and Sword* (New York: Macmillan Publishing, 1975) pp. 114-115, 123, 127, 187-188.

[29] Massive errors in the War Department's procurement process in 1790 gave Alexander Hamilton an excuse to implement complete central purchasing by the Treasury Department. In 1798, a congressional committee determined that the purchasing process was still divided and wasteful, and re-transferred purchasing authority to the War (and Navy) departments. White. pp. 360-362; Kohn, *Eagle and Sword*, pp. 111, 123-125.

[30] Revere's experience was far from unique. For example, James O' Hara, an army contractor, had still not been paid for his 1796 contract in 1801. White, *The Federalists*, pp. 148, 343-4, 33.

single individual. This paradox explains many of the factors that influenced Revere's copper rolling contracts and says much about the Navy's first chief executive.

The establishment and growth of the navy department would not have been possible without the financial prosperity and expansion of trade fostered by the Federalists, largely as a result of the philosophy and policies of Alexander Hamilton. Hamilton's policies bore fruit by the mid 1790s, when America enjoyed a restored public credit, stable national currency, huge quantities of investment capital, and a thriving merchant marine. America's growing merchant fleet went hand in hand with improved coastal fortifications, the creation of a navy, and a pro-British foreign policy, culminating in Jay's treaty. Jay's treaty allowed American merchants to continue their profitable activities (American exports increased in value from $33 million in 1794 to $94 million in 1801) but alienated powerful interests both at home and abroad.[31]

Although many Americans, and particularly Democratic-Republicans, protested the unfairness of Jay's generous treaty with Britain, France did more than protest. Viewing it as a tacit alliance with Britain, France declared war on American shipping in 1796 and 1797, as both her privateers and her warships began capturing merchant ships, particularly in the vicinity of the West Indies. By 1799, America had lost approximately $20 million of mercantile property to French attacks and shipping insurance increased from 6 to 25 percent. When John Adams' diplomats to France were told they would not receive an audience until they paid a large bribe (later known as the scandalous "XYZ Affair"), America revoked its earlier treaty with France and retaliated against France with its privateers and navy. Thus began an undeclared naval war with France in 1798, often called the "Quasi-War." This "war" was unique in American history because of America's lack of clear wartime goals. America did not seek victory or French defeat, privateering against French merchants was prohibited, and French warships were avoided except under special circumstances. America's only goal was the protection of its overseas commerce, best measured in terms of insurance rates.[32]

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[31] Donald Hickey, *The War of 1812: A Forgotten Conflict* (Urbana: University of Illinois Press, 1989), p. 6. Note that America's prosperity also resulted from the war between France and Britain, which created huge markets for goods and reduced the competition among merchants.

[32] Stanley Elkins and Eric McKitrick, *The Age of Federalism* (New York: Oxford University Press, 1993), p. 647; Michael A. Palmer, *Stoddert's War* (Annapolis: Naval Institute Press, 1987), pp. 4-6. Note that the French hostility against American shipping originated in the West Indies as much as the French Directory:

With the increasing complexity of naval affairs, Congress took the controversial step of establishing a separate Department of the Navy. Prior to 1798, the Secretary of War supervised all naval operations.[33] The creation of a separate department of the navy inspired new arguments between Federalists and Republicans over the ideal size and strength of the new navy. Federalists supported a strong navy that could defend American shipping interests and generate international respect, while Republicans felt the distance between America and Europe rendered a large navy useless and prohibitively expensive. A nation with a prominent navy anticipated international interactions and conflicts, while a nation without one expected a future of neutrality and isolation. Amidst all the conflict and rhetoric, 1798 also marked the appointment of America's first Secretary of the Navy, Benjamin Stoddert.[34]

Benjamin Stoddert was the only cabinet member President Adams did not inherit from Washington, and was by some accounts the President's most trusted advisor. Born in Maryland in 1751, Stoddert belonged to a major landholding family and served as a major in the Pennsylvania militia during the Revolutionary War until he received an appointment to the Board of War, which provided him with administrative experience and political connections. He established and managed a successful shipping firm in Georgetown after the war, until he received his appointment as Secretary of the Navy in June of 1798. Stoddert was a Federalist to the core and used his office to promote his vision of America as a powerful, self-sufficient, commerce-driven nation. Throughout the turbulent years of the early republic, Stoddert's intelligence, leadership, and drive stand out against a host of less experienced government employees.[35] According to Treasury Secretary Oliver Wolcott, "Mr. Stoddert is a man of great sagacity, and conducts the business of department with success and energy: he means to be popular; he has more of the confidence of the president than any officer of the government."[36]

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the Directory instructed French vessels and courts to treat neutral shipping the same way Britain treated it, but since local courts had no way of knowing what this meant, they did as they pleased. In the West Indies, this led to numerous captures and mock trials that always resulted in condemnation of American ships.

[33] In the late 1790s, the Secretary of War was James McHenry, described by contemporary friends and foes as a bureaucratically inept administrator. His lack of talent aided the birth of a separate navy department, since administrators hoped he would perform better if his responsibilities were reduced. Elkins and McKitrick, *The Age of Federalism*, pp. 629-630; Palmer, *Stoddert's War*, pp. 7-8.

[34] White, *The Federalists*, p. 156.

[35] Elkins and McKitrick, *The Age of Federalism*, pp. 634-5; Palmer, *Stoddert's War*, pp. 12-13.

[36] Quoted in Palmer, *Stoddert's War*, p. 125.

Stoddert inherited a single four-week old vessel, several appointed captains whose only experience lay in the merchant marines, two office rooms, and no administrative staff whatsoever. However, he would soon receive the services of three "superfrigates" whose construction had begun years earlier. The Naval Act of 1794 provided for the armament of six ships under the Department of War to protect American shipping from pirates of the Barbary states. Republican opposition to the idea of a standing navy resulted in the insertion of a clause stating that these ships would be decommissioned if hostilities ceased, and indeed, a peace treaty was signed with Algeria in 1795. However, George Washington lobbied in favor of at least a partial armament, and three of the frigates survived. Christened the USS Constitution, United States, and Constellation, they were completed and seaworthy by July of 1798. These ships had been brilliantly designed by Joshua Humphreys, and were longer, faster, heavier, more durable, and more efficient than any ship of their class in the world. They could usually outfight anything their own size, and outrun anything bigger.[37]

Stoddert's largest obstacle was the shortage of skilled manpower for all aspects of naval operations. He personally performed all administrative tasks, whether diplomatic, financial, technical, or logistical, from the development of national policy to the addressing of envelopes. Although administrative tasks occupied an enormous amount of his time, the manpower shortage gave him free reign to shape the navy as he saw fit and allowed him to handle every detail properly.

Because of bipartisan concerns with national defense, Stoddert was not excessively constrained by governmental stinginess. Republicans lost support after the XYZ controversy, and Congress voted fairly large appropriations to the Navy Department along with explicit permission to build three frigates, purchase more than 40 ships of all sizes, arm merchant ships, and establish a marine corps. Stoddert interpreted this mandate in the broadest possible terms, and immediately developed a network of naval agents who served as important links in the navy's administrative chain, acting as purchasing agents, recruiters, supervisors, local technical experts, and general "handymen." One agent generally supervised each naval yard, although they also

[37] White, *The Federalists*, p. 157; Elkins and McKitrick, *The Age of Federalism*, p. 644; Hickey, *The War of 1812*, p. 91. Note that a ship's class is based upon its size and the number of guns it carries. Humphreys' superfrigates carried 44 guns.

oversaw transactions between the government and the numerous merchants and private contractors who supplied the navy.[38]

By the early fall of 1798, Stoddert dispatched his small fleet to the West Indies to engage the French privateers. Although the logistics of waging America's first naval war at a vast distance from home ports were daunting, the young navy performed so well that it more than paid for itself within eight months. By 1800, American ships had defeated two French frigates (including the dramatic and much celebrated defeat of l'Insurgente, reportedly the fastest ship in France's navy), captured over 100 French privateers, and recaptured more than 70 captured American merchant ships. The price of shipping insurance dropped dramatically during this period, and hostilities came to a halt after the Convention of 1800 suspended all political ties between America and France.[39]

An ardent and utilitarian Federalist, Stoddert frequently had long-term national goals in mind when he took short-term actions. While managing the conduct of the Quasi-War, he also implemented many procedures to make the navy more efficient, modern, and self-sufficient. He embodied the "loose construction" philosophy by repeatedly and creatively reinterpreting his mandates to justify the expansion of governmental authority. For example, when Congress authorized only the pursuit of "armed" ships on the high seas, Stoddert informed his captains that any ship was armed if any of its crewmen carried a musket or pistol. And even though Congress voted against the acquisition of public naval sites in 1794, 1797, 1798, and 1799, Stoddert used $135,000 of a $700,000 shipbuilding appropriation to purchase six navy yards. He also interpreted a $200,000 timber appropriation as permission to purchase two wooded islands for $22,000. Later Congressional investigations condemned both of these purchases, but the government nevertheless chose to retain all of this property, which proved valuable to the 19th century American Navy.[40]

On December 29, 1798, Stoddert wrote a letter to Josiah Parker (Chairman of the House Committee of Naval Affairs) illustrating the full scope of his farsighted Federalist industrial policy. He began by observing that ships should be built locally instead of

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[38] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 1, pp. v-vi, 185; Leonard D. White, *The Jeffersonians: A Study in Administrative History* (New York: MacMillan, 1951), p. 291.
[39] Hickey, *The War of 1812*, p. 7; Elkins and McKitrick, *The Age of Federalism*, pp. 653-4.
[40] Palmer, *Stoddert's War*, pp. 141, 127.

purchased internationally, because building them insured that government expenditures enriched local industries. Similarly, he believed that ship construction should rely upon domestic raw materials and manufacturing establishments. America's long shipbuilding tradition simplified this requirement, since all commodities required for ship outfitting could be manufactured in the United States with the exception of hemp, canvas, and copper. Americans could privately grow or manufacture hemp and canvas if a steady demand could be assured via large government contracts, and indeed, under Stoddert's encouragement the hemp and canvas industries fully took root.[41]

Stoddert's belief that self-sufficient domestic industries lay in the nation's best interests separated him even from his fellow federalists. Even Alexander Hamilton's controversial *Report on Manufactures,* written for Congress in 1791, refrained from proposing government sponsorship of manufacturing establishments. Like most federalists, Hamilton primarily attempted to support commercial and financial institutions. His 1791 report avoided any pro-manufacturing proposals that might frighten merchants and as a result failed to address the proto-industrial segment's most pressing concerns, which were savage competition from cheap British imports, high labor costs, and lack of capital. Tench Coxe, Hamilton's assistant, was a much stronger proponent of manufacturing, going so far as to propose protective tariffs and government loans and land grants to manufacturers in a draft version of Hamilton's *Report.* Hamilton rejected these proposals, and undoubtedly avoided a confrontation with the strict constructionists and agricultural interests who opposed all extensions of federal power, and particularly the promotion of seemingly corrupting factory cultures.[42]

Stoddert shared Coxe's views, but unlike Coxe, he had the freedom and authority to act on them. His promotion of hemp and canvas industries required little effort or funding, and therefore took place without complications. Thus, the close of the century found Stoddert one major step away from his dream of a powerful navy built entirely in

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[41] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 2, pp. 129-134. According to Tench Coxe's *Statement of the Arts and Manufactures of the United States of America for the year 1810* (Philadelphia, 1814) hemp was produced in every state in 1810, with Kentucky providing the largest quantity.

[42] John R. Nelson, "Manufactures Reconsidered," in *Major Problems in the History of American Technology*, edited by Merritt Roe Smith and Gregory Clancey (Boston: Houghton Mifflin Company, 1998), pp. 132-3.

America, by Americans, from American products. But first, he had to solve the problem of rolling copper.

The Search for Sheathing

Stoddert's interest in naval self-sufficiency had permanent ramifications on the future of copperworking in America. America's copper history prior to his actions was a decentralized story of itinerant smiths and small, poorly operated copper mines, all operating in the looming shadow of British technology. By creating a demand and allocating government funds for the research process, Stoddert opened the door for entrepreneurial interest but lacked technological expertise.

Following the failure of early colonial copper mining efforts, imported copper products cheaply met the small American demand, and itinerant copper workers kept these items in good repair. If not for a growing navy that increasingly used copper, the colonial situation would have prevailed for much longer, with copper remaining a costly luxury item, easily replaced by other metals. The navy saw copper in a completely different light, as an essential resource able to save money by prolonging ships' operating lives. America's lack of copper mines and expertise suddenly became an expensive and potentially disastrous liability.

It had been known since Roman times that all wooden ships cruising in tropical or Mediterranean waters faced hull problems as their service life grew long: teredo shipworms weakened hulls by boring into planks, and barnacle accumulation rotted wood and reduced ship speed. Ship hulls became dangerously weakened in as little as two years, and the expensive refitting process required months. A solution to this problem would not only save money and labor, but would increase the number of operating ships in the fleet at any time. The mid-18th century British navy tried using different types of wood, lead sheathing, tar, hair, or paper to prolong hull life, with no success. Copper sheeting finally solved this problem, greatly prolonging a ship's working life by deterring or killing sea creatures that attempted to adhere to it.

The first ship to receive an experimental layer of copper sheeting upon its hull was Britain's H.M.S. Alarm, which was coppered in 1758. By 1763, the British Navy recognized the effectiveness of that technique, and by the American Revolution most British ships had coppered hulls.[43] This technology slowly migrated to America. Prior to 1795, very few United States ships used copper sheeting. That changed as merchants and later the Navy noticed the increasing presence of copper on the hulls of visiting ships, and copper sheathing was added to ships in the New York harbor as early as 1792. In April 12, 1794, Joshua Humphries advised Secretary of War Henry Knox of the radical changes being incorporated into new ships, including copper sheathing. Identifying the need for this technology was a big step, but America had a long way to go before implementing it.[44]

Although most copper objects were made from copper sheet, coppersmiths used the "battering" process to make sheets before the advent of water-driven rolling mills. This slow process involved repeated hammering and measuring of copper bars until they became sufficiently thin, long, and uniform. These techniques closely resembled silverworking skills, including reuse of old copper, cleaning, repairing, and cutting of copper sheets. One particularly complex and important task involved joining the edges of sheets to form a watertight seal. The battering technique sufficed during the period of low colonial demand, but any form of mass-produced sheet copper would have to be rolled in a water-powered rolling mill. Such a machine probably did not exist in America before 1800.[45]

Copper sheet rolling was an even greater technological challenge than other forms of copperwork, primarily because the manufacture of copper sheeting remained a guarded

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[43] Harris, *Industrial Espionage and Technology Transfer,* pp. 262-264; Edgard Moreno, "Patriotism and Profit: The Copper Mills at Canton" in *Paul Revere -- Artisan, Businessman, and Patriot*, (Boston: Paul Revere Memorial Association, 1988)p. 98.

[44] Margaret H. Hazen and Robert M. Hazen, *Wealth Inexhaustible*, p. 92; Maxwell Whiteman, *Copper for America: The Hendricks Family and a National Industry 1755-1939* (New Brunswick: Rutgers University Press, 1971), p. 47; Moreno, "Patriotism and Profit: The Copper Mills at Canton," p. 101.

[45] Mulholland, *A History of Metals in Colonial America*, pp. 92-3. Note that several copper rolling attempts may have succeeded in the 1770s and 1780s. Some surviving advertisements imply that a rolling mill was built in New Jersey before the Revolution, when it was destroyed. Another rolling mill in Maryland supposedly operated for a year in the early 1780s. These reports have not been confirmed, and other errors in Kauffman's work cast doubt upon this information. But even if earlier mills had operated, they were certainly dismantled and forgotten by the 1790s. Henry Kauffman, *American Copper and Brass* (Camden: T. Nelson, 1968), pp. 20-23.

technological secret in Britain and Europe. Sheathing a ship in copper was expensive and time consuming, but the process saved far more money and effort than it cost. The nation that mastered copper rolling technology was one huge step closer to a powerful navy and merchant fleet, and the person who could provide this sheeting was assured of profit and service to his country.

The failure of the most prosperous British copper mine in 1798 added further urgency to the copper situation in America. Britain first restricted copper exports in 1798 by declaring copper a vital naval store, thereby depriving the United States of its primary supply. While the United States Navy purchased refined copper from many places (e.g., copper plates from Sweden and Turkey, pigs from South America, and bars from Russia), Britain remained the most consistent and trusted source of high quality copper. Demand for copper bolts, spikes, and sheeting reached unprecedented levels during the merchant boom and naval armament period of the late 1790s, and British exports became highly unreliable due to the war. Britain's demand for copper ship sheathing caused the price of copper to rise from 25 cents per pound in 1791 to 50 cents per pound in 1798.[46]

Under Stoddert's direction, the Navy made several attempts to foster American copper refining, manufacturing, and rolling, by dispensing loans to defray research and startup costs to private firms followed by promises of large contracts. He first attempted to create an American copper industry on May 16, 1799, by granting a $10,000 naval loan to John Ross and Benjamin Henfrey, described as "Esquires" in the contract. Stoddert insisted they use the copper output of American mines to produce bolts, spikes, nails, and copper sheets "of quality equal to the rolled English, patent copper." He gave them seven months to produce bolts and spikes, and an additional year to learn to roll sheet copper.[47] Succeeding correspondence indicates that Stoddert had abandoned this attempt within three months, long before the first deadline, although he was quick to try again.

On August 22, 1799, Stoddert wrote to South Carolina's Robert Goodloe Harper, the Chairman of the House Committee of Ways and Means. "On the subject of coppering

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[46] Whiteman, *Copper for America*, p. 47; Moreno, "Patriotism and Profit: The Copper Mills at Canton,"p. 99; and Mulholland, *A History of Metals in Colonial America*, p. 161.

[47] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 3, p. 194.

our ships in London," he said, "don't you think it high time we should be out of leading strings—I hope the whole Copper for the 74's will be the produce and manufacture of our own Country and have made arrangements to that end which I believe will be attended with success."[48] Although it might appear that the "arrangements" mentioned in this letter referred to the Ross and Henfrey endeavor, his next piece of correspondence indicated that Stoddert had already given up on it and shifted to a second plan.

The very next day (August 23, 1799), Stoddert signed Articles of Agreement with Jacob Mark and Nicholas J. Roosevelt of New York City, whose professions are listed as "merchants." This contract stated that, in exchange for a $30,000 government loan, Mark and Roosevelt would erect machinery for the production of copper bolts and sheeting equal to the best British goods, and exclusively use domestic ore supplies from the Soho mine near Newark, New Jersey, which he owned. Compared to the Ross and Henfrey contract, this one was more legalistic and defensive, invoking several provisions to protect the government against default. The Navy's principal stated object was "establishment of domestic manufactures of copper on a scale proportional to the probable demands of the United States for the Navy Department." This was Stoddert's most ambitious and costly effort to secure an American source of copper. The Roosevelt enterprise intended to incorporate all aspects of the copper production process, from mining the ore to smelting, refining, and forging usable naval products. If this proposal succeeded, the United States would be self-sufficient with respect to copper in one stroke. Stoddert gave them one year to produce copper bolts and spikes, and an additional six to nine months for the copper sheeting.[49]

Stoddert revealed his doubts about the success of the Roosevelt venture in a letter to General Swan (his Baltimore purchasing agent) on January 17, 1800, and despite the contract that should have supplied all of the Navy's copper needs, asked Swan to look into importing bolts and spikes. For the domestic-minded Secretary, this request was an admission of defeat. Regardless of the funds Stoddert allocated, Americans seemed incapable of refining and rolling copper. The next day (January 18, 1800), he informed

[48] "The 74's" refer to the new 74-gun ships under construction. United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 4, p. 112.
[49] Ibid., pp. 118-9.

Roosevelt that Joshua Humphries had inspected the first batch of sample spikes and declared them unusable. Apparently, Roosevelt had hammered some of the spikes while they were still hot, rendering them too soft, and had cast other spikes directly, rendering them too brittle. Stoddert's letter betrayed a sense of exasperation, and provided Roosevelt with a brief lesson in metallurgy:

> The process is to take a piece of copper, heat it, and draw it near the size of a spike then cool it in water, hammer point & head it cold. If hammered hot, the spike will be too soft, will not drive, but bend in driving & often so far in the ship as not to be got out without great difficulty. As to cast spikes, there never can be certainty that they are solid... You can judge whether you can make such spikes, & if you cannot, the best way will be to give up the thing at once.

In the midst of Roosevelt's failure, Stoddert renewed his devotion to a self-sufficient American navy in a new letter to Josiah Parker. In particular, he focused on the vital importance of an American copper industry:

> ...as for copper the manufacture of this article requires the expenditures of so much money, that without effectual Public assistence it will not soon be established in the United States[50]

This seemingly obvious statement marked Stoddert as something of a visionary. He defied proponents of agriculture, strict constructionists, and champions of federal armories by taking the novel step of loaning money to a private manufactory, in the hope of increasing national industry.

Stoddert concluded his letter to Parker with the observation that Britain no longer exported any copper items because its largest mines were failing. America was on the verge of being completely cut off, and even a controversial $30,000 loan was not enough to enable Roosevelt to master the technical challenges of copperworking, to say nothing of the more complicated smelting and rolling processes. But hope was not lost. Revere had produced many tons of malleable copper bolts and spikes by this time. The stage was set for his entrance.

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[50] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 5, pp. 58-62.

Enter Revere

Paul Revere's copper rolling ambitions arose haphazardly, in contrast to Stoddert's grand plans. Revere had always wanted to expand the scope of his operations, and spent most of the 1790s adding new functionality to his operations, while gradually increasing their scope and profits. However, he also desired something different, as illustrated by his local government offices, attempts to serve in a federally appointed position, ferocious defense of his Revolutionary War record in a long and drawn out court-martial, and leadership role in fraternal and labor organizations. In addition to financial prosperity, Revere wanted social status, and respect from serving the public good. He first contacted Stoddert in an attempt to win a new copperworking contract and further increase his income, but as time passed he came to realize that he might satisfy both of his goals. But first he had to prove himself.

By the end of 1798, Revere had more bolt and spike orders from merchants, shipbuilders, and naval contractors than he could handle, primarily because copper shortages constrained his output. Malleable copper working brought him success and profit, but he already had his eye on the next step of the copper ladder, the final step of a lengthy professional evolution. Bolts and spikes were unquestionably important, but sheeting stood apart as the Holy Grail of copper technology. In a January 27, 1800 letter to Robert Goodloe Harper, Chairman of the House Committee of Ways and Means, Stoddert reported that the estimated copper cost for six proposed 74-gun ships was $170,000, compared to $300,000 for the frames and $180,000 for other timber. In general, copper constituted around 15 percent of a ship's total construction cost, and sheeting made up 60 percent of the copper expense.[51] If Revere could master this new product, he would have a monopoly on a product desperately needed by his country. First, he had to persuade Stoddert to give him a chance.

On the last day of December in 1798, Revere wrote the first of many letters to Stoddert, whose name he misspelled as "Stoddard." This letter is quoted at the beginning of this chapter. Although he would later work with Stoddert on copper sheeting, at this

[51] Paul Revere to Jacob Sheafe, Esq., December 7, 1798, RFP Volume 53.1; United States Office of Naval Records and Library, *Naval Documents Related to the Quasi-war Between the United States and France*, Volume 5, p. 139; Moreno, "Patriotism and Profit: The Copper Mills at Canton," p. 101.

early time he was primarily concerned with producing as many items as possible for the Navy department. Revere's information network efficiently informed him of Stoddert's position only six months after Stoddert's appointment. Revere listed the many copper products he was capable of producing, offered to learn to produce sheet copper if Stoddert could find a reliable copper source, and concluded by asking for information about any potential domestic copper sources.[52]

In spite of the fact that this letter arrived at the perfect time, Stoddert ignored it and instead made contracts with the two other would-be copper manufacturers before turning to Revere. Stoddert was a careful planner, unlikely to invest money in a man who was hardly known outside of Boston. Revere was still a small businessman who employed very few workers and owned limited equipment and capital. In contrast, he addressed Ross and Henfrey as "Esquire," and related to Roosevelt and Marks as fellow merchants who happened to own a copper mine. Revere lacked a sufficiently convincing advocate or reputation to help him receive a contract at this time.

He had a much stronger case by 1800. Revere wrote Stoddert a second letter on February 26, 1800, which is presented in figure 3.4 at the end of this chapter. He began by reminding Stoddert that he produced large quantities of malleable copper products that were currently beyond the abilities of Philadelphia and New York manufacturers. He then offered to build a special furnace and learn to smelt domestic copper ore into malleable copper, if the government would send him ore and pay his expenses. Revere honestly admitted "I have never tried, but from the experiments I have made I have no doubt I can do it." To sweeten the deal he promised to teach his two sons his business, and referred Stoddert to Congressman Harrison G. Otis and President John Adams as character references. More importantly, he enlisted Joshua Humphries as an ally. Aware of the scarcity of copperworking knowledge in America, Humphries had urged Stoddert to reject Revere's earlier letter, thinking Revere's claims were impossible. However, after visiting Revere's works, Humphries asked him to contact Stoddert again and make use of his name. He was clearly impressed.[53]

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[52] Paul Revere to Benjamin Stoddard (sic) Esq., December 31, 1798, RFP Volume 53.1.
[53] Paul Revere to Benjamin Stoddard (sic) Esq., February 26, 1800, Ibid.

Revere's letter to Stoddert was revealing. Although his self-confidence ran unchecked, he supported his claims with a convincing record of accomplishments. At a time when other Americans could not make copper malleable enough to form strong bolts, he had finished tons of products for various clients. Still, his boldness is evident: without ever having handled a substantial quantity of raw copper ore, he was certain he could smelt it. Some of this confidence possibly originated from his experience with refining iron (and possibly copper) in his furnace, although he surely realized the major differences between refining and smelting. However, a new awareness of his own mortality partially offset this confidence, moving him into a slightly defensive position. He was 65 years old, but offered his sons as a guarantee of future production. His old views of family continuity in apprenticeships and artisan shops still affected his thinking.

He followed up this letter by writing his version of a "Short History of that valuable & necessary Metal in this Country" in a letter to Congressman Otis, the Representative from Revere's district, on March 11, 1800. In this attempt to enlist the government, Revere discussed his long experience with bell and cannon manufacture and estimated that he had "made the greatest improvements in that metal of any man in this State, if not in the United States. I am confirmed in this opinion, from conversing with Col. Humphries of Philadelphia." It is interesting that Revere's history of copper in America was in fact a history of his own experiences with copper. He was acquiring a national mindset, and started imagining himself as the founder of a new American industry, a servant to his country.[54]

These letters soon bore fruit. Revere traveled to Philadelphia in May of 1800 and received a contract to produce bolts and spikes for two ships being built in Boston and Portsmouth. The results of this meeting were more than he expected, because Stoddert finally trusted him with his own pet project and reminded Revere of his 1798 offer to learn to roll sheet copper. In addition to signing a contract for bolts and spikes, Stoddert asked Revere to refine some domestic ore, and use it to roll sheet copper for testing and evaluation. On May 21, 1800, Stoddert told Stephen Higginson, his Boston naval agent, that it was more important to prove that Revere was capable of making sheeting than to have the sheeting meet any specific or immediate demand. Stoddert seemed impressed

[54] Paul Revere to Harrison G. Otis, March 11, 1800, H.G. Otis Papers, Massachusetts Historical Society.

with Revere, because he told Higginson to hire him on "such terms as may be considered liberal."[55]

On June 28, 1800, Stoddert asked Higginson to judge whether Revere could manufacture sheet copper equal to the British. If so, he would soon be asked to manufacture a large amount. On October 31 of the same year, Stoddert reemphasized the importance of determining if Revere could manufacture sheeting, "for it is very uncertain whether we shall long be permitted to import this article from any foreign country – England will not now supply it." Stoddert then laid out the terms of this contract. Higginson should offer Revere a $12,000 government loan (later reduced to $10,000) to help him establish his copper mill.[56] After years of independent frustration, Revere and Stoddert had finally found each other. The success or failure of their partnership now lay entirely on Revere's aging shoulders.

When Revere returned from Philadelphia in May of 1800, he had three objectives: smelt and refine a barrel of domestic copper ore provided by Stoddert; work it into spikes and bolts; and roll it into copper sheets. His first task, smelting the ore, would challenge him the most because he had absolutely no exposure to mining or smelting outside of theoretical texts he might have read. In addition, this was the most technically complex process. Copper smelting is a physical and chemical process requiring great heat (above 1084 degrees Celsius) and a chemically "reducing" atmosphere rich in carbon but lacking in oxygen. British smelters used a sixteenth century German process in which they roasted the ore to drive out sulfur and then melted it to draw off slag. They repeated these steps dozens of times on each batch of ore over a period of weeks or months until the right consistency was reached. Most miners switched to the simpler "Welsh process" after it was developed in 1750, because it used enormous quantities of coal to minimize the length of the operation.[57]

Revere already had extensive experience making malleable copper bolts and spikes, but sheet copper was a different matter entirely. As usual, he turned to established fields when approaching a new one, and in this case he turned to his own

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[55] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 5, p. 542.
[56] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 6, pp. 95, 517.
[57] Hyde, *Copper for America*, p. 9.

silver shop and observations of larger iron establishments. Revere had acquired a silver rolling mill in 1785 and used it extensively to produce sheet silver. By 1800 he would have become quite proficient in its use, but it was a small device used to process extremely malleable silver without the benefit of waterpower. It would teach him some aspects of copper rolling, but not all.

In contrast, iron rolling mills had much in common with copper mills, but Revere's exposure to them was limited and indirect. Iron rolling mills appeared in America with the first ironworks at Saugus, but were far from common. Colonial ironworkers passed red-hot bars through a set of water-powered rolls repeatedly, making the iron thinner each time. A cutting wheel or shears could eventually be used to slice the sheet into strips for wagon wheel ties and barrel hoops, or into small strips for nail making. Low-quality remains from Saugus indicate the lack of skilled expertise on these tasks.[58] Again, although Revere could learn the basics and the theory of rolling from iron rolling mills, he had to master the most relevant details independently. Low quality work sufficed for nail making, but not for Revere's clients.

The details of Revere's copper rolling preparations are unknown because they fell outside of any of his accounts at the time. He bought an ironworking mill in the town of Canton for $6,000 from Messrs Robbins, Leonard, and Kingsley either in 1800 or 1801.[59] Leonard and Kingsley had operated an ironworks on this property for many years, and Revere's new purchase included the right to utilize the water in the Neponset River and a deed to several buildings. These buildings contained useful equipment such as a water-powered slitting mill that could be used to cut iron or copper into workable bars or rods. By replacing the cutting wheel with parallel rollers, this machine could be converted into a rudimentary rolling mill, sparing him the problem of installing and adjusting the shafts and wheels associated with water power. Revere originally estimated that he could renovate the existing buildings and equipment by June of the same year. Undoubtedly, he saved money by renovating instead of buying or building new equipment. He had

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[58] Robert B. Gordon and Patrick M. Malone, *The Texture of Industry* (New York: Oxford University Press, 1994), p. 247.

[59] The uncertainty surrounding the exact date of Revere's land purchase, which could have happened at any time between January of 1800 and March of 1801 is described in Jayne E. Triber, *A True Republican* (Amherst: University of Massachusetts Press, 1998), p. 268 (footnote 4).

never controlled a water source before t his point, and it would prove both essential and limiting in the years to come.[60]

One cryptic record in Revere's memoranda book indicates that he built a new furnace in September of 1800. The notation reads:

> "Memorandom Septem 1800
> It took to build the new furnace 3000 Red &
> 200 White Brick
> 4 Cask lime
> Sano came to live at our house Tuesday Octo 14 1800 @ 2½ doll p week
> David Oliver came Octo 20 2½ p week[61]

This notation does not mention whether the new furnace was located in Canton or in his Boston workshop, and does not include prices for the bricks, lime, or total labor.

On January 13, 1801, Revere asked a friend traveling in England to purchase a set of iron rolls. "I can procure them here," he explained, "but not in such perfection as the English ones, neither are they so good." In addition to specifying dimensions for the rolls (20 inches long by nine inches diameter) he asked his friend to try to observe some British copper works, and determine how they heated their copper.[62] This is an understandable question, since copper sheets had to be heated before each pass through the rollers. If this could be made more efficient, the rolling mill's productivity would increase dramatically and the sheets might be less brittle. Whether Revere received any benefits from his friend's espionage is unknown, but other references in this letter to Joseph Pope, "a good mechanic and an ingenious man" reveal that Revere had other sources of information upon which he could draw, occasionally extending to Britain. A letter written in May of 1802 reveals that Revere was then using rolls of his own making, and he still desired British rolls, this time from Bristol.[63] Poor roll quality probably accounted for many of his early production errors such as irregularly sized sheets or "pitting." But because of his ingenuity in iron casting and turning, at least he had rolls.

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[60] Moreno, "Patriotism and Profit: The Copper Mills at Canton," p. 102. Waterpower issues are discussed in more detail in the following chapter.
[61] September 1800 memorandum in "Memoranda Book 1797-1801, Reel 14, Vol 51.14, RFP.
[62] Revere to Eben [Lux], January 13, 1801, RFP Volume 53.2.
[63] Paul Revere to William Bennoch, May 12, 1802, Ibid.

By January 17, 1801, Revere sent Stoddert a piece of sheet produced from the barrel of domestic ore, proof of his mastery of the smelting and rolling processes. The creation of this one sheet was grueling: by the time he finished, Revere converted approximately 400 pounds of ore into 30 pounds of copper sheathing. Along with the sample sheet, Revere submitted a letter describing the many difficulties he had to face:

> My apparatus is not calculated for smellting, but for refineing only, by which means it gave me more trouble, & a greater expense ... I had to refine that small quantity on a hearth, where I refine 1800 lb at one time, & I had to roll it by hand in a silver smiths plating mill.[64]

Because of his lack of equipment, Revere had to pound the ore by hand, smelt and refine the copper in an inefficient oversized furnace, and manually roll it into sheets on his small silver plating mill. He claimed that his yield would be doubled if he owned the proper equipment, and this was probably not an exaggeration. However, he was one of the few Americans to own this strange combination of silverworking and founding equipment, if not the only one, and his success was no small matter. In a later letter to Joshua Humphries, Revere apologized for the small width of his sample sheets, but pointed out that "the mill I rolled it in is the best there is in this Town."[65]

In the same letter that accompanied his sample sheet, Revere reported that he also finished a large shipment of bolts and spikes (60,000 pounds) and was working on his copper rolling mill. He estimated producing rolled copper sheets as early as June 1801. This letter also contained the first reference to his government loan. According to the final terms of the loan, after proving he could refine and roll copper he would receive a $10,000 interest-free advance that he could pay off in finished copper. This advance was intended to allow him to research and construct a copper rolling mill, since these high startup costs blocked most entrepreneurs from entering the field. However, Revere had not waited for the advance. By the time he submitted his sample sheet he was already in debt from his purchases of the Canton property, equipment, and copper. To expedite the repayment of his debt he asked to receive payment for his bolts and spikes whenever he delivered each order, a reasonable request that would not be heeded.

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[64] Paul Revere to Benjamin Stoddert, January 17, 1801, RFP Volume 53.1.
[65] Paul Revere to Joshua Humphreys, January 22, 1801, Ibid.

Ironically, the tests Revere passed in order to secure his loan and contract from Stoddert were vastly harder than any of the copper work he would later perform. Compared to smelting, all other copper fabrication processes were simple, and the 500-pound sample from Maryland was probably the last unworked ore Revere ever handled. The equipment he used for the sample sheet also added layers of complexity to the process, since none of it was intended for the task at hand. When Revere finished rebuilding his Canton rolling mill, his technology greatly surpassed the original equipment. Revere's workers regularly refined copper by pounding it with water-driven triphammers and heating it in air furnaces, and then drained the pure end product into flat bar-shaped molds. They heated these bars and passed them repeatedly through parallel rollers, decreasing the distance between the rollers each time until the proper sheet thickness was attained.[66]

After sending his first sample sheet to Stoddert, Revere recapped his success in triumphant letters to Harrison G. Otis and Joshua Humphreys. Revere informed Humphreys, by now a good friend, that he was modifying his recently purchased iron slitting mill to roll sheet copper according to "the English method." He proudly told Otis to see for himself the sample sheet in Stoddert's possession, adding "It is one Evidence that Copper can be got in our own Country & manufactured into Materials for Ship Building." Revere concluded his letter to Otis with the remark "What a dreadful change in Politicks" – perhaps the most prophetic statement he ever made.[67]

Reenter the Government

Thomas Jefferson's election and the impending change in administration would soon be worse than dreadful for Revere and his business. The Adams administration expired on March 3, 1801, and Jefferson's officers quickly replaced most of Adams' appointees, including Stoddert. Jefferson was the first truly unwelcome President in the eyes of New England Federalists such as Revere, and the new administration almost seemed like a

[66] Moreno, "Patriotism and Profit: The Copper Mills at Canton," p. 104.
[67] Paul Revere to Harrison G. Otis, January 17, 1801; Paul Revere to Joshua Humphreys, January 22, 1801, RFP Volume 53.1.

hostile coup. The political chaos that dominated and complicated the end of Revere's career had its origins in the differences between the first two political parties.

Alexander Hamilton, Washington's Secretary of the Treasury, was the prime mover of the Federalist party. He envisioned a powerful national government, led by an almost kinglike chief executive in command of a powerful army and navy to deal with both internal and external threats. Because America was not yet a world power, Hamilton favored close ties with Britain to insure continued trade revenues and support against other European powers. His vision required solid financial footing, and he implemented measures such as forming a new national Bank, consolidating all state and federal debts, issuing loan notes as a paper currency, intended to both restore fiscal stability and promote commercial growth. He also favored government support of large-scale industry, but these proposals, alone amidst his entire program, went unfulfilled due to powerful opposing interests. Hamilton's ongoing feud with John Adams, Washington's successor to the presidency, split and weakened the Federalist party.

Many factors contributed to Adams' administration losing the election, including the bitter internal rift between Adams and Hamilton, rising taxes to pay for national infrastructure and the Quasi-War with France, opposition to the Alien and Sedition acts, and the common association of Adams' party with elitist and pro-British policies. The Republicans attempted to reverse these trends when they assumed office, with Thomas Jefferson representing the primary opposition to Hamiltonian ideals. Jefferson promoted an agrarian future for America, strict interpretation of the Constitution in favor of states' sovereignty, close ties with the new French Republic, and democratic ideals. His supporters, including southern landowners and many northern artisans and laborers, joined together in their opposition to a powerful central government and artificial privilege. The Jeffersonians had constituted a vocal minority under the Washington and Adams administrations, but gained control of the legislative and executive branches in 1800, with many dire consequences for manufacturers.

Jefferson's succession to the presidency immediately shattered Stoddert's long-term plans for the United States' Navy. Stoddert's term lasted until April 1, 1801 and his successor, Robert Smith (Jefferson's Secretary of the Navy), did not take office until July 27. Interim Naval Secretaries included Secretary of War Henry Dearborn and General

Samuel Smith, who signed for the Secretary of War.[68] This slow and clumsy changing of the guard contributed to administrative delay on all outstanding contracts. During this confusing period the Quasi-War drew to a close as word of a peace treaty from Paris gradually reached administrators and naval commanders.

Jefferson began his first term of office with many goals, chief among them quieting the partisan strife, minimizing the size of government, and repaying the huge federal debt. His major administrative measures addressed the second and third of these goals, primarily by shrinking the army and navy, abolishing excise taxes, and cutting budgets wherever possible. According to historian Leonard White, "The full impact of the Jeffersonians' passion for economy and for the reduction of the debt fell upon the navy." Secretary of the Treasury Albert Gallatin launched an economy drive in 1801 and repeatedly decreased all naval appropriations, including work on wharves and dry docks. The 1800 naval appropriation of approximately $3 million was reduced to under $1 million by 1802, and continued shrinking until 1805 when Jefferson increased funding to build his conception of the ideal American navy: numerous small coastal gunboats instead of a small number of expensive ocean warships. Robert Smith had to deal with angry naval officers faced with demotions or the dry-docking of their ships, but could not affect this policy: in 1807 he told his brother-in-law "never was there a time when executive influence so completely governed the nation."[69] This was not an opportune time to ask for naval funding.

Revere's hopes and expectations were nearly smothered in early 1801. He wrote to Stoddert on March 5, attempting to collect the "advance" loan he was promised. Revere fulfilled his portion of the deal by preparing contracts and obtaining sufficient securities (collateral in the form of real estate) to cover the loan. However, when he brought them to Higginson, the Boston Naval Agent, he was informed that Higginson had new orders from "government," not to mention personal misgivings about whether Revere really needed the loan after all. Revere's letter to Stoddert reiterates that Revere did, in fact, desperately need the loan:

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[68] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 7, p. 128. This confusing transition was caused by Jefferson's inability to find a new Secretary of the Navy: many prospective candidates rejected Jefferson's offer.
[69] White, *The Jeffersonians*, pp. 75, 265, 267, 142-3.

> you, Sir, I am sure, are Sensible, that a business of this kind can not be carried on without money ... I was in hopes that I should be able to git thro with out the loan not doubting that I should obtain the loan if I wanted it. I now find I cannot go on with out it. I beg Sir you be so kind as to give Mr. Higginson such orders, as that I may be able to go on with the business. I have no doubt by the Month of June next I shall be able to produce Sheet Copper equal to the Brittish.[70]

Without the $10,000 advance from the Navy, Revere suffered from a critical cash shortage, and could not repay the private loans he had incurred to purchase the mill property, equipment, and operating expenses. The payment delay affected all aspects of his vulnerable new business. In a letter to William Bartlett of Newbury Port, he turned down an offer to purchase some copper, an opportunity he would ordinarily have seized, given the perpetual copper shortage. He explained that the change in the Administration (although he first, suggestively, wrote and crossed out the word "Government" instead of "Administration") had made him wary, and he therefore had to decline any new offers, especially until he knew the identity and plans of the new Secretary of the Navy.[71]

Throughout this trying period of administrative confusion and opposition, Revere sent a barrage of nearly identical letters to all relevant government officials (Stoddert, Samuel and Robert Smith, and Levi Lincoln), repeatedly restating the terms of the promised loan, his massive debt, and the pressing need for the government to pay him immediately. Robert Smith echoed the prevailing Jeffersonian belief in limited government power through strict Constitutional interpretation when he told Revere "I know of no law which authorizes this Dep't to lend money for the creation of copper works." Stunned that the federal government would even consider this sort of Constitutional question so late in the process, Revere pointed out in a follow-up letter that "I had no doubt but the present Administ. would have fulfilled what the last had promised. It is exceeding [missing words] individual should suffer, when he is exerting himself for the good of the Government." Revere was not going to be drawn into a

[70] Paul Revere to Benjamin Stoddert, March 5, 1801, RFP Volume 53.2.
[71] Paul Revere to William Bartlett, date prior to April 3, 1801, Ibid. The date and some of the text of the letter is missing, but it immediately precedes an April 3, 1801 letter.

theoretical debate regarding loose or strict Constitutional authority: he wanted the money he had been promised.[72]

Revere's persistence, string pulling, and letter writing campaign eventually paid off. On June 6, 1801, Samuel Smith told Samuel Brown, the new Boston Naval Agent, "altho I do not entirely approve of such Contracts yet as the faith of the Government is in some measure implicated it has been determined to comply therewith."[73] Although this approval and funding arrived frighteningly late, it still represented a victory for Revere. The monetary advance kept his business solvent, and he could repay it in copper products instead of cash.

Revere's ledgers confirm the financial hardship mentioned in his letters. One account record titled "1801 Furnace" lists his income and expenses between January 1, 1801 and March of 1802.[74] The debit and credit lists begin with the entry "to foot of account in Old Book," which carries over $10,431 of expenses and $14,351 of credits from 1800, the year before he began rolling copper. These values can be taken as a very rough approximation of Revere's costs and expenses before he began rolling copper, producing an estimate of approximately $3,900 of profits for the year 1800. In the 1801 ledger, Revere recorded a total of $28,608 of expenses, and $30,364 of income for a fifteen-month period, yielding a profit of $1,756. However, the income figure includes the $10,000 loan, which he received in two installments: $6000 on October 30 1801 and $4000 on February 1 of 1802. Without this loan, he would have faced over $8,000 of losses for this period.

Figure 3.2 presents a breakdown of Revere's income for 1801 and the first two months of 1802:

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[72] Paul Revere letter (addressee missing, but other sources indicate that it was Robert Smith), May 11, 1801, Ibid.

[73] United States. Office of Naval Records and Library, *Naval Documents related to the Quasi-war between the United States and France*, Volume 7, p. 247.

[74] "1801 Furnace," in Account Book, Boston 1793-1810, Roll 6 Volume 10 of RFP. These records are presumably comprehensive, but as always, this cannot be claimed with certainty, given Revere's incomplete and often confusing recordkeeping style.

Figure 3.2: Revere's "Furnace" Income Breakdown, 1801

Client	Amount	Percent of Total
United States Loan	10,000	32.93
Sam Brown, US Naval Agent	7,468	24.59
Stephen Higginson, US Naval Agent	3,343	11.01
Amasa Davis (State of Massachusetts)	2,916	9.6
Bell Sales (9 different clients)	1,973	6.5
Other	4,663	15.36
Total	**30,364**	**100**

The $10,000 loan stands out as the single largest revenue source for this period, representing almost a third of his total income. But even though this loan was extremely important, Revere's income records reveal other reasons for his financial survival. His next largest sources of revenue were payments of $7,468 and $3,343 from two federal naval agents, Sam Brown and Stephen Higginson, who continually bought large quantities of bolts, spikes, and other copper items. Unfortunately, these payments did not equal Revere's sales during this period. Revere lobbied to receive this money while simultaneously pushing for his $10,000 loan. In a letter to Levi Lincoln, the brother of two of Revere's sons-in-law and also the Attorney General of the United States, he mentioned that he already made 84,718 pounds of bolts and spikes and delivered them to the Navy.[75] At 24 cents profit per pound, the government owed over $20,000 for these bolts and spikes, and paid him a total of only $14,500 by December of 1801. Furthermore, he continued his production, amassing new government charges that had

[75] Revere to Levi Lincoln, April 21, 1801, Volume 53.1 RFP. Note that Levi Lincoln was Revere's good friend, finally a close personal contact who was well placed in the government. Revere wrote to him occasionally over the next few years whenever a contract encountered difficulty. As Attorney General, these matters had absolutely nothing to do with Lincoln's job responsibilities, and it is unclear whether he provided Revere with any assistance.

yet to be paid.[76] The payments that he did receive, however late and incomplete they might have been, certainly kept him afloat. Even while he struggled with the copper rolling process, Revere's workers continued churning out bolts and spikes, producing a steady revenue stream. Payments from the State of Massachusetts, sales of bells, and other transactions also helped him survive this difficult transitional period.

Figure 3.3 lists Revere's expenses during the same period. As always, raw materials represented Revere's largest expenditure, at almost 40% of his total. However, several charges for the purchase of his Canton property, stonework, and insurance for his rolling mill, constitute the second largest cost, which was substantial. Payments of loan principle and interest charges almost equaled the property costs, and greatly exceeded the cost of labor and fuel. The property and loan fees collectively drove Revere to the verge of financial loss during this period.

Figure 3.3: Revere's "Furnace" Expenses, 1801

Expense	Amount	Percent of Total
Raw Materials (copper and iron)	11,213	39.2
Property Purchase, Insurance, and Modification	6,589	23.03
Loans and Interest	6,258	21.88
Labor	4,267	14.92
Fuel (coal and wood)	281	0.98
Total	**28,608**	**100**

Revere eventually received his loan, at which point the mill had cost him well over 15 thousand dollars. By this time, Revere's works were operational, and he had rolled more copper, in addition to maintaining his production of malleable copper bolts and spikes. He expressed great pride in his achievement: "I have Erected my Works & have Rolled Sheat Copper which is approved of by the best judges here as being equal to

[76] A letter to Robert Smith on October 26, 1801 mentions that Revere had received "nearly 120 thousand weight of copper most of it refined ready to draw into bolts and spikes." This copper was the property of the government, and would serve Revere well through many future government contracts.

the best Cold Rolled copper." In November of 1801, the Navy corroborated this by giving his copper a rating of "excellent," and by the following May Revere informed Robert Smith that he had rolled over 20,000 pounds of sheet copper, which, when added to the bolts and spikes he made for the navy, fully repaid his $10,000 loan and completed his contract.[77]

Unfortunately, the government's administrative paralysis had only begun. Revere's steady stream of government correspondence did not abate with the receipt and completion of his loan terms. On July 1, 1803, he asked Smith for the return of the surety bond he originally provided as collateral for the government loan. Also, the government had not yet paid for further copper bolts and sheeting which Revere supplied, and he needed the money. This situation reached the crisis point in November of 1803, as described in a letter Revere sent to Robert Smith. He began by reminding Smith that he had delivered more than 64,000 pounds of worked copper to the government and had yet to be paid. Worse yet, in expectation of receiving his fees, Revere took out a $14,000 loan and used it to buy overseas copper, since the government was not providing enough to match his production. By the end of 1803 he had been paying interest on this loan for the past 13 months. He was owed $15,000 at this point, and Smith would soon buy an additional $10,000 of copper without paying for it. Revere's frustration was especially visible by the end of this letter, when he said "We beg leave to mention, that it is more than two years since we have received one Shilling from Government 'tho we have been at work for them the whole time." He tried to appeal to Smith's sense of fairness, saying "We are now Sir distresed for Money ... you must be sensible that it requires a considerable capital to carry on a Business the Stock of which cannot be purchased but with cash."[78] This comment certainly shows the great distance Revere and America had traveled from the barter and credit relations of colonial Boston.

This letter illustrates the type of institution that Revere was dealing with, a government that bears little resemblance to the government of today. He procured and paid for the copper used in the government contract, incurred debt and interest payments in doing so, and his reimbursement was over two years late. One has the impression that

[77] Paul Revere to Robert Smith, October 26, [1801], RFP Volume 53.2; Paul Revere to Robert Smith, May 24, 1802, Ibid.
[78] Paul Revere to Robert Smith, November 27, 1803, Ibid.

without constant goading from Revere, the government would have kept taking his copper without bothering to pay for it. This administrative lethargy was not a calculated attempt to save money or trick Revere into doing extra work. The government was, it seems, incapable of doing any better. Administrative inexperience or shorthandedness exposed all transactions to major postponements. Constitutional questions such as the Navy's right to offer loans to new industries produced huge delays as precedents and legal interpretations were sought. Consultations on practical and technical questions were even more difficult to conclude, because expertise on copperworking was hard to find anywhere in America, and especially scarce in the nation's capital.

A Match Made in Heaven?

Without naval funding and guaranteed contracts, Revere could have never afforded to research copper rolling. Without Revere's experience and technical flexibility, the navy seemed incapable of founding a copper rolling industry. In many ways, this was a match made in heaven. Or so it seemed.

The Revere-government partnership's effectiveness can only be measured according to how it enabled each party to achieve their goals. Although Stoddert had to deal with Constitutional and financial limitations, he had clear ideas about the direction he wished to take the navy. Stoddert was aware of the risks involved in loaning money to Revere, since he had already failed, twice, to jumpstart a copper industry with government loans. He undoubtedly considered his investment in Revere a major success, because it finally gave him the solid domestic source of copper sheeting that would complete America's ability to produce all naval commodities. His short tenure in office prevented him from realizing major practical benefits from Revere's operations, but his immediate successors would receive many tons of copper products from the small Canton mill. Other indirect benefits of Stoddert's investment included the transfer of Revere's technology to other American rolling mills in time for the War of 1812.

Revere's copper rolling startup experiences also illustrated the ideology and practical limitations of the early government, and in particular, of Benjamin Stoddert and

the Federalists in John Adams' administration. Stoddert's bold, loose interpretation of the federal government's powers to foster new industry clearly reveals that the government sponsored private endeavors as early as the 1790s. At a time when even Alexander Hamilton could not arrange for the House of Representatives to vote on his *Report on Manufactures*, Stoddert quietly found ways to support American industry, fund private research, and develop a powerful, self-sufficient navy. But at the same time, the government's administrative and bureaucratic limitations are more evident in this period than in Revere's earlier transactions. No government official, including Stoddert, seemed capable of paying for goods at the time of purchase or meeting their contractual obligations.

And what about Revere? Once again, he exploited his ability to apply one form of technical expertise to new endeavors, broadening the definition of technology transfer. In this case, Revere pioneered a new field and became the first to roll sheet copper. Although this sounds dramatic, it was not a terribly new experience in his life, since he had been jumping into new fields and mastering new technical challenges for years. The difference, of course, was the riskiness and scale of the rolling venture. Revere had no local practitioners to emulate or consult; British copper rollers were both distant and secretive; and the financial risk was far larger, threatening his life's savings. But although he could not rely upon equipment or personnel from Britain, he could draw upon other metallurgical fields, and after mastering the basic rolling process he could gradually refine his techniques by comparing his products to British output. The rolling mill, like his silversmith flatting mill, was a machine capable of producing fairly standardized output. This enabled him to participate in the technical experimentation and modification process, but step back and let his laborers perform the bulk of the work.

Revere probably did not understand the risks he was about to face because many of them fell outside his own experiences. He surely realized the technical challenges he had to overcome, but he confidently and correctly assumed he would master this process in time. However, he never realized the government would consistently fail to pay him on time, or question the propriety of a loan to private industry after it had been offered. Someone who valued honor and status as highly as he did probably assumed that an organization as powerful and important as the federal government would honor all of its

commitments unquestionably. And in the long run, in spite of endless delays, this is exactly what happened.

Revere rolled enough copper to pay his loan by May 1802, and successive huge contracts with the Navy continued to keep his business profitable for several years, although the government's payments were late more often than they were on time. If this was the price of a relationship with the early federal government, it was one Revere would gladly continue to pay. The size of these government contracts dwarfed all of his other work, and also augmented his reputation. Without the promise of a loan and the assurance of a huge contract that would let him repay the loan in goods instead of cash, would 65-year-old Paul Revere have risked bankruptcy to begin a new American industry? The answer is clear: without the United States Navy, there would have been no rolling mill at Canton.

Figure 3.4: Revere's Second Letter to Benjamin Stoddert

Benjamin Stoddard Esq.
Sec'y of the Navy

Boston, Feb'y 26, 1800

Dear Sir,

In Decem 1798 I had the honor of addressing a letter to you respecting Malleable Copper, wherein I mentioned that I manufactored either old or new copper into Bolts, Spikes, or any Matereals that was wanted in Ship Building.

In consequence of some conversations with Col. Humphries, since his arrival in Boston, I have been induced to trouble you again on that subject. I learn by that Gentleman, that there are no persons in either Philadelphia or New York that can make copper so Malable that it can be drawn in Bolts, Spikes, +c under the Hammer.

Within the last 16 months I have Manufactored into Bolts, Spikes, +c, upward of 10000 thousand weight for the Ships Boston & Essex. And upward of 13000 lb for the Merchants of Boston & Salem. I melt it into Pigs of 250 lbs each & draw it hot down to the size I want, some of it I have done into 10 penny nails.

Col Humphries tells me you have it much at heart to finish all the Ships built for our government with copper from mines in the United States and that there is a mine in Maryland & another in the Jerseys which produce a large quantity of Copper Ore but they cannot find any person that can smelt it so as to make it Malleable. I have never tried, but from the experiments I have made I have no doubt I can do it & if Government will send me ten or fifteen hundred weight of Oar & will pay my expenses I will Build a Furnace on [purpose?] this furnace is different from a Common Air Furnace & will endeavor to perfect myself in it. I have two sons who are concerned with me, if I make my self Master of the Business I will teach them. If these matters are worthy of your Notice, you know my character from his Excellency, the President of the United States, & from the Hon. Harrison G. Otis, member of Congress, to whom I am personally known.

If Government are not provided with bolts & spikes for the Ship which is to be built here, I shall be glad to supply one, or two, tons; which I suppose will be the most I shall be able to git old copper for. But if Government can purchase old copper sufficient for the whole, I will undertake to make all the Bolts & Spikes & cast work for her. The wrought work such as Bolts, Spikes, Dove tails, Brace Nails, +c for which I find the copper at 50 cents pr pound the cast work at 41 cents. I will allow 26 cents pr pound for all copper turned in by Government.

Col. Humphries has been at my works & after examining the Bolts & Spikes +c He had the frankness & goodness to say that He saw my letter to you & that he really believed He was the cause why there were no attention paid to it, for he then thought that no person in America could do it & but few in Europe.

CHAPTER FOUR: BECOMING INDUSTRIAL

Copper Roller and Manager (1802-1811)

Writing to naval secretary Robert Smith on May 24, 1802, Paul Revere mused about the presence of error in a new industry:

> You must be sensible, that every new manufacture that is attempted in our country will be attended with many dificultys ... this has been the case with us, but we have succeeded better than we feared, considering that the business was as new as if it had never been done any where; for we could git no information respecting it ... it can be no wonder if we made some mistakes.[1]

As anyone would guess after reading this preamble, bad news would soon follow. Revere and his workers had not yet mastered the nuances of the rolling process, and many of the sheets they rolled for this first shipment were too short. Indeed, saying he faced "many dificultys" was certainly not an understatement: he was deeply in debt, experimenting with new equipment, searching for skilled laborers, and competing with cheap imported goods, all while managing his Boston foundry.

By 1809, the situation had changed. In response to a government survey on manufacturing endeavors, Revere reported:

> The principle manufacture and that on which we most depend is Manufacturing Copper into Sheets, Bolts, Spikes, Nails, and every article used for fastening and Covering Ships Bottoms and Copper Smiths use. Ours is the only one in the United States. ... Benja Stoddert Naval Secretary as long as he remained in office fostered our manufactures. We manufacture Church and Ship bells of every size and weight cast every kind of Brass ordnance all our manufactures we warrant equal in goodness and manufacture to the English.[2]

Although he did not estimate his capital and profits, they were substantial by contemporary standards. He employed more than ten workers and owned a variety of new machines including two rolling mills, two air furnaces, a trip hammer, a wire drawer, and massive equipment for turning and boring his own cannon. Revere had branched out

[1] Revere to Robert Smith, May 24, 1802, Vol. 53.2 RFP.
[2] Revere to Henry Dearborn, September 13, 1809, Vol. 53.3 RFP.

into new markets for copper sheeting, including the manufacture of cooking utensils and boilers for Robert Fulton's steamboats, and still practiced the casting processes he began in 1792. By this point he was thinking big, bigger than his own growing operations, and he devoted more and more of his efforts to convincing Congress to raise a protective tariff on imported copper sheets. Perhaps Revere's greatest achievement was his partnership with his son Joseph Warren Revere (1777-1868), who by this point played at least an equal role as his father. Less than a year and a half after responding to the government survey, Revere retired from the business entirely and lived with his wife on their Canton property, confident that his business was in very good hands.

Revere's journey from his initial rolling operations to the success he achieved by his retirement in 1811 spans all of the issues faced by all American manufacturing concerns during the first 40 years of the new republic. As the market economy quickly encompassed all aspects of American life, new business practices appeared to enable shop owners to function on a larger scale. The application of technology also increased throughout this period, as manufactory owners tried to increase their productivity and the consistency of their output in scarce labor markets. At the same time, society's relationship with its natural environment evolved in the courts, the practices of manufacturers, and the consciousness of different individuals. All of these changes, occurring in unison, heralded the arrival of the age of industry.

The Onset of Industrialism

Many historians have remarked that America undertook two revolutions at the same time: a political struggle against British domination, and the ongoing Industrial Revolution that transformed all aspects of society and work.[3] The synchronicity of these revolutions was no coincidence: freedom from British regulation inspired a number of manufacturing endeavors, as well as a general spirit of enterprise and experimentation. But this freedom

[3] See John F. Kasson, *Civilizing the Machine* (New York: Hill and Wang, 1979), Carrol W. Pursell Jr. *Technology in America* (Cambridge: MIT Press, 1981), and Eric Hobsbawm *The Age of Revolution* (New York: Vintage Books, 1962).

and the rapidity of change must not be overstated: America remained completely within the British mercantile sphere well into the 1800s, and American cycles of prosperity and depression directly related to European wars and Britain's willingness to retract credit or flood the American market with inexpensive goods. In 1775 British America still operated in a pre-industrial manner that combined largely medieval technologies with a colonial economy.[4] The vast majority of the population lived on small farms in rural settings, and non-agricultural necessities were either imported or produced in small owner-operated craft shops. The growth in the size and number of manufacturing establishments at the end of the 18th century jeopardized this centuries-old system and led to a lengthy political debate on the future of the nation.

The debate surrounding manufacturing and its impact on America's future began in earnest after the Revolution and continued well into the 1800s.[5] This controversy originated in republican and agrarian notions of the nature of society. Republicanism contended that power was inherently aggressive and liberty was fragile. Both the virtue of the population and the checks within an ideal constitution had to act as restraints upon the natural tendencies of power to protect liberty. An agricultural ideal initially served as the ideal model for society because a geographically widespread nation of property owning farmers would (theoretically) remain virtuous by their hard labor, equality, and independence. Manufacturing complexes, in contrast, were linked to urban overcrowding and poverty, the oppression of the propertyless poor by factory owners and urban politicians, and excessive production of luxury goods that made the people self-indulgent and vile.[6]

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[4] John McCusker and Russell Menard, *The Economy of British America* (Chapel Hill: University of North Carolina Press, 1985) pp. 70, 327.

[5] The term "manufacturer," derived from the word "mano," originally described anyone who made items with their hands. Similarly, a "manufactory" was a gathering place for skilled workers. When the abbreviation "factory" gained prominence in the early 1800s, it took on additional connotations as a place of machinery. By 1835, Andrew Ure defined a factory strictly as a place in which workers and machines worked together for a single purpose. Later, factories would also be characterized by the presence of salaried supervisors, a further distinction from "shops" administered by their owner. Michael B. Folsom and Steven D. Lubar, *The Philosophy of Manufactures* (Chapel Hill: University of North Carolina Press, 1985), p. xxiv.

[6] Walter Licht, *Industrializing America* (Baltimore: Johns Hopkins University Press, 1995), pp. 2, 16; Kasson, *Civilizing the Machine,* pp. 7-8; John R. Nelson, *Liberty and Property* (Baltimore: Johns Hopkins Press, 1987), pp. 41-45.

Thomas Jefferson became one of the leading spokesmen for this viewpoint in the 1780s and 1790s, although he later mitigated his opinion and promoted certain types of manufacturing. Jefferson urged Americans to focus upon agriculture and leave manufacturing for Europe, which was already decadent and corrupt. As mentioned earlier, early federalists, including Alexander Hamilton, only halfheartedly advocated manufactures, because they didn't wish to endanger their support from commercial and financial interests. Part of the controversy surrounding manufactures resulted from the shifting and divided loyalties of merchants. Some merchants invested in industrial interests (and this proportion increased into the 1800s, particularly during embargos) while others opposed all forms of domestic production that might compete with their import trades. As late as 1810, Tench Coxe specifically mentioned the great mutual advantages received by merchant-manufacturer alliances in Britain and the comparative lack of such alliances in America.[7]

As manufacturing grew more prevalent, its supporters adopted new arguments to align it with republican goals. The Philadelphia physician-scientist Benjamin Rush expressed the earliest version of the pro-manufacturing viewpoint and voiced several key points: American manufactures would free the nation from British economic dominance and would preserve the virtue of the country by employing women, children, and the poor, thereby saving them from idleness. Tench Coxe eventually became the manufacturing community's most eloquent spokesman and adopted Rush's arguments, along with the belief that machines and factories would actually increase agricultural productivity by saving labor:

> These wonderful machines, working as if they were animated beings, endowed with all the talents of their inventors, laboring with organs that never tire, and subject to no expense of food, or bed, or raiment, or dwelling, may be justly considered as equivalent to an immense body of manufacturing recruits, suddenly enlisted in the service of the country.[8]

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[7] Folsom and Lubar, *The Philosophy of Manufactures*, pp. xxiii, xxvi; Nelson, *Liberty and Property*, pp. 43-45; Merritt Roe Smith, "Technological Determinism in American Culture" in *Does Technology Drive History*, ed. by Merritt Roe Smith and Leo Marx (Cambridge: MIT Press, 1994) pp. 2-5; and Tench Coxe, *Statement of the Arts and Manufactures of the United States of America for the year 1810*, p. xx.

[8] Coxe, *Statement of the Arts and Manufactures of the United States of America for the year 1810*, p. xxv.

American society gradually came to view manufacturing as a positive asset, with the hardworking laborer efficiently using America's vast natural resources to protect his countrymen from the profiteering foreign merchant.[9]

Luxury goods also lost many of their negative connotations after the increase of domestic manufacturing. Politicians gradually shifted elements of their republican philosophy to equate individual self-interest (such as the pursuit of luxury items) with the public good: if all members of society worked hard to earn enough money to buy luxuries, American prosperity would increase and idleness would diminish. Similarly, Americans no longer exclusively identified manufactures with luxury goods after defense armaments and productivity-increasing tools grew in volume and importance. The barriers to industrial capitalism eventually eroded and vanished by the War of 1812. In the words of John Kasson, "By ostensibly providing the means of wealth for all, technology made luxury safe for democracy."[10]

Late 18th century fears concerning machinery and manufacturing were far less prominent in New England because regional circumstances prevented machines from having visible harmful effects on agrarian life. By the end of the 18th century, most farmland in New England was already occupied and many younger sons had begun migrating to the west. Machines posed a negligible threat of stealing labor from agriculture, but could increase output, save labor, and provide new employment opportunities. New England also contained fewer recent immigrants and slaves than other areas, further diminishing fears of concentrated labor. As a result, New England cities became centers of industry and eventually fostered technological advancement because of the vast quantity of technical exchanges made possible through subcontracting, equipment comparisons, open shops, a relatively large pool of skilled labor, and technically competent entrepreneurs such as Revere. Merritt Roe Smith's comparison between the Harpers Ferry and Springfield armories illustrates the relative advantages enjoyed by New England manufacturing firms: the Harpers Ferry Armory in Virginia was hampered by a lack of discipline and constant resistance of skilled workers to change, while the Armory in Springfield, Massachusetts fed off of its community and

[9] Licht, *Industrializing America*, pp. 13-14; Kasson, *Civilizing the Machine,* pp. 10, 19, 30.
[10] Kasson, *Civilizing the Machine,* pp. 38-40.

had an easier time purchasing equipment and hiring technically proficient laborers. Nathan Rosenberg coined the term "technological convergence" to describe this phenomenon: when a large number of firms work on similar challenges and trade knowledge and solutions, rapid technological advancement usually results.[11]

Dynamic revolutions always run the risk of eclipsing the traditional settings from which they spring. By 1810 and even 1820, industrial establishments, cities, and power machinery still represented anomalies on the American landscape. In 1810, clocks and watches were rarities throughout the 90% of the country that still followed agrarian work and lifestyle patterns. Rural "work time," determined by natural and seasonal cycles, had a much greater influence than the carefully calibrated "clock time" that began to appear in factories and industrial establishments.[12] The individuals who operated in this new culture, and particularly the risk takers who first took this leap, constituted a small but extremely active minority that would play a primary role in shaping the nation's future. Paul Revere stands out amidst this unusual minority as a prominent participant in the older labor system who nevertheless pioneered the transition to the new managerial mindset.

Revere's Managerial Practices: Traditional versus Modern

At some point between the late 1780s and the 1820s, all of America – and New England in particular – underwent major changes that fostered the growth of a market and industrial culture. Transportation networks (fostered by improved roads, canals, and steamboats) expanded dramatically, merchants and stores grew more numerous and specialized, cash replaced barter exchanges, putting-out work became a common income source for many families, and hired labor accounted for a larger proportion of the work force. Labor historian Walter Licht contends that industrialism was first a product and

[11]Robert Gross, *The Minutemen and Their World* (New York: Hill and Wang, 1976) pp. 85-87; Merritt Roe Smith, *Harpers Ferry Armory and the New Technology* (Ithaca: Cornell University Press, 1977); Nathan Rosenberg, "Technological Change in the Machine Tool Industry," in *Journal of Economic History*, XXII (1963) pp. 423-443.
[12] Jonathan Prude, *The Coming of Industrial Order* (Cambridge: Cambridge University Press, 1983) p. 17.

then an agent of change. The same market growth that destroyed the British mercantile system also favored the growth of a modern industrial society, which created a series of new problems and governmental reactions.[13]

Technological and managerial change evolved in parallel. One major feature of early American craft establishments was their use of power machinery only for the initial processing of raw materials, for example, to saw lumber, grind grain, or forge iron. Skilled workers typically took over at that point and converted the processed materials into usable goods. These practices changed in the decades following the Revolution when entrepreneurs began emulating British practices by applying powered machinery to the production of finished goods such as textiles and copper sheets. The simultaneous growth of a market economy, among other factors, inspired many artisans and entrepreneurs to abandon the craft principles in which they had been educated and adopt new machinery and managerial practices aimed at producing more goods for broader markets. With the growing prevalence of machinery, owners brought larger numbers of workers together in factory settings, along with specialized supervisors to coordinate and even synchronize their operations. The large amounts of capital required for the purchase and support of land, labor, and equipment also inspired new forms of corporate ownership and the growing separation of owners and managers.

As a former artisan, Paul Revere might have resisted these changes. His reasons for joining the vanguard of the industrial and managerial revolution included his lifelong eagerness to master new processes and his desire to enter the increasingly anachronistic gentry class. Since a mid-18th century gentleman would not sully his hands with manual labor, Revere quickly adopted new practices that enabled him to identify himself as an owner and manager instead of a laborer, even though he previously stood among the most skilled laborers in the nation.[14]

It took more than willingness to become an effective manager, particularly in the turbulent decades after the Revolution when elements of old and new systems coexisted. Revere had plenty of experience from his prior business endeavors, but had to explore a

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[13] Licht, *Industrializing America*, pp. 4, xvii; Winifred Rothenberg, *From Market-Places to a Market Economy* (Chicago: University of Chicago Press, 1992), pp. 143-144, 242-244.

[14] See Merritt Roe Smith's *Becoming Engineers in Early Industrial America* (Cambridge: MIT STS Working Paper Number 13), especially pages 22-24.

variety of new techniques from 1802 until 1811, while focusing on his rolling mill. Most of these new techniques concerned Revere's internal policies, pertaining to his day-to-day production and sales. Strategies for his company's organization, labor relations, raw material procurement, accounting, and operational practices include an interesting mix of familiar traditions and new techniques, implying that his operations were affected more by raw material limitations (particularly copper and water shortages) than labor constraints. But in addition to altering his internal policies, Revere had to adopt new external policies to accommodate the increasing scale of his operations and the changing political and economic climate. In particular, he had more conflicts and litigation with other manufacturers in his area because of the competition for waterpower, and he spent more effort lobbying the federal government for direct and indirect aid, with little success.

Organizational Changes: Single Proprietor, Partnership, or Corporation?

As a silversmith, Revere never gave a moment's thought to the type of business he would run. The question was virtually meaningless. As a skilled artisan who owned his own tools, he had enough independence to work for himself, without partners. Therefore his operation was by default a sole proprietorship even though he never filed papers to register his practice. Other than insuring that he paid the proper tax on his property, there weren't any papers to file. Similarly, his business had no independent existence or a name – anyone wanting silver would hire Paul Revere even if an apprentice completed the work. As Revere mastered new processes throughout the end of the 18th century, he had no reason to alter the status quo. The most important consideration in choosing a business type was the ability to raise capital and pool expertise. Even though he was "only" a sole proprietor, Revere amassed many years of income from his various endeavors, and had a vast amount of technical knowledge and experience to draw upon. Even the capital requirements of the new rolling mill did not faze him, since he successfully lobbied for a substantial government loan.

In the midst of ever-increasing prosperity a few years after building his rolling mill, Revere decided it was time for a change:

> I have spent for the last three years most of my time in the Country where I have Mills for Rolling Sheets & Bolts, making Spikes, and every kind of copper fastening for ships. It has got to be a tolerable advantage business. I have one of my sons in partnership with me; he takes the care of the business in Boston, I take the care at Canton about 16 miles from Boston.[15]

On June 7, 1804 Revere signed Articles of Agreement to form a partnership with his second oldest son, Joseph Warren Revere. Paul listed his title, which indicated his occupation, as a "Gentleman" while Joseph Warren was a "Bell & Cannon Founder," a title he would later change to "Merchant" in spite of the fact that he spent nearly all of his time working at the Canton mill. Neither Revere nor his son wished to emphasize his manufacturing-oriented livelihood. The signing of these papers created a new entity, "Paul Revere and Son." This agreement combined elements of old and new business arrangements. The partners agreed to practice "the art & mystery" of bell and cannon founding for a period of three years, to work for the company's good and not their private interests, to pay all taxes and expenses equally, to divide profit equally ("share & share alike"), and to have equal access to all company books and records. In the case of the death of a partner or other reason for dissolution of the partnership, company assets would be divided according to the ownership ratio at the time of the contract's signing. Since Paul contributed $32,400 of stock and tools while Joseph Warren contributed $16,200 (rough approximations, as demonstrated by the lack of inventory records at this time), Paul became the "senior partner" and claimed two thirds of all company assets.[16]

Why would the elder Revere form a partnership at this time? Most likely this new arrangement explicitly acknowledged the relationship that had evolved over the past 14 or so years. Joseph Warren helped his father operate the foundry from the beginning. When Paul devoted the lion's share of his efforts to managing the Canton mill and property, Joseph Warren provided an invaluable service by becoming the supervisor of the Boston

[15] Revere to Thomas Ramdsen, August 4, 1804, Roll 2 RFP.
[16] Partnership agreement between Paul and Joseph Warren Revere, June 7, 1804, Ibid.

shop. This arrangement persisted until a storm destroyed the foundry building roof on October 9, 1804, inspiring the Reveres to consolidate all operations in Canton, although they still maintained a store for retail sales in Boston.

When this partnership expired on June 7, 1807 father and son renewed it until March 10, 1810. The renewal specified a fixed date for the termination of Paul Revere's career: if he was still alive in 1810, he would allow Joseph Warren to run the business alone after that point and would sell or lease his share of all stock and property at a fair price, with the exception of his house.[17] Apart from delaying his retirement until the beginning of 1811, this is exactly what Revere did.

Revere had another option in addition to a partnership. Many manufactories overcame their inability to raise large amounts of capital by forming corporations. If they could arrange to receive a corporate charter from the state legislature, the manufactory owner could sell shares of stock to raise enormous quantities of funds. Although limited liability did not appear as a corporate benefit until 1829, corporations often received corporate privileges such as monopolies, tax relief, or land grants from local or state governments. However, incorporating remained a rare organizational strategy at first. State legislatures only granted corporate charters in the 1790s and early 1800s to endeavors that served the public good. Most early corporations directly served the public welfare such as colleges and libraries, although profit-seeking endeavors such as banks and turnpike operation groups became increasingly prevalent. Massachusetts only granted three corporate charters to manufacturers between 1789 and 1796, but granted 15 between 1800 and 1809 and another 133 in the next decade. Also, the legislature rarely rejected these petitions as time passed, and frequently allowed the scope of these charters to include peripheral activities.[18]

Revere definitely knew about the existence of corporations – he was the first President of the Charitable Mechanics Association, which applied for a corporate charter

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[17] Partnership renewal between Paul and Joseph Warren Revere, June 7, 1807, Ibid.

[18] In 1801, only eight manufacturing corporations had received charters in all of America. Folsom and Lubar, *The Philosophy of Manufactures*, p. xxvii; Morton J. Horwitz, *The Transformation of American Law* (Cambridge: Harvard University Press, 1977) p. 308; Oscar Handlin and Mary Flug Handlin, *Commonwealth*, p. 162; Pauline Maier "The Revolutionary Origins of the American Corporation," in *William and Mary Quarterly* (Vol. L, No. 1, Jan. 1993) pp. 51, 53, 82.

in the 1790s and received it in the early 1800s. He probably gave little thought to the corporate option since he overcame the worst symptoms of his capital shortage in 1802 when he received his government loan. Perhaps he did not want to share the ownership of his shop with strangers, or perhaps he preferred to involve the government as little as possible in his business. At any rate, Revere and Son eventually incorporated in 1828 under the able leadership of Joseph Warren Revere.

Accounting, Contract Management, and New Business Practices

Although Revere did not radically alter his accounting methods at any point during his copper mill career, he continued evolving the procedures he had begun forty years earlier. For most of his life, Revere led the learning curve in the subject of bookkeeping methods. William Mitchell published the first American bookkeeping text in Philadelphia in 1796, explaining double entry, periodic balancing, and profit and loss.[19] Revere had been using these methods since the 1780s. However, by the time he included the Canton mill in his list of operations some of his older strategies led to confusion and omissions.

Revere categorized his operations in his record books. His most rigidly recorded transactions, understandably, were the sales he made to customers and the payments or barter he received in exchange. From a very early period he used the double entry system to keep track of these changing totals, and he continued the system throughout his life. Wastebooks allowed him to record sales and payments as they took place, and ledgers allowed him to compute the amount owed at any point.

Revere's general operating expenses, in contrast, occupied a much lower priority in his mind. If an expense could not be directly attributed to a client, Revere's system usually lacked a consistent place to record it. For example, a series of ledgers covering his workers' salaries, employment dates, and debts is contained in his Canton Ledger, but this only applied to the period from 1803 to 1808. In addition, this record seems incomplete, as it drew upon other information such as a list of each worker's absences that no longer exists in written form, if it ever did. Occasional receipts or records of

[19] Thomas C. Cochran, *Frontiers of Change: Early Industrialism in America* (New York: Oxford University Press, 1981), p. 36.

contracts describe specific payments or contractual agreements, but the very existence of these tidbits further illustrates the lack of a methodology to track such practices. Revere either was not aware or chose not to estimate intangible costs such as depreciation allowances upon his equipment or buildings. Eli Whitney began estimating and billing these costs for his Mill Rock armory as early as 1812, shortly after Revere's retirement.[20]

In general, Revere took a practical view of his business and recorded all information he believed would help him in the future. Sales and cash receipts had an immediate practical value because they helped him collect his debts, but lists of his overhead expenses did not serve an immediately obvious purpose. Revere lacked this element of the managerial mindset, and preferred to deal with employees and suppliers on a personal basis, using his best judgment to determine how much of a certain good to order, or what salary he should pay. The unpredictability of the nation's economy and international trade conditions might have contributed to Revere's lack of long term planning: when prices, raw material quantity, and consumer demand change radically from year to year, predictive record keeping might have seemed pointless. One result of this policy was the fairly common raw material shortages he faced, although external conditions certainly had a greater impact.

Revere continued changing the credit and payment practices he began with his foundry sales. As of 1805 he offered 60 days credit on all sales, although when he produced material for a ship, he expected the payment by the time the ship launched.[21] He also adopted a new policy to account for the interchangeability of many of his products: Revere and Son would buy back any bolts or spikes not used. This served as both a warrantee on his output as well as a testament to the volume of sales he experienced – unused bolts would soon find a new buyer in the Boston market. He offered a more explicit warrantee on all his composition copper and tin, offering to provide a full refund if requested.[22]

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[20] Merritt Roe Smith, "Eli Whitney and the American System of Manufacturing," in *Technology in America*, ed. by Carroll W. Pursell Jr. (Cambridge: MIT Press, 1989), p. 51.
[21] Revere to Hathaway and Davis, March 1, 1805, Vol. 53.2 RFP.
[22] Ibid.

In 1808 Revere implemented a different policy: customers now had four months of credit before their bill came due, but received a 5% discount for paying immediately.[23] By this time he was willing to offer discounts (effectively paying his customers a small fee) in exchange for faster payments. This undoubtedly reflected the new business climate, in which quick access to cash produced great benefits. In addition, Revere probably hoped to avoid the hassle of chasing down late payments, certainly not a new development. Prior transactions indicate that he was willing to subcontract this task to a professional. He hired Attorney Thomas Selfridge in February of 1806 to collect some of his outstanding debts. Selfridge received a commission of $6.40 per debt collected, and brought in four immediate debts ranging from $23 to $501.[24]

Many of these new concerns and policies arose from the increasing scale of operations at Canton. Until this point, Revere had conducted most business interactions personally. He solicited new orders in person or via letters to friends or contacts. He also relied upon intermediaries to spread the word of his product line, but these men were usually his friends (such as Joshua Humphreys) and may or may not have received a fee for their services. This system proved adequate when his output was low, but was not efficient in the growing capitalistic markets of the early 19th century. Revere recognized this problem, and sought the help of an expert located in America's largest manufacturing center. Joseph Carson was a Philadelphia factor who received commissions for arranging transactions between distant suppliers and producers. He first wrote Revere on June 6, 1809, with good news: the Philadelphia braziers he met with "all seem disposed to purchase your copper instead of English and seemed to regret not knowing of the establishment before." Carson's letter seethed with enthusiasm, as he described all of his contacts among the industrial centers in the Philadelphia area.[25] A prolific correspondence followed, and many contracts and raw material purchases resulted from Carson's work.

Historian Edgard Moreno calculated Revere's sheet copper sales, expenses, and profits over two one year periods, from June 1804 to June 1805, and again from June

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[23] Thomas Hazard to Revere, June 9, 1808, Roll 2 RFP.
[24] February 26, 1806 entries in Revere's "Boston Wastebook 1804-1811," Volume 5 RFP.
[25] Joseph Carson to Revere, June 6, 1809, Roll 2 RFP.

1806 to June 1807. The selection of these periods provides a representative sample of "typical" production quantities for Revere's mill. These results are displayed in Figure 4.1:

Figure 4.1: Revere's Sheet Copper Profits, 1804-5 and 1806-7[26]

Transaction	Cost	Percent of Total Cost	Percent of Total Sales
COSTS			
Labor	$424.	6%	4%
Transportation	$300.	4%	3%
Energy	$300.	4%	3%
Copper[27]	$6208	86%	58%
TOTAL COSTS:	$7232.		68%
TOTAL SALES:	$10,642.		
PROFIT:	$3,410.	47%	32%

Moreno totaled all of Revere's sales and determined that the total value of all sheet copper sales (approximately $10,642) constituted only 17% of Revere's total sales of all goods (roughly $62,600). During the two years of analysis listed above, copper sheet sales constituted only 17% of Revere's total mill output. This illustrates the diversity of his operations: in addition to sheet rolling he continued casting cannon and bells while producing enormous quantities of bolts, spikes, nails, and other items. When one product faltered, he depended on continued income from others.

[26] Edgard Moreno, "Patriotism and Profit: The Copper Mills at Canton," in *Paul Revere – Artisan, Businessman, and Patriot* (Boston: Paul Revere Memorial Association, 1988) p. 112.
[27] This copper cost includes an estimated 10% "wastage," which was the figure used by Revere. He was contractually responsible for absorbing the cost of all wasted metal.

Because Revere did not present any details about his use of labor and different resources, Moreno had to compute Revere's total costs and assume 17% of them applied to sheet copper production. These figures are extremely rough estimates that ignore all costs other than labor, transportation, fuel, and copper purchases. Although many of these hidden costs (such as advertising) would be negligible in comparison to the listed ones, others, such as equipment purchase, repair, and insurance, would be larger. Therefore, the profit listed above is an overestimation, by at least several percent.

An October 21, 1810 letter to Army paymaster Josiah Snelling catalogued Revere's output near the end of his involvement in the business:

> We have manufactured in one year 122976 lbs of copper Bolts & Spikes at 50 cents – 27659 pounds [of sheeting] at 50 cents 12976 pounds of brass cannon at 55 cents – 10845 pounds bells and 16547 pounds composition casting at 42 cents amount including stock $93959.16 the works are now capable of extending the mark to three times the amount that has ever been done.[28]

According to these figures, he sold almost $94,000 of merchandise in one year, approximately 15% of which came from sheeting. Revere's total sheeting sales of $13.830 for this year dwarf his earlier sales. This increase resulted from many factors, including the removal of all embargo and non-importation restrictions, renewed naval armament, increasing prosperity, and of course, Revere's increasing skill at producing and marketing copper.

Labor Practices

America suffered from a chronic labor shortage throughout its colonial years, a situation that persisted well into the 19th century. With local exceptions in major port cities, regions of high immigration, or congested areas, most Americans took advantage of cheap land prices to purchase and operate their own farms. Many historians have used the "labor scarcity" thesis to explain America's rapid industrial progress, willingness to

[28] Revere to Josiah Snelling, October 26, 1810, Vol. 53.4 RFP.

employ machinery, consumer behavior, and other trends.[29] The perceived consequences of the labor shortage even appear in Revere's correspondence. In 1803, Caleb Gibbs of Providence requested Revere's copper sheet and nail prices on behalf of several merchants, since "it will be better for them to purchase here, than to send to Europe." Gibbs then added "but they ought not to think that matters of this kind can be had in our Country yet as low as in Europe when we have to give such price for labour."[30] Clearly, labor was viewed as a limiting factor for American manufactures. But was it?

This question relates to the changing relationship between management and labor. The growth of the market economy and the spread of industrial production eroded and changed craft labor traditions. With the growing emphasis upon standardized goods, the division of labor, machine operation, daily wages, and regulated workdays, artisans no longer felt they received the privileges worthy of skilled laborers. Master-apprentice relations gradually shifted from an exchange of obligations to short, practical, and specialized training periods to prepare them to perform standardized tasks and receive a fixed wage. For example, Harpers Ferry Armory initially used an apprenticeship system that blended old and new work methods. Apprentices received a fixed monthly wage of $12 that largely paid for their room and board. In addition, they received a piecework wage for all their output above a certain minimum level. Their apprenticeship contracts bound them until they were 21, and promised to teach them the "Art and Mystery" of gunsmithing. They also received a new suit of clothing when they graduated. In 1809, managers changed this system to the "noncontractual training program" that treated apprentices as wage laborers. Harpers Ferry gave young boys a salary and nothing else, and their education suffered as a result. However, since many of the master armorers employed their own sons, many craft traditions and secrets propagated to the new generation.[31]

Changing traditions led to friction and protest. Early 19th century journeymen objected to wage cuts, the lengthening of the workday, deskilling, and competition from

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[29] H. J. Habakkuk, *American and British Technology in the Nineteenth Century* (Cambridge: Cambridge University Press, 1962), pp. 4-43; Licht, *Industrializing America,* p. 43; Paul A. David, *Technical Choice Innovation and Economic Growth* (Cambridge: Cambridge University Press, 1975) pp. 21-33.
[30] Caleb Gibbs to Revere, July 15, 1803, Roll 2 RFP.
[31] Smith, *Harpers Ferry Armory*, pp. 62-67.

day laborers. Masters, journeymen, and apprentices flocked to Jefferson's political party to oppose these changes, which they attributed to the Federalists. In short, they protested the erosion of the craft system, demanded to be treated as skilled laborers, and expected to enjoy all the privileges of the prior generation of artisans. For the most part they favored republican ideals and opposed "aristocratic" government dominated by wealthy property holders and investors.[32]

Paul Revere avoided all of these labor conflicts and did not share the "typical" artisan mentality. While operating his brass and copper endeavors throughout the 1790s he evolved a system of wage labor employment that adopted some trappings of the craft system, and he applied these practices to the new copper mill. The results were largely (although not entirely) successful, and he maintained a continual pool of from five to twelve mill workers between 1802 and 1810. The number of employees on his payroll and the total salary they received is displayed in Figure 4.2.

Figure 4.2: Size of Workforce and Labor Costs[33]

Year	Number of Workers	Total Labor Costs
1802	5	$1,276.
1803	5	$1,108.
1804	5	$1,002.
1805	7	$1,573.
1806	7	$1,831.
1807	10	$2,292.
1808	6	$1,490.
1809	12	$3,420.
1810	12	$3,641.
TOTAL:		**$17,633.**

[32] Licht, *Industrializing America*, pp. 49-51, 69.

[33] These figures are taken from Moreno, "Patriotism and Profit," p. 106. A comparison with Table 6.2, "Employee Salaries 1802-1806" reveals small discrepancies in the number of employees each year. In some cases Revere's records are ambiguous and subject to interpretation, and in other cases Moreno and I disagree, for example, as to whether twelve months of service beginning in December should count as one year of employment or two.

These figures reveal a general trend of growth, broken only in 1808 during Jefferson's non-importation and embargo policies. Revere relocated all his Boston foundry operations and equipment to Canton after October of 1804, which might account for some of the payroll increase because these figures apply to Canton and do not include Boston-based employees.

Revere's ledgers and correspondence do not betray any chronic reduction of output because of labor scarcity. Revere did face different labor problems at different times, as would be expected in any establishment. For example, in September of 1809 all of his workmen were unable to work for ten days because of sickness.[34] Throughout the period when workers and managers argued over who had the right to set schedules and the pace of work, many employees resorted to strategies such as a "slowdown" or feigned sickness to increase their leisure time. Revere's records do not indicate whether this crippling work stoppage had feigned or natural causes, but the former seems unlikely. Throughout all his employee records, frequent reports of absenteeism indicate that any worker could begin a leave of absence whenever he wanted as long as he was willing to forego his salary. Workers did not need to act sick in order to earn free time. Of course, this particular incident might have been a form of protest against a new policy. A second worker conflict occurred in 1810 when two of his principle workmen left in the middle of a job.[35] This abrupt and damaging departure almost certainly reflected unhappiness with Revere's conditions, although it might have indicated a sudden new business opportunity that lured them away. These were the only two instances throughout all of Revere's records when he attributed a production delay to labor problems.

Revere's labor relations are better understood in the context of early 19th century legal trends. Many disputes between laborers and managers reached the courts and in nearly all the early cases the courts favored the employer, a throwback to earlier court support for master craftsmen against their apprentices. Nineteenth century labor relations were more quantitative than the earlier system, frequently relying upon written contracts whose full impact had to be decided in the courts. In particular, most judges viewed labor

[34] Revere to Joseph Carson, September 8, 1809, Vol. 53.4 RFP.
[35] Revere to Joseph Carson, December 28, 1810, Ibid.

contracts as "entire" agreements that became null if violated in any way. In several egregious cases, employees signed yearlong contracts, missed a few days of work, and therefore had to forfeit all wages as their penalty for breaking the contract.[36] Revere never faced this problem with his laborers, partly because he seems to have relied upon informal verbal contracts. His son, Joseph Warren Revere, recorded four explicit written contracts in his "Canton Ledger," a notebook often used for miscellaneous record keeping tasks. These four notes are the only ones of their kind, possibly signaling an early experiment that was not continued. On November 15, 1805 he agreed to hire Enos Withington for one year (beginning the *prior* September) for eighteen dollars a month, with a raise to nineteen dollars a month for the last five months. On November 18, he enlisted Thomas Pattersole until April 1, at the rate of three shillings and sixpence per working day. On November 25 he contracted with Isaac Bosworth for one dollar per day, and on February 18, 1806 he hired Timothy Allen for one dollar a day.[37] The different agreement types are interesting: Withington's contract reflected months of work that had already taken place paid at a monthly rate, Pattersole's rate used shillings and pence to pay a day wage, and Bosworth and Allen were paid a dollar a day, as agreed before work began. Clearly, father and son lacked a consistent method for contracting salaries and labor.

Many early 19th century factory owners considered themselves responsible for the moral and spiritual well being of their workers. Examples of this practice include Eli Whitney, who styled himself a "steward of the Lord," and the Waltham and Lowell textile mills, which attracted young women from rural communities with their paternalistic emphasis upon regular church attendance and proper behavior. These new procedures arose in response to the widespread fear of industrial decadence and oppression, as different factory owners attempted to demonstrate that manufacturing establishments could educate and enlighten their workers. These attempts often led to employee dissatisfaction as the owner's attempts at rigid supervision diminished laborers' prior privileges: liquor and swearing on the job, and workers' freedom to spend the Sabbath as

[36] Horwitz. *The Transformation of American Law*, pp. 186-7.
[37] Page beginning with "15 Nov 1805," in "Canton Ledger 1802-6," Volume 29 RFP.

they saw fit were often curtailed or eliminated.[38] Revere never considered or implemented any policies along these lines. Despite all his attempts to become a gentleman, former craftsman Revere did understand the needs of skilled labor and seemed capable of dealing with his workers amicably.

In spite of the good relationship with his laborers, Revere was always in the market for new employees and occasionally wrote letters in search of recommendations or leads. One such exchange provides our only glimpse of a negotiation process. Revere received such a favorable report of Isaac Bosworth, a Plymouth copperworker, that he contacted him by letter to arrange a trial in his shop. Revere waited for his son to return from Europe before opening the negotiations, a sign of his faith in his partner. On October 19, 1805, Revere said he would not meet Bosworth's request of nine shillings a day (approximately $1.30 to $1.50) because this high rate would upset the current wage hierarchy. At the time he paid one man 18 dollars a month and had several job applicants request 20, so he offered Bosworth 26 dollars a month, which translated to one dollar a day for 26 working days (implying a six day workweek). Revere believed his wage system was advantageous for his laborers, saying: "you will judge wether that wages paid punctually in Cash is not better that the way you have received your wages." If Bosworth came for a trial month and both parties wished to continue the relationship, Revere then offered to engage him for a year. This is exactly what happened, because Revere sent Mrs. Bosworth 40 dollars in December of the same year (at his request), and informed her that Mr. Bosworth would remain at Canton over the winter.[39]

Figure 4.3 elaborates the salaries and employment periods for workers prior to 1807:

[38] Thomas Dublin, *Women at Work* (New York: Columbia University Press, 1979); Smith, "Eli Whitney and the American System of Manufacturing," pp. 51-53.
[39] Revere to Mr. Bosworth, October 19, 1805; Revere to Mrs. Bosworth, December 21, 1805, Vol. 53.2 RFP.

Figure 4.3: Employee Salaries, 1802-1806[40]

Name	Years of Employment	Salary
Willaby Dexter (foreman)	1802-1803	$45/month raised to $49/month
Jeremiah Dexter (foreman)	1802-1806	$1/day raised to $2/day
Amos Fales	1802-1804	$14/month
Jeremiah Vase	1802-1803	$11/month
Joseph Pettier	1802-1803	$1/day
John Story	1802-1805	$10.50/month raised to $16/month
Asa Smith	1803-1807	$7/month raised to $12/month
Otis Withington	1804	Unlisted, approx. $14/month
Jason Clap	1804-1806	$150/year raised to $16/month
Epparim Leonard	1804	$17/month
Enos Withington	1804-1806	$17/month raised to $18/month
Benaiah Wilder	1805	$16/month raised to $18/month
Thomas Pattersole	1805-1806	$15/month
Isaac Bosworth	1806	$1/day
Timothy Allen	1806	$1/day
Josiah Johnson	1806	Unlisted, approx. $.66/day

[40] Revere's "Canton Ledger 1802-1806," Vol. 29 RFP.

One obvious trend was Revere's switch from a monthly wage to a daily wage between 1805 and 1806 (although one worker received a daily wage before that). This change had no bearing upon Revere's treatment of issues such as absenteeism or pay schedules, since he converted monthly wages into daily rates whenever he had to deduct money from workers' accounts for missed days. The Bosworth letter mentioned above computes wages in both daily and monthly terms.

A second trend is the high rate of employee turnover. Most workers stayed for only one or two years and a stay of four years was exceptional. New England presented many opportunities for skilled laborers, as well as the ever-present lure of running one's own farm after amassing enough money. Revere's manufactory represented a good opportunity for workers to learn some useful technical skills while earning an excellent salary. This transient behavior could conceivably become a problem, but Revere's total number of workers steadily increased. As long as he could replace his losses and train the workers relatively quickly, Revere's labor situation would remain beneficial.

The only description of a worker's skills and/or job responsibilities applied to foreman Willaby Dexter, succeeded by his brother Jeremiah Dexter after Willaby left. Revere clearly trusted and respected Willaby, who received by far the highest salary in the plant (three months wages at $45/month and five months at $49/month) and who gave evidence for the court proceedings in Revere's lawsuit against Leonard and Kinsley in 1804. Jeremiah Dexter received the most raises of any employee in Revere's service, and became the highest paid worker after his brother left, as well as the first one to receive a daily wage.

Willaby Dexter also received money for the board of many of Revere's employees: Jon Battler, Pettier, Vase, Story, Withington, Mr. May, Jacob Perkins, Asa Smith, Joel Fales, and finally, "Nath Morton & Apprentices." (The apprentices probably belonged to long-time Revere employee Nathaniel Morton, and not to Revere himself.) These board charges totaled $182, a not inconsiderable sum.[41] Some of these workers (such as Battler, May, Perkins, and Morton and his apprentices) do not appear on Revere's ledgers, raising the question of why Revere paid their board. He might have

[41] Receipt from Paul Revere to Willaby Dexter, September 20 1803, **Roll 2 RFP**.

employed them in non-mill operations, for example, as carpenters or millwrights. After Willaby Dexter left his job, Revere paid his employees directly for their lodging at a rate of two dollars a week, presumably so they could make their own living arrangements. Subsidized lodging was definitely a throwback to artisan obligations, and Revere might have discontinued this practice in 1805 when he stopped recording lodging subsidies. In 1808 he revealed that he hoped to build "a large dwelling House" for his workmen on an unused part of his property, a plan that he never mentioned again.[42]

As far as their origins can be determined with any certainty, none of Revere's employees came from Britain. This is not from want of trying: one letter to friend William Bennoch in Britain announced "I should be glad to give good wages to a Man aquainted with the business."[43] But Bennoch never responded and Revere never mentioned this again. Given the prominence of British manufactures, he would probably brag about any British expertise he could recruit. His two foremen, the Dexter brothers, definitely came from the Canton area, and they would have the largest impact on most of his shop proceedings.

Raw Material Shortages and Procurement Strategies: Copper and Wood

Revere's operations did not suffer from labor shortages, but raw material availability was another matter. He quickly discovered that copper was much scarcer in America than iron. The roots of this problem traced to colonial practices. Unlike iron ore, which was plentiful throughout New England, copper ore was only occasionally found, and then in small quantities.[44] Most American copper mines consisted of "Appalachian sulfide" ore, difficult to smelt because of its extremely high sulfide content. Deposits of "oxide" ore, which is more desirable because it can be refined easily, were far smaller, and early American mining attempts typically failed to produce significant quantities of copper.[45]

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[42] Revere to the Selectmen of the Town of Canton, February 20, 1808, Roll 2 RFP.
[43] Revere to William Ben[noch], May 12, 1802, Volume 53.2 RFP.
[44] Vast deposits of copper were discovered throughout the Great Lakes region in the 1840s.
[45] Otis E. Young Jr., "Origins of the American Copper Industry," *Journal of the Early Republic*, Volume 3, Summer 1983, pp. 118-123, and James A. Mulholland, *A History of Metals in Colonial America* (Alabama: University of Alabama Press, 1981), pp. 43-47, 53.

Furthermore, even if miners discovered new sources of copper, the advanced state of British technology convinced American copper mine owners to ship nearly all of their copper ore to Britain for smelting and fabrication. Although several refineries operated briefly in the colonies to satisfy colonial demand for copper, operating costs were too high and local demand was too low for these operations to be profitable. At any rate, most colonial copper mining activities had been discontinued by the Revolution.[46]

America's chronic copper shortage plagued Revere throughout his career. Without a domestic supply, he either reused "old copper" or relied upon overseas copper shipments. Neither supply was trustworthy. Old copper was of extremely dubious quality, often containing pieces of iron or other metals, which ruined the finished product. In a 1796 letter to Nathaniel Gorham, Revere complained that "I was obliged to purchase it [copper] in small parcels which were utensils that had been burned in the West Indies and their was frequently among it Iron that I could not found." Imported copper usually had a higher quality, but its quantity and price depended on international trade conditions. While the United States Navy purchased refined copper from many places (e.g., copper plates from Sweden and Turkey, pigs from South America, and bars from Russia), Britain was its most trusted source of high quality copper. The failure of the most prosperous British copper mine in 1798 added further urgency to the copper situation in America. Britain first restricted copper exports (by declaring copper a "vital naval store") in 1798, depriving the United States of its primary supply.[47]

Revere summarized his problem in a June 10, 1803 letter to Naval Secretary Robert Smith: "We find it extremely difficult to procure Stock, either old Sheeting or other Copper, sufficient for our small Manufactory, the merchants not being in the habits of importing it." He then offered two suggestions: old copper sheathing stripped from government ships should be reserved for the recoppering process, and naval ships returning from the Mediterranean sea should purchase cheap, quality copper at the port of

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[46] An additional reason why colonists exported copper and locally fabricated iron lies in the average yields of both ores: usable iron typically comprises less than 10% of the weight of iron ore, while copper ores reached and exceed 50% usable metal. Transatlantic iron ore shipping was therefore more costly and wasteful than copper, because much of the shipping cost was wasted on useless dross. Mulholland, *A History of Metals in Colonial America*, pp. 49, 53, 91, 166.

[47] Charles K. Hyde, *Copper for America* (Tucson, University of Arizona Press, 1998), p. 10; Whiteman, *Copper for America: the Hendricks Family and a National Industry 1755-1939*, p. 47.

Smyrna to use as ballast for the trip home. Revere added that Britain imported much of its copper from Smyrna, and voiced the Stoddert-like sentiment "Should any difference arise between that government & ours would it not be difficult to procure a sufficient quantity from any other power for publick purposes?"[48] Once again, Revere seemed remarkably well informed about international politics, and predicted the War of 1812 about nine years in advance. Revere reiterated this advice in March of 1805 to Naval Officer Jacob Crowninshield, hoping he might alter Smith's policy. Revere had conducted even more extensive research by this point, and determined that copper in Smyrna could be purchased for as little as 20 cents a pound, while it cost 27 cents in Leghorn, the next cheapest source. This information partially resulted from Joseph Warren's fact-finding mission in Europe.[49]

Other than his unsuccessful attempts to alter naval policy, Revere did whatever he could to arrange a steady copper supply. He told Robert Smith "We are endeavoring to git in the way of importing it but that will take time" as early as 1803, but lacked the contacts and capital to deal directly with overseas suppliers.[50] He had better results from many small partnerships with different factors, or purchasing agents, such as Joseph Carson, and with larger importers such as New York City merchant and copper importer Harmon Hendricks. Hendricks and Revere arranged an informal "gentlemen's agreement" in 1805 in which they each agreed to avoid buying copper shipments arriving in the other's region. In addition, Revere and Hendricks occasionally made joint purchases of overseas copper, or sold raw and finished copper to each other. In October of 1809 Revere tried to arrange an unspecified form of partnership with a New Jersey mine that would have solved many of his problems, but this did not end up taking place.[51] Since copper was too important to do without, in the end he was forced to alter his work cycle and adjust his prices in response to the changing international supply. Although he occasionally complained to friends or clients about temporary copper shortages, his records suggest that his output was never impacted for long.

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[48] Revere to Robert Smith, June 10, 1803, Vol. 53.2 RFP.
[49] Revere to Jacob Crowninshield, March 30, 1805, Ibid.
[50] Revere to Robert Smith, October 29, 1803, Ibid.
[51] Revere to Joseph Carson, October 21 1809, Vol. 53.3 RFP; Whiteman, *Copper for America*, pp. 55-56.

Revere had a much easier time procuring wood and charcoal in comparison to copper. Although the land around Boston grew steadily deforested throughout the colonial and postrevolutionary period, fuel could always be obtained at a reasonable price. Throughout the year, he repeatedly purchased two to three cords of wood at a time from various suppliers. He preferred buying oak and chestnut woods (which are both hard woods) for $10 to $16 a cord, and purchased pine wood for under $7 a cord as a last resort. These suppliers are listed in his records under their individual names, and probably represented a variety of small landowners (in possession of wooded land) rather than merchants. These transactions, combined with the ready availability of wood within a short distance of Boston, kept prices fairly low and stable. He had to pay transportation as well as raw material costs (a common practice that also affected his copper purchases) but they represented a small fraction of his operating expenses. Factory-wide raw material costs were approximately $987 in 1806, and transportation costs were around $900. In contrast, Revere paid over $18,000 for copper.[52]

Interestingly, Revere seems to have purchased more wood than charcoal, which is peculiar because charcoal burns at a far higher temperature and would probably be necessary to actually melt the copper or iron. Incomplete or misleading record keeping may account for this discrepancy, or Revere may have included wood purchases for other uses (such as heating his home) in his company records.

Revere's relative ease of procuring fuel would not continue forever. In his 1810 report on Manufactures, Tench Coxe already noted the increasing number and severity of regional fuel shortages across the nation. He did not develop a comprehensive or long term solution other than to recommend industries such as wire drawing, cannon boring, and cutting establish themselves in low-fuel (coastal) regions, while the more fuel intensive industries should relocate to forested regions.[53] Most existing manufacturers, including Revere, did not have the luxury of relocating.

As a manufacturer, Revere could not fail to realize that the success of his business depended upon his ability to procure the necessary quantities of fuel, metal, and

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[52] Moreno, "Patriotism and Profit," pp. 107, 112.

[53] Tench Coxe, *Statement of the Arts and Manufactures of the United States of America for the year 1810*, p. lviii.

waterpower at reasonable prices. But neither Revere nor the other members of early 19th century America connected raw material usage to any larger entity such as nature, and the modern conception of environment did not even exist at that time. Nature was highly valued, but its bounty appeared infinite and unthreatened by America's ability to exploit it. He expressed his realization of resource constraints in economic terms and focused upon the pricing habits of merchants, suppliers, or the government. Instead of connecting the rising price of wood with regional deforestation, for example, he looked for different suppliers or for methods of cutting his transportation costs, raised his prices, or, most frequently, merely paid the higher price and made no comment. The market economy was far more tangible for him than any modern conception of the environment, and served as a mediator between nature and his industrial operations.

Water Power: Shortages and Control Strategies

Revere had to think about waterpower as soon as he began operating his copper mill. When he first purchased the Canton property, it contained several buildings and equipment from an ironworks that previously occupied his property. The ironwork buildings were stretched along the banks of the Neponset River in Canton, and included waterwheels that used the river's power to cut iron bars into small strips. Revere modified this equipment, enabling it to roll copper into sheets and thereby saving the major expense of building his own rolling mill or importing equipment from Britain. Revere used two waterwheels to drive his two rollers, and another for operating a triphammer. Waterwheels might also have driven bellows and turned a boring device for cannon.

Assuming that basic hydrological conditions remained roughly the same between 1800 and 1909, an estimate of Revere's available waterpower can be taken from an early 20th century study. In 1909, the Revere Copper Company offered its Canton land, buildings, and waterpower privileges for sale at public auction. The property description in the auction booklet describes this water privilege as an "average daily water power of 100 h.p. 12 hours a day." This power resulted from the drainage over a 27.5 square mile

region, with a net fall of 16 feet. The property included a small millpond on Revere's old property as well as the right to use some or all of the water in the Kinsley, Massapoag, and Reservoir ponds upstream. The engineer observed that the use of all of these additional water sources allowed 12 hours of flow even during the dry months. Figure 4.4 presents his findings of the waterpower throughout the year, if allowed to pass naturally over a 24-hour period and if stored at the dam and released over a 12-hour period.[54]

Figure 4.4: Neponset River Flow in 1909

Month	24 Hour Horsepower	Horsepower if Concentrated over 12 Hours
January	68.39	114.9
February	83.35	129.1
March	183.16	228.9
April	145.4	191.9
May	71.02	117.1
June	51.2	97.3
July	29.52	59
August	29.52	59
September	26.17	52.3
October	34	68
November	47.1	94.2
December	88.58	137.5
AVERAGE[55]	**58.8**	**100.3**

[54] J.E. Conant & Co., *The Plant (Real Estate) of the Revere Copper Co.*, (Lowell: Butterfield Printing Company, 1909).

[55] The average excludes the rainfall in April and March that exceeded the rainfall in December. This was probably done to compensate for wasted water during periods of high flow.

The middle column, measuring the waterpower over a 24-hour period, probably does a better job of approximating Revere's circumstances because he did not have access to all of the ponds his company could utilize in 1909. He did operate a dam, as will be discussed below. The river flow pattern described in Figure 4.4 reveals a dramatic seasonal cycle, with extremely powerful flows in March and April, and extremely low flows from July to October. This cycle explains the frequency of entries in his wastebook as well as his labor hiring practices, since each year's major activity began in November and ended in June. This contrasts with Revere's work patterns when he operated from Boston, because he then adjusted his schedule to correspond to the patterns of his customers.

Unfortunately, the river's flow left much to be desired. Although it usually met his needs in spring and late autumn, the river occasionally froze in the winter, and long dry spells in the summer often forced him to cease his copper rolling operations for weeks at a time. New York City merchant Harmon Hendricks mentioned this water shortage in an 1807 letter to Congressman Gordon Mumford. Hendricks wished to convince Mumford that Revere could not roll enough copper for all of America's needs, arguing:

> I do not hesitate to say it is out of his power to supply Boston market solely. His miniature manufactory & works have not one third of the year the advantage of water, I have been at Canton where are established those works and I write from my own observations.[56]

One possible solution to Revere's water shortage would have been to produce and stockpile large quantities of copper sheets when the river cooperated, and perform other tasks when it was too low. Although he might have done this to some degree, he often had to reserve his scarce supplies of copper for specific jobs. In general, the copper demand remained fickle throughout Revere's tenure, and stockpiling invited risk.

His second option involved regulating the river flow as much as possible by building and operating a dam, which he did at a very early point in his copper rolling

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[56] Whiteman, *Copper for America*, p. 78, quoting an undated 1807 letter from Harmon Hendricks to Gordon S. Mumford. Hendricks wrote this letter in response to Revere's tariff proposal, which would have increased the duty on the finished copper products Hendricks imported.

endeavors. Although the dam's effectiveness certainly depended upon the river flow, it allowed Revere to regain some control over nature by letting him store water overnight, on holidays, or when the river level was low, and release it in short, powerful torrents when he wished to run his mill. Although this solution might have struck him as an extremely efficient way to make the best of a bad situation, other river users did not agree with him.

Riparian Litigation: Competing for Control of a Scarce Resource

Revere was far from the only businessman operating dams along the Neponset and Charles Rivers (the two rivers had been connected by a diversion in 1639 to alleviate flooding along the Charles). By 1800 the Charles River contained at least eight dams and twenty mills, the majority of which had been built since 1775. As the river became more congested, different constituents engaged in lawsuits that forced the courts to interpret and alter early riparian legal philosophies to correspond with changing societal demands.[57]

Natural resource legislation provides an excellent window into the environmental attitudes and different definitions of property held by different members of the community. In colonial times, all restrictive legislation emanated from Britain, since the British government was most aware of the consequences of resource depletion following its own deforestation. Colonists greatly resented these impositions, and were unable to accept that the needs of a distant empire justified depriving them of economic opportunities. This attitude spilled over into the postrevolutionary government, which produced as few restrictions as possible. Circumstances eventually ran ahead of legislation. Numerous lawsuits, particularly concerning competition for waterpower, illustrated the finite extent of natural resources and provoked the formation of ideology and policy to optimally distribute these common goods.

The earliest water-use policies treated mills leniently because of their role in community development. Water-driven mills, typically saw and grist mills, often played

[57] Theodore Steinberg, *Nature Incorporated* (Amherst: University of Massachusetts Press, 1991), pp. 33-35.

a vital role in the economic strength of frontier developments. These mills blurred the boundary between private and public institutions, and as a result, enjoyed significant legal protection under various "mill acts."[58] This protection was usually invoked as a response to dam construction, which produced the majority of river use conflicts. Dams and holding ponds allowed the mill operator to efficiently regulate the flow of water to his equipment, which was vital during periods of low flow. The dam could stockpile water throughout the night, and release it gradually or in spurts throughout the day. Unfortunately, these dams obstructed the passage of fish or people, flooded the land upstream of the dam, and deprived downstream farmers of a steady supply of water (sudden surges of water frequently produced erosion). Because of the obvious utility of early "public" mills, most judges and legislatures, particularly in New England, considered industrial uses of rivers more important than all others with the exception of navigation. Under these acts mill owners could flood their neighbor's land without permission as long as they paid a yearly sum to cover any losses incurred.[59]

Gradually, protests against the vast leeway granted to mill owners forced a reevaluation of these laws. In particular, the increasing use of waterpower for personal profit and not directly for the public good necessitated a consistent quantification of the rights of different river users. According to legal historian Morton Horwitz, "By 1814 the growing separation between public and private enterprise was only beginning to penetrate the judicial mind." Some favoritism continued in New England after newer industries such as ironworks operated for blatantly private purposes, primarily because many judges believed all forms of industrial development lay in the public's best interests.[60]

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[58] Prude, *The Coming of Industrial Order*, p. 11; and Louis C. Hunter, *A History of Industrial Power in the United States, 1780-1930,* volume 1 (Charlottesville: University Press of Virginia, 1979), pp. 140, 142. Many of the early saw and grist mills had relatively small water demands and had smaller impacts upon river flow than the larger and more numerous mills of the early 19th century.

[59] The mill act represented a major departure from common law, which allowed punitive as well as compensatory damages and also granted the injured party the right of "self-help" (i.e., destruction of the offending dam) to correct the problem. Massachusetts passed the first mill act in 1713, and a more comprehensive version appeared in 1795. The mill acts reached their greatest extent after revisions in 1825 and 1827 which allowed virtually unlimited flooding of lands both above and below the dam, and allowed dam owners to avoid all damage payments if they could prove that the flooding provided economic benefits. Beginning in 1830, the courts reversed their support of the mill acts in response to widespread protest from small landowners. Horwitz, *The Transformation of American Law 1780-1860,* pp. 47-52; Louis C. Hunter, *A History of Industrial Power in the United States,* pp. 147, 148.

[60] Horwitz, *The Transformation of American Law 1780-1860,* pp. 49-50.

Preferential treatment for industrial water users constituted a significant departure from British common law, which defined rivers and streams as transient, ancient entities not subject to exclusive ownership by anyone. In Britain, any alteration to a river's "natural flow" was considered illegal. This doctrine was never used to limit drinking, bathing, or the servicing of livestock – traditional activities that themselves appeared "natural" – but instead applied to larger alterations of the river's flow such as irrigation or industry. A series of 18th and early 19th century legal decisions, particularly in Connecticut and Massachusetts, began altering the "natural flow" precedent after it was seen to prevent the establishment of new industries. Early laws proposed the "prior use" or "prescriptive" doctrine, which implied that mills had the right to use rivers for industrial purposes as long as they did not "wholly" obstruct their flow. Once any industry or individual established a pattern of water appropriation, it could sue latecomers who interfered with it. The law eventually dropped the "prior use" doctrine in favor of the "reasonable use" theory, which contended that land ownership included the right to use and alter the river water for business purposes, as long as such use did not "unfairly" injure other present or future users. This concept allowed each judge to apply their own definition of fairness, modified by the details of each case. In Massachusetts the results usually favored large business interests.[61]

This situation became more complicated when the majority of lawsuits pitted industries against other industries, which coincidentally took place when Revere was constructing his own water powered copper rolling mill. By the 19th century, many rivers had been congested with industrial developments, and dams regularly interfered with each other. An upstream dam controlled the water flow to all downstream users, and could easily choke off their supply or release water so quickly that it overflowed downstream dams. However, downstream users could "retaliate" (although the harmful consequences of "retaliation" were usually unintended) by building larger dams and producing "backwater," flooded riverbanks that either slowed or stopped upstream waterwheels. No single waterway could possibly satisfy all of these users under the old legal precedents. The philosophy and law of the river demanded change.

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[61] Theodore Steinberg, *Nature Incorporated*, pp. 140-141 and Horwitz, *The Transformation of American Law 1780-1860,* pp. 34-38.

Mill versus mill lawsuits highlighted the strong correlation between the law (in particular, property law) and private economic growth. The rapid growth of mills (primarily for textile production) after 1815 forced courts to acknowledge that dams could interfere with both upstream and downstream users. At the same time, judges realized that the "prior use" doctrine favored monopolistic control of waterpower: the first user could claim that all future users at any point along the same river interfered with his established rights. As a result the "reasonable use" criteria grew in popularity, particularly after 1825, until it became the established policy before mid-century.[62]

Horowitz lists three types of water use controversies throughout this period. First and most important, downstream users sued upstream mills for altering the river's natural flow via their dams. Second, upstream users sued their downstream neighbors for producing backwater that stopped their waterwheels. And third, neighboring landowners sued mills for flooding their land.[63] Although Revere settled some of his controversies out of court, he had the dubious distinction of being involved in all three types of dispute.

In October of 1804, Revere sued Jonathan Leonard and Adam Kinsley, the owners of an upstream ironworks (and, not coincidentally, the men who sold Revere his land four years earlier) for erecting and operating a dam that he claimed "obstructed and diverted the water" before it reached the waterwheel of his copper rolling mill. Revere's dealings with Leonard and Kinsley were not always hostile. After buying the Canton property from them, he carried out a large number of small miscellaneous transactions with them through 1803, including the purchase of rum, corn, cast iron, lime, and other items. He also shared surveying expenses with them, to establish the boundaries of each firm's

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[62] Horwitz, *The Transformation of American Law* pp. 38-45. Theodore Steinberg's study of New Hampshire water law points out a similar but slower evolution, with common law remaining dominant until about 1820, different prescriptive models holding sway from the 1820s until the 1850s, and a reasonable use doctrine appearing in the late 1850s. Theodore Steinberg, *Nature Incorporated*, pp. 140-147. According to Donald Worster, the doctrine of prior appropriation ("he who is first in time is first in right") survived in the Western United States, because large land developers and industries preserved it. Donald Worster, *Rivers of Empire* (New York: Oxford University Press, 1985) pp. 89-91.

[63] Horwitz, p. 35.

property in October of 1802. This territorial action might have foreshadowed the boundary disputes about to take place.[64]

Revere commissioned a study into the history of his land in preparation for this lawsuit. His research is included in 11 pages of notes dated in 1804 (one section is further dated "March 10, 1804").[65] The notes were probably submitted to the judge or paraphrased by Revere's lawyer when he took Leonard and Kinsley to court later that same year. This research indicated that Sam Briggs sold land to the Colony of Massachusetts in 1776 for the development of a gunpowder mill. The land included very specific water rights to insure that gunpowder production took place at steady levels: the colony had the right to uninterrupted water flow, and could order any upstream dams to open their gates in times of water scarcity. Massachusetts sold this land after the war and it passed through several other hands before Revere purchased it, but this water privilege was transmitted verbatim through all the deeds. Revere's 1801 deed from Leonard and Kinsley included a similar water right, granting him the right to "commanding the water thro any gates that are, or may be constructed between the Slitting Mill aforesaid and the Forge Dam on Taunton Road so called, whenever the same may be necessary for the use of the Slitting Mill Privilege."

Revere immediately recognized that this privilege was quite ambiguous. What if Leonard and Kinsley erected a dam beyond the forge dam? Also, was the forge dam in the privilege the same as the dam on Taunton Road? He attempted to prove that the forge dam did indeed correspond to the primary Leonard and Kinsley dam, which was also the source of all his problems. But this was where he ran into treachery from Leonard and Kinsley, on two separate charges. First, he discovered an "erasure" on the deed in the place where a precise description of the dam's location should have been. Revere might be able to command the "forge dam," but the "forge dam" was now unspecified, and Leonard and Kinsley could indicate a lower dam on the river even though Revere exclaimed "Ask any indifferent man in the Town where the Dam is on Taunton Road:

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[64] A list of Revere's payments to Leonard and Kinsley were submitted to the clerk's office of the court of common pleas on September 20, 1803. Leonard and Kinsley expense sheet, September 20, 1803, Roll 2 RFP.

[65] The following analysis was taken from Revere's 11 pages of unlabeled legal notes, dated March 10, 1804 at one point, Roll 2 RFP.

they point to the one above." Second, Leonard and Kinsley added language to the deed, preventing Revere from raising the river flow above a hole they drilled in a rock along the riverbed. He claimed they drilled this hole and inserted the new language "after the bargain was made & before the deed was delivered." As in many of his earlier interactions with customers or suppliers, Revere placed immense importance upon the concept of honor, which he believed Leonard and Kinsley did not possess. Revere also blamed his son's absence and his own naivety for the problems, implying that his son would not have been fooled the way he was. On both of these occasions Revere signed deeds based upon verbal agreements and later learned the specific wording deprived him of important assets.

Revere's description of the water shortage reveals his frustration. He admitted that when he first bought the property he was "very ignorant of Water Works." In 1802, Leonard and Kinsley built a new reservoir that was larger and deeper than the prior reservoir and controlled by a more efficient mechanism, whereas the older one leaked. Reading between the lines, a breakdown in the relations between Revere and Leonard and Kinsley after 1802 also contributed to the problem:

> ...it not being a dry season, we scarcely knew the want of water, when we did, they drew the gates for us. It is in their power in a dry time to keep the water from us ... if their saw and grist mills do not go, the water cannot come down the natural stream by reason of a mud sill which they have placed in the river ... the water which passes their common works will not supply us one quarter of the time. They have frequently kept the water from us all day & lett it down in the evening after we had left work.[66]

Revere described at some length the actions he was forced to take to continue his production at a reasonable level. He reported that he "has been obliged to make a new wheel, a foot wider than the old one, to make a new floome so as to lengthen the gate a foot, or the mill would be of little service to him."

He finally had his day in the Massachusetts Supreme Judicial Court during the 1804 October session. The court case transcript confirmed, "it became important to ascertain the place of the forge-dam mentioned in the deed – the parties not agreeing to its

[66] Ibid.

location." Testimony was called from Mr. Robbins, a source Revere claimed was allied to Leonard and Kinsley, and indeed, he upheld their definition of the dam. The court ruled against Revere on every count. The right to command all gates between his mill and the forge dam did not apply to the dam itself; he failed to prove definitively that his operations were harmed by the ironworks' operation of the dam; and he had "no right to command the defendants to open the gates" of any dam, but at best could open the gates himself. The judges viewed his lawsuit as an unfair attempt to injure his competitors, and defended everyone's right to both use and manipulate the river. Revere had to make two sets of payments to Leonard and Kinsley, in addition to paying his legal costs.[67]

This matter was far from over. In 1808, Leonard and Kinsley threatened to sue Revere for building his own dam and raising its height until it impeded their operations. The pair claimed the dam was "considerable higher" than his water right allowed and "does much damage by causing the back water to flow against our forge, grindstone, and gristmill wheels."[68] Revere apparently reacted to his earlier failed lawsuit by taking the water situation into his own hands. If he could not control the rate of water release from the upstream mill, he could build a high dam to catch the water before it reached his waterwheels, and then release it as he saw fit. But he might not have stopped there.

Revere's papers include an undated deposition from Abner Crane that was later dated "1808?" and took place no earlier than 1807. Abner Crane was related to Elijah Crane, a neighbor of Revere's whose land was flooded when he raised the dam. According to Crane, Revere had the right to a certain quantity of water as measured by a hole driven into a stone along the riverbed. Crane measured the height and location of the hole in 1803 and again in 1806, and noticed that the hole had been raised. The original location showed signs of tampering and the new hole was smaller.[69] Leonard and Kinsley probably sent this deposition to Revere in preparation for their lawsuit. Did Abner have an incentive to provide false testimony? Or did Revere – or perhaps his son – actually move the hole to increase their water right and rebel against Leonard and Kinsley's many underhanded practices? These questions cannot be answered from the available evidence,

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[67] Ephraim Williams, *Reports of Cases Argued and Determined in the Supreme Judicial Court of the State of Massachusetts from September 1804 to June* 1805 (Northampton, 1805) microfilm roll 2, pages 91 to 95.
[68] Leonard and Kinsley to Revere, April 20, 1808, Roll 2 RFP.
[69] Deposition from Abner Crane, dated "1808?," Ibid.

but at any rate this matter appears to have been resolved without the need for additional lawsuits. Considering the low flow of the Neponset River, the movement of new industries to the Canton area, and the increasing scale of Revere's business, we can safely assume that competition for water did not end in 1808.

Throughout his legal battles over his use of the river, the key environmental issue was not one of supply or demand, but one of control and competition. Even if the river had a larger volume, the different users would have interfered with each other's operations by regulating the river flow to suit their own schedules. Revere and his competitors used both technological and legal tools in their attempt to harness this natural power source, and the harsh language and threatening actions taken by both sides leaves no doubt about the importance of this issue. The river was a form of property, a natural resource essential for growing industries. To lose control meant defeat.

Continued Litigation: Control of Property

Revere's riparian lawsuits spilled over to other disputes involving land use. On February 20, 1808, he wrote a furious letter to the Selectmen of the Town of Canton. On the 17th the Selectmen sent Revere a letter announcing that they would build a road through his property "within a few hours," leaving him no opportunity to protest. Revere hinted at a possible motivation for this sudden action: "The petitioners do it from wiked hearts, their whole view is to hurt us and not help themselves." These petitioners happened to be the Cranes, the same family whose land was flooded when Revere built his dam and who testified that he moved the hole in the rock. Revere believed the Cranes "have aimed at our ruin since Jonathan Leonard returned from Kent to Canton. We know their views and we believe that their intention is to drive us from Canton, that they may purchase our Estate for less than nothing."[70]

In his usual thorough manner, Revere analyzed the situation. For starters, the letter was dated the 17th but sent on the 19th by Jonathan Leonard's servant, intentionally waiting for a time when both Revere and his son were in Boston. The proposed road:

[70] Revere to the Selectmen of the Town of Canton, February 20, 1808, Roll 2 RFP.

> would reduce the value of our Mills & Works to less than one half they cost us; for were it a Common highway it would lead every kind of Creature by our works, and our Stock of Manufactures would not be safe. Besides, the passage way between the house and river is so narrow that a Horse or Ox passing by in the night allways disturbs the family.

In this letter Revere also mentioned some of his future plans for the land that the road would occupy. He needed to enlarge his gardens, which were already too small for his family. He planned to build a new forge building, possibly representing the relocation of the Boston foundry. And he expected to build "a large dwelling House" for his workmen. Revere concluded that he had to "improve every inch of ground on that side of the river," and asked if it was fair to attack two men "who spend more real money in the Town of Canton than any five men in it."[71] This revealed many elements of Revere's philosophy, such as the need for privacy and security, his frustration with "every kind of Creature" who might travel public highways, the value of his contributions to the town's economy, and the respect he deserved as a result. America might have been moving towards a classless society dominated by the "middling" sort, but Revere held old fashioned values, and at the end of his life felt he had earned certain privileges.[72] And perhaps he had. Unlike the water regulation cases, Revere won this battle. His angry protest and defense of his right to develop his own property forestalled the new road construction. Although the water control lawsuits represented a version of a property dispute, a river does not look or act like property. Judges had a hard time believing Leonard's control of the dam could prove injurious, since the same water would eventually arrive at Revere's stretch of the river. The road through Revere's land was entirely different. Anyone could understand the intrusion presented by a public highway, and the local government did not feel comfortable imposing this upon an unwilling landowner.

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[71] Ibid.

[72] Gordon Wood, *Radicalism of the American Revolution* (New York: Vintage Books, 1993), pp. 347-351.

In 1802, Revere thought of his rolling mill in very restricted terms. Funded by a hard-won loan from the Department of the Navy and faced with thousands of pounds of government copper waiting to be rolled into sheets, he saw this new enterprise primarily as a tool for the completion of government contracts. Although his mill had been operating for a very short time, he had no trouble imagining it on a large scale, as a vital component of America's defense program. This confidence and enthusiasm was an important prerequisite in Revere's attempt to create a major manufactory. He had abandoned much of his small craft shop mentality and was willing to think big, to lobby for major contracts and federal protection. But would this be enough?

Revere's early contracts paint a picture of great productivity and prove how much the government counted on his ability. He received over 193,000 pounds of copper from Boston naval agent Stephen Higginson in 1802, enough copper to satisfy all the bolt, spike, sheathing, and other copper needs of the two 74-gun ships about to be constructed. By November he already delivered almost 85,000 pounds of bolts and spikes to the navy yard, and had another 40,000 pounds of bolts and spikes ready for shipment. The remaining copper (over 68,000 pounds) was refined and melted, ready to be made into whatever was needed, probably sheeting. The navy trusted him with all the copper manufacturing for two major vessels, and he was well on his way to finishing the entire contract.[73]

Unfortunately, the federal government and Revere had many frustrating interactions in the years to come. Federal payments were more often late than on time, and different government representatives gave him repetitive or confused requests. His requests for tariff protection, federal appointments, or new contracts were almost never granted. He dropped a clue about his opinion of the relative importance of his federal and state contracts in a November 6, 1802, letter to Robert Smith. Revere could not account for all of the sheets he rolled a few months earlier, because "about that time I had an application for thin sheet copper to cover the Dome of the new State House, which was

[73] Revere to Robert Smith, November 6, 1802, and Revere Letter, recipient unknown (probably Samuel Brown), November 6, 1802, Vol. 53.2 RFP.

an order of so considerable consequence to us, that we undertook it."[74] Unlike the federal government contracts that always involved late payments, misunderstandings, and voluminous correspondence, this Boston job did not require any letters and the payment was both simple and prompt. Revere later provided sheathing for the dome of New York city hall, and the transaction unfolded smoothly.

In general, Revere's Federalist sensibilities did not endear him to the Republican administration. His dissatisfaction became evident in an 1804 letter:

> I very much doubt my influence with the present Administration. My sentiments differ very widely from theirs in politicks – My friend, you know I was allways a warm Republican; I always deprecated Democracy as much as I did Aristocracy; Our Government is now completely Democratic, they turn every person out of office who are not nor will be of their way of thinking & acting.[75]

Instead of favoring aristocracy or democracy, Revere was a die-hard supporter of the meritocracy. After a lifetime of hard work and technical accomplishments he believed he should occupy one of the highest social tiers. His dispute with the government had practical as well as ideological roots. The Jeffersonian administration wanted to restrict naval funding and abandon all large oceangoing warships that would need his copper sheathing. After numerous letters failed to produce new contracts or any form of encouragement, Revere was ready to write off his elected leaders. Fortunately, he had plenty of work orders from merchant ships and Massachusetts contracts.

Jefferson's non-importation and embargo policies made matters worse. The period from 1793 to 1806 was, with minor exceptions, one of vast American prosperity. A large proportion of this economic boom resulted from European wars that increased demand for American goods while removing commercial competition. Starting in 1805, however, Britain increased its attacks upon American shipping to minimize trade with France. Other practices such as impressment of American sailors continued unchecked. Jefferson's administration responded to attacks on American shipping with the Nonimportation Act of 1806, a prohibition on certain British imports intended to coerce

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[74] Revere to Robert Smith, November 6, 1802, Ibid.
[75] Revere to Thomas Ramsden, August 4, 1804, Roll 2 RFP.

Britain into amending its aggressions without dragging America into a war. When Britain continued its hostile activities into June of 1807, Congress passed the Embargo Act to end all American shipping to all countries. Between December 1807 and March 1809, Jefferson's administration maintained this policy against violent protest from merchants, particularly those from New England. Incidentally, this policy had little, if any, effect upon the economies of Britain or France.[76]

Although it was disastrous for merchants, the embargo actually produced several substantial benefits for manufacturers, who no longer faced foreign competition and received new investment backings from moneyed interests who no longer counted upon merchant income. In many ways, Revere deviated from most manufacturers. For starters, the thought of backing any Republican policy revolted him. Also, he did not need or want investment capital from outsiders; the majority of his sales were to merchant vessels that no longer operated; and his raw materials usually arrived from abroad. In a March 6, 1809 letter to Joseph Carson in Philadelphia he exclaimed:

> The miserable conduct of our Rullers in laying that Cursed Embargo has nearly deprived us of selling copper for ships, but as good sometimes comes out of evil and there being no chance of gitting copper for stills from England we have turned our attention that way. We are supply some Gentlemen in New York with upwards of 16,000 lb of sheet 3 feet wide by 5 feet long to make two boilers for two Steam Boats.[77]

The New York gentlemen in question were none other than Robert Fulton and Robert Livingston, who will be discussed later. In spite of his complaining, however, even Revere had to admit he benefited from the lack of British competition. His market for naval sheathing temporarily evaporated, but other markets appeared. And while he had a harder time finding sources of raw copper, he and his purchasing agents managed to obtain enough, often by increasing purchases of recycled copper, to keep the output from drying up.

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[76] Leonard D. White, *The Jeffersonians, A Study in Administrative History*, (New York: MacMillan, 1956) pp. 423-425, 472-473; Douglass C. North, *The Economic Growth of the United States*, (New Jersey: Prentice Hall Inc., 1961) pp. 38, 46, 55.

[77] Revere to Joseph Carson, March 6, 1809, Vol. 53.3 RFP.

Even after the Republicans lifted the Embargo in 1809, Revere's relationship with the government (by this time, with Madison's administration) did not improve. In September of 1810 Revere offered Joseph Carson a commission if he could iron out any contracts with the federal government to produce bolts, spikes, or sheeting. In Revere's own words, "We are not favorites of Washington." In spite of political differences, he desperately wanted to renew his ties with the Republican government, so he could receive more contracts of exceptional size.

One final problem between Revere and the government was tariff protection. More than any other dispute, Revere's ongoing efforts to raise a protective tariff revealed the differences between each party's goals and methods. Britain revoked America's favorable trade status shortly after independence and imposed tariff duties against American vessels. Under the new Constitution, America equalized matters somewhat by imposing duties on goods from British ships. These duties were usually around 5 percent – enough of a tariff to soothe angry exporters without angering people who depended upon imports.

Ongoing tensions between merchants and manufacturers created by the major tariff debate ended only in the 1830s when a large number of merchants shifted their investments and purchased shares of different manufacturing concerns. Tariffs truly polarized society: merchant importers hated them because they raised the price of their goods while protecting domestic products. Artisans hated them because they increased the price of tools and imported items, revealing a growing consumer mentality. Southerners hated them because they helped the North while raising the prices of imported goods. But manufacturers and their investors strongly supported tariffs as a weapon to free America from the shackles of economic colonialism.[78] Congress raised the tariff on manufactured copper and brass products (among other items) in June of 1794 from 5 to 15 percent, and raised it again in 1804 to 17.5 percent.[79] This duty was one of many intended to protect domestic goods from foreign competition. In other words, it

[78] Folsom and Lubar, *The Philosophy of Manufactures*, pp. xxiii, xxvi.
[79] These rates were doubled for the extent of the war, readjusted to 20% in 1816, and to 25% in 1818. Charles K. Hyde, *Copper for America,* p. 12; Nelson, *Liberty and Property*, p. 153.

was made with producers such as Revere in mind. Unfortunately, a small loophole led to large problems.

In April of 1806, Revere wrote a short and informal letter to Treasury Secretary Albert Gallatin (by way of his Congressman Josiah Quincy) to point out two related problems. First, the duty on Old Copper raised his raw material costs considerably. And second, the lack of a tariff on imported sheet copper provided him with low-cost foreign competition. These problems occurred via a possibly intentional misunderstanding of terminology. Under the existing law, all manufactured copper items such as sheets and bolts should have been subject to a 17.5% tariff, and unworked copper, a raw material in forms such as plates, bars, and pigs, should have been duty free. This law was misinterpreted at the custom stations because inspectors often classified Old Copper as "sheets" and added the import duty, while classifying imported copper sheeting (a manufactured item) as "plates," which were duty free.[80] At the heart of his request lay the misunderstanding of terminology: when words like plates and sheets could alternately relate to raw or finished products, customs inspectors understandably had a difficult time making the proper call. This misunderstanding injured Revere's operations by raising the cost of his raw materials while allowing imported British sheets to be sold at extremely low prices.

Unfortunately, powerful interests stood to benefit from the continuation of the status quo. Merchants purchased more copper sheets than any other client, and did not care about the competitive disadvantages faced by Revere's rolling mill. They wanted sheeting as cheaply as they could get it, and for the most part they preferred to stick with high quality British products wherever possible. In addition, other copper workers often purchased sheet copper for the manufacture of utensils or stills. The combined actions of a subtle moneyed interest and a blunt popular one would prove formidable.

Several drafts of a letter to Josiah Quincy reveal that Revere took the next step of the process very seriously. Quincy was Revere's Congressional Representative, and Revere asked him to deliver a petition on his behalf to officially clarify American policy.

[80] Revere to Albert Gallatin and revere to Josiah Quincy, April 3, 1806, Roll 2 RFP.

He explained the confusion of terminology in great detail, but then tied his argument to his own efforts:

> ... for Instance the duty on Bolts, Spikes, +c, makes them come so high that no person presumes to import them, and we sell Cheaper (and of equal quality) ... in Boston no person for several years have imported Sheet Copper for sail but Inglish merchants. We sell for the same prices they do; if they had the duty to pay it would give us a sufficient profit.[81]

Revere clearly imagined his business to be large and important and tied his own welfare to that of the nation. In particular, he implied that he could provide all sheeting needs for the country if he had sufficient federal encouragement.

This was exactly the wrong approach to take. On January 21, 1808, the Committee of Commerce and Manufactures submitted their report. They agreed with Revere that no duty should be collected on Old Copper, but dismissed his request for a protective tariff on sheeting. To aid their decision, they drew upon contrary petitions from "Sundry Copper Smiths" from Philadelphia and "Sundry Manufacturers of Copper" from New York City. Both of these groups as well as the Congressional Committee took offense at Revere's contentions. According to the final report:

> To induce the national legislature to impose the aforementioned duty on copper in sheets, the petitioners state, that they have at considerable expense erected works which will enable them to supply copper in sheets commensurate to the demand of the United States ... [should Congress take this action] and the quantity of copper in sheets furnished by them prove to be insufficient for the demand, the copper-smiths and braziers, a respectable class of manufacturers, would sustain injuries ... The committee have had no satisfactory evidence affered to them that copper in sheets, in quantity sufficient for the use and consumption of the United States, can be supplied for the petitioners, or that the quality of the same is equal to that which is imported.[82]

Throughout this petition the language reveals the committee's Jeffersonian viewpoint: they sought to avoid "hasty legislative acts" and "legislative interference" that might "fasten on the community oppressive monopolies" as has been done "too often" in the

[81] Revere to Josiah Quincy, February 12, 1807, Vol. 53.3 RFP.
[82] Report of the Committee of Commerce and Manufactures, January 21, 1808.

past. In contrast, the petition by large groups of "respectable" manufacturers was praised for its confident assertions. The Committee made one factual error in describing "the flourishing state of manufactures, which have supplanted foreign articles of the same kind." Without a doubt, imported copper sheets and other fasteners were more plentiful than domestic ones.

In a long response to Josiah Quincy, Revere fumed about the Committee's verdict. Most of his ire was leveled at the petitions of the coppersmiths and braziers, which Revere believed were completely unfounded. He defended his petition as "just" and claimed it would benefit other copper workers as much as himself:

> If we had whished for an exclusive right we should have applied for it when we erected our works, had we then done it we have no doubt the government would have granted it. It was as much a new invention as any thing for which patents have been granted by our government.[83]

Apart from its bearing on this situation, this statement proves Revere was aware of patents and their monopolistic consequences, but still chose not to apply for one when he first perfected this process. In the remainder of the letter he repeated the great expenses and trials he incurred while mastering copper rolling, and proudly claimed "we were willing that any Americans who could attain to so usefull and necessary a manufacture should be on a footing with our selves." Concluding his rebuttal, Revere angrily denied the petitioners' claim that:

> a sufficient quantity for supplying the United States can not be afforded by our manufactory or that we do not manufacture enough for the Town of Boston! The fact is that we have supplied different Merchants in Quebec, Newhamshier, Connecticut, Rhode Island, N York, Philadelphia ... & that the sheets with which the Constitution's Bottom was covered before she went to the Mediteranean was manufactured by us ... We again assert that if we were properly encouraged we have not the least doubt that we could Manufacture a sufficient quantity for the US. We have now 20,000 lbs by us and have but one pair of rolls whereas we can make use of six pair.[84]

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[83] Revere to Josiah Quincy, December 12, 1808, Vol. 53.3 RFP.
[84] Ibid.

By changing the petition from a clarification of terminology to a request that his business receive preferential treatment in exchange for its functioning as a national industry, Revere destroyed any chance he had for its passage.

Years later, Revere shared all his information on the subject with James Prince. Apparently, some copper importers realized Revere's petition would increase their material costs, and rallied the Philadelphia and New York copper workers and braziers against Revere, insinuating that he wanted to raise a duty on raw copper. If this rumor were true, it would explain much: a bloc of manufacturers would carry more persuasive power against Revere than a group of wealthy merchants. Revere also contended that once he became aware of the opposition he explained the goals of his petition to the Boston copper workers, who then refused to join the coppersmiths of other cities against him.[85] Of course, many of these Boston copper workers were probably his friends.

Revere's desire for tariff protection never left his thoughts. In August of 1809 Henry Dearborn asked him to participate in the survey of the Report on Manufactures. Seeing at last a willing government audience, he brought Dearborn up to speed on the tariff situation and presented his request for the encouragement of manufactures, and sheet copper in particular, via a 17.5% protective tariff of domestic made goods. He also wanted the federal government to hire him for all of its copper needs since many judges rated his work equal or superior to British products. He reasoned that big contracts would help him get even better. Unfortunately, Dearborn could not help him.[86]

By 1810 he was ready to try again, using a new approach. An August 20, 1810 letter to Treasury Comptroller Gabriel Duval reiterated all his old concerns about ambiguous terminology and the unfairness of protecting all imports except sheet copper. He was quite frustrated by this time, and pleaded for protection that he felt was both just and vital for his economic survival. Duval responded on September 4, simply stating that the courts had decided that bolts and sheets would not receive a tariff, and only the legislature could protect him at this point with new legislation.[87] Furthermore, the situation was about to grow worse. By December Revere learned that Secretary of the

[85] Revere to James Prince, December 10, 1810, Vol. 53.3 RFP.
[86] Revere to Henry Dearborn, September 13, 1809, Vol. 53.3 RFP.
[87] Gabriel Duvall to Revere, September 4, 1810, Roll 2 RFP.

Treasury Gallatin submitted a circular letter to all customs collectors requesting that copper bolts also be imported duty free. This measure would prevent Revere's two major products from receiving any tariff protection against cheap foreign imports. Revere once again planned to petition the government to collect the same tariff on bolts and sheets as on other items.[88] The outcome of this new effort is unknown, but no duty was collected on copper sheeting until the Civil War.

The tariff controversy alone explains Revere's complaints about the Republican government's hostility toward him. It is strangely ironic that the man who always wanted to become a merchant ended up losing his fight against a merchant lobby in a Republican administration. However strongly Revere might plead his case, he would never win as long as his pride in his achievements caused him to stress the uniqueness of his business. The United States government would not levy a tariff that protected only one copper mill at the expense of merchants and copper workers. In spite of his defeat, Revere's persistence, energy, confidence, and pride are evident throughout this lobbying period. The same characteristics that helped him receive his first government loan and enabled him to overcome innumerable technical challenges could not win over the new administration, a testament to changing times and a former artisan's constancy.

The Ultimate Technology Transfer: Industrial Espionage

In 1804, four months after becoming the junior partner of Revere and Son, twenty seven year old Joseph Warren Revere sailed to Britain to begin a yearlong overseas trip. Although he posed as a tourist and made a fair number of pleasure trips, he and his father had a different objective in mind. Joseph Warren was an industrial spy, perhaps the first in America's history, and he planned to visit the major copperworks in Britain and Northern Europe to learn their methods and study their equipment.

Industrial espionage represents a variation on the "modification" stage of technology transfer, in which local managers and workers alter the transferred technology

[88] Revere to James Prince, December 10, 1810, Vol. 53.3 RFP.

to better suit local conditions or the changing marketplace. Revere had similar goals, since he had been experimenting and modifying his processes from the very beginning. Earlier letters illuminate his painstaking attempts to gather as much relevant information as he could from books, experts, and the observations of travelers. Although he received most of his early help from American craftsmen and metalworkers, he looked to Britain for verification after his mill was operational, to learn if he was on the right track and to correct errors. Industrial espionage was a highly efficient form of technological transfer because the search for information aimed at answering specific questions. In this case, Joseph Warren had years of experience with Revere's processes, and could orient his search at the most complicated parts of the process. The fruits of this labor were guaranteed to fall on fertile ground.

This espionage must be understood in the context of the times, as Revere and his son viewed it. Instead of apologizing for his son's spying, Revere cited it as a major asset of his operations for the remainder of his life. He was a borrower, trying to duplicate the best available technical processes, and industrial espionage represented the most direct and helpful manner of becoming a "master of the business" and helping his country close the technological gap.

Before Joseph Warren embarked, father and son worked hard to prepare him for different contingencies. Joseph Warren obtained a Commonwealth of Massachusetts passport signed by the governor and his father obtained letters of introduction from the Attorney General, influential friends, and himself. These documents enabled Joseph Warren to enter Britain, and once there he received a passport from foreign minister James Monroe that allowed him to travel to other countries. In the age before photography, these passports contained a physical description, broken down into categories such as his height (five foot ten), eyes (light), mouth (small), nose (common), forehead (common), chin (large), complexion (rather light), hair and eye-brows (dark brown), and face (full). During his travels he received other official documents from American consuls in Hamburg, Rotterdam, and Kiobenhavn, containing copies of his passport description.[89]

[89] Various passport documents are all contained in Roll 2 RFP.

Throughout his trip Joseph Warren maintained a journal and sent many letters to his father detailing his discoveries. These letters contain a wealth of observations on European society from an American perspective American. For example, he noted that Sweden had "by far the best roads I have ever seen" and marveled at repeated evidence of ongoing political turmoil: the French captured him on his way to Rotterdam, he was detained on his way to Sweden, and had to circumvent a blockade of the Elbe river. He also took time for several personal messages, informing his father that his old friend and former silvershop customer John Jay had recently died in England, and urging his younger brother John to stop smoking cigars because he felt the practice was harmful.[90] However, the majority of his observations concerned manufacturing matters. He left with the expectation of learning about superior European technologies, and he succeeded – probably in ways he had not expected.

Joseph Warren's notes often reveal as much about his own operations as the ones he observed. For example, he often seemed frustrated by the lack of quantitative precision of the workers. While studying a London bell foundry on December 12, 1804 he complained, "They did not weigh the tin which they added but took out some metal & broke it & then added as they thought it wanted." This provides an interesting juxtaposition of working styles: the young American had already adopted more of a quantitative mindset, while the Old World artisans remained craftsmen to the core. He also felt their new furnace was unimpressive – it resembled a baker's oven "inside a one story building which I should have supposed would have burnt the first time they used it." But even amidst disappointment he noted that their bell moulds and other tools were superior to his own.

The trip enabled Joseph Warren to learn more about state-of-the-art waterwheels. On December 19 he visited an Eastbridge rolling and slitting mill, built for copper working but improved for iron. This was a high-technology version of the main operation of his shop back home. He noted that the mill drew power from a "good" stream with only a four-foot fall. The rolls fit into a "cast iron frame similar to a goldsmiths plating mill" using only one shaft and cog to move the bottom roller, which itself moved the top

[90] Joseph Warren Revere Journal and Letterbook, Vol. 56 RFP.

roller. He included an excellent diagram of this machine, and a later diagram illustrated how the two rollers could be powered independently in a more complicated setup. By 1809 the Revere mill used separate waterwheels to drive the top and bottom rollers. British firms still used the horizontally inclined breastwheels, as opposed to the more efficient enclosed turbines that would appear soon after.

Joseph Warren also realized the importance of managerial coordination and efficiency. On December 22 he visited a gigantic, comprehensive copper works in Harefield, which cast, rolled, and cut copper in different buildings. The Canton property eventually adopted a similar layout. Joseph Warren's overall amazement was best expressed in his concluding paragraph:

> This works all the time imploy 150 workmen night & day, before I saw these I thought the works for Iron extremely well fitted but this is beyond description altho so many wheels & all of iron there is no noise no chattering but all goes like clock work & you can talk & be heard the same as in open air these works have been all newly built within fourteen years & should suppose from the immense stock not less than a million sterling capital.

One can imagine the noise and "chattering" that must have taken place at his own mill in contrast to this one. Joseph Warren seemed most impressed by the organization and continuity of operations, as large quantities of copper and fuel were continually added to the casting furnace, which produced a steady output: "as soon as the pig on tile was black another was poured on the top of it & so on untill full." Although he noted the rolling mill's six-foot width and very impressive set of water wheels and cogs "as true as clock work altho of this imence weight," he in general was not impressed by the degree of mechanization – workers even used manual cutting shears to slice the copper. However, some of these efficient procedures would eventually improve his own operations. He answered his father's long-standing copper cleaning problem by noting that one boy mopped the copper sheets with urine or chamber lye before heating them, making them "sinfully clean & not liable to tarnish." Also, workers rolled copper sheets "square then corner ways then square untill got to the width then length ways until thin enough to

shear." This simple, easily copied process would produce superior and more uniform results.

His other travels drew a complex picture of old and new methods. He could not believe the amount of manual labor used where machines could have been employed in Birmingham watch, toy, and pin manufactories. In contrast, brass works in Bristol impressed him with their use of steam power and ancillary equipment (a crane and a stretch of wooden rollers) to simplify the maneuvering and rolling of tremendous sheets. Best of all, a cog enabled the mill's rollers to turn in either direction, so the workers could simply move it forward and backward until it was finished.

In light of Britain's strict policies regarding technological secrecy, Joseph Warren had a fairly easy time gaining entrance to a vast range of establishments. He occasionally mentioned that he was turned away, or that an owner refused to share proprietary information, but his journal pages are filled with detailed observations and drawings. His journal from the other countries on his itinerary is not included in the Revere papers, but his correspondence and other writings allude to interesting visits to mines, foundries, and other copperworks.

Revere never discussed specific consequences of his son's espionage, but many of the technological improvements of the next few years undoubtedly drew upon these observations and sketches. As important as these improvements were, Joseph Warren's most valuable discoveries related to organizational procedures. He witnessed gigantic concentrations of labor and capital, dwarfing anything in America at that time, all laid out "like clock work" to efficiently transform raw materials into finished products. In the years to come, the Revere mill would alter its processes as well as its machinery, bringing it a major step closer to the modern factory.

Revere's Technical Practices and Improvements

In spite of some early difficulties, Revere's technical achievements soon earned praise from impressive sources. On May 22, 1803, well-respected Captain Edward Preble of the

U.S.S. Constitution informed the Secretary of the Navy that the Constitution's copper sheathing was worn out and needed replacing, and "that made by Mr. Revere, is good, and of proper thickness." This endorsement represented Revere's strong reputation among the merchants and shipbuilders of Boston. After he received a contract to replace the Constitution's sheet copper, a June 18, 1803, article in the *Columbian Centinel* stated that Revere's sheeting "is the first ever manufactured in the United States, and will not suffer by comparison with the best sheets imported." On June 25, 1803, the USS Constitution's logbook recorded "The carpenters gave nine cheers, which were answered by the seamen and caulkers because they had in fourteen days completed coppering the ship with copper made in the States."[91] Apparently Revere was not the only person who believed his successful mastery of copper rolling constituted an important national service.

Revere owed his rapid progress through a prohibitive technological learning curve to his lifetime of metallurgical knowledge and experience and efficient transfer of techniques between different metalworking fields. In fact, by the 1800s he might have been the most skilled metallurgist in America, combining theoretical awareness (demonstrated in different letters to clients or colleagues in need of advice) with practical know-how. But his past success depended on more than this background preparation, which would soon grow obsolete in the dramatic industrial expansion of the 19th century. Revere also possessed an experimental spirit, fueled by the drive for improvement and aided by his son's fresh new perspective. Although he often devoted the majority of his efforts in his younger days to the improvement of his social standing through attempted career changes, by the time of his Canton endeavors he was wholeheartedly focused upon manufacturing. In fact, as soon as he moved all of his different mechanical operations under one roof he began altering earlier production methods and incorporating new pieces of equipment.

Revere's altered technical methods shed light on contemporary trends. As craft and proto-industrial workers shifted from the use of multi-purpose (and usually hand-

[91] United States. Office of Naval Records and Library, *Naval Documents related to the United States Wars with the Barbary Powers*, Volume 2, (Washington: Government Printing Office, 1939), pp. 414, 426, 462; *Columbian Centinel*, June 18, 1803.

held) *tools* to less versatile and externally powered *machines*, the duties and nature of the workforce changed. Creativity, versatility, and independence became less important than machine-based mechanical skills, discipline, and consistency. At the same time, increases in population, changing consumer habits (such as increased spending on items previously considered luxuries), and circulating currency – in short, the expansion of markets and capitalism – inspired manufacturers to begin moving toward the "American system" that served as a predecessor to mass production.[92] Historian Eugene Ferguson defined "American system," as "the sequential series of operations carried out on successive special purpose machines that produce interchangeable parts." One of the major goals of the American system (and of 20th century mass production) was the cheap, large-scale production of standardized output often featuring a collection of processes in one facility. Four technological components paved the way for large-scale standardized production: efficient machinery, high quality raw materials, the intensified application of energy, and the use of gauges to measure the quality of the output.[93]

Revere's operations certainly met most of these criteria by 1802, when advances in other fields enabled him to receive more reliable machine parts and raw materials. He never mentioned any use of gauges, although he always classified his output into different grades, usually measured in terms of ounces per square foot. The majority of his earlier production depended upon skilled laborers, and produced carefully crafted individual items such as church bells. But Revere started incorporating machinery and experimenting with standardized output for his silver shop operations as early as the 1780s, and by the 1800s his Canton mill contained many devices for a variety of operations. After relocating all his operations to Canton and exploiting its waterpower and concentrated workforce, he made even greater strides towards the methods and goals of the American system.

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[92] Historian of technology David Hounshell observed that "mass production" is a grammatically ambiguous term, potentially implying either "large scale production" or "production for the masses." Since "mass production" did not enter widespread usage until the 20th century, other terms will be used in this study. However, many of the connotations of mass production apply to Revere's operations. David Hounshell, *From the American System to Mass Production* (Baltimore: Johns Hopkins University Press, 1984), pp. 1-12.

[93] Ibid, p. 15, and Alfred Chandler, *The Visible Hand* (Cambridge: Harvard University Pres, 1977), p. 241.

By the time of his retirement in 1811, Revere had set up a fairly complex copperworking complex housed over three buildings. Several letters describe his layout, including the titles of his facilities. The rolling mill building contained a rolling mill powered by two 21-foot diameter water wheels, two furnaces for heating the copper bars and sheets, "Machiniary for Boring from the solid," and machinery for turning cannon, drawing wire, and heading spikes. The hammering mill building contained one heating furnace, two forges and two trip hammers, powered by an 18-foot waterwheel. And the foundry building contained "two large furnaces for melting with the necessary apparatus for moulding."[94] This setup seems to have been designed with raw material flow in mind. He initially processed all raw materials in the foundry building, where he might cast his own copper pigs or pour bronze into bell or cannon moulds. Copper pigs would then be brought to the hammering building for reshaping, annealing, and possibly some refining as well, before traveling to the rolling mill for drawing into spikes, rolling into bolts or sheets, and any additional annealing that might be required. Similarly, workers carried solid cannon to the rolling mill building for boring and finishing.

All of these processes had evolved considerably since Revere's earlier days. The following sections describe the changes he made in the production routine for each product, and the ways that each product moved closer to the ideals of standardized production.

Bells and Cannon

In the midst of sizeable and lucrative bolt and sheet contracts, Revere continued his bell and cannon production. In fact, his output gradually increased until his retirement and his son continued both product lines for long after. Revere's bell and cannon casting initially took place in his Boston foundry under the supervision of Joseph Warren. After a gale on October 9, 1804 destroyed the Boston shop, Revere and Son moved all their operations to Canton, seeking greater efficiency and access to water power for large cannon-turning equipment.

[94] Revere to Josiah Snelling, October 26, 1810, Vol. 53.3 RFP.

Ever pragmatic, Revere's pricing indicates the amount of labor and time required for each operation. Revere's price lists at various times reveal that he reserved his cheapest rates for bell manufacture and his highest rates for cannon. For example, from 1809-1810 he charged 42 cents per pound for bells, 50 cents for bolts and spikes, and 55 cents for cannon. Once he perfected his own recipe for bell metal and moulds for bells of different sizes, the bellmaking process was merely a matter of measuring metal, mould preparation, pouring, and cooling. While these were not simple tasks, they did not require the complex melting, hammering, annealing, and shaping routines needed for bolts and spikes. Also, a bell required an enormous weight of metal, so the amount of labor per pound was far less than for individually prepared spikes and sheets. Revere's bell list, presented in table 2.2, indicates that he produced between 2 and 12 bells a year throughout the 1800s until his retirement. One happy customer told Revere "The Bell proves a very good one – it gives universal satisfaction."[95]

Although cannon casting might appear similar to bell casting, it involved two expensive and unpleasant processes. The cannon casting process became fairly regular once a metal recipe and mould preparation routine survived the test of time. After that, however, Revere had to bore the cannon. He hired two machinists from North Providence, Abraham and David Wilkinston, to install a lathe for him in June of 1804. This might pertain to his cannon turning device, but probably describes a different piece of equipment used for smaller jobs.[96] At any rate he certainly bored his own cannon by 1807, and probably earlier than that. In September of 1810 he told factor Joseph Carson that his works were only established to bore one gun at a time "but should they [more cannon] be wanted at short notice we could extend them."[97] Following the boring, all cannon had to be proved. This not only necessitated additional transportation fees, but also ran the risk of bursting a cannon and starting the entire process from the beginning.

Even in 1802 Revere rightfully considered himself a cannon-casting expert. Amasa Davis of the Massachusetts militia remained the primary customer for ordnance,

[95] Pitt Clarke to Revere, May 29 1810, Roll 2 RFP.
[96] Receipt to Abraham and David Wilkinson, June 28 1804, Ibid.
[97] Revere to Joseph Carson, September 22, 1810, Vol. 53.3 RFP.

buying pieces on many occasions. Revere also lobbied the federal government for contracts. In 1802 he informed Attorney General Levi Lincoln that he made

> ... very great Improvements in the Foundry line, especially [words missing] Casting Cannon. I think I can say without vanity that I [missing] cast them as well as they are cast in Europ ... I believe I have cast more brass cannon than [missing] people in America. I have cast more than one hundred for this & some of the other states...[98]

Revere received a small number of federal orders, and occasional requests from other states. In 1810 he even received a secret request from the Spanish government to furnish twenty pieces of cannon, a tremendous order at the time.[99]

Revere's bells and cannon would never be mistaken for standardized products. Even the weights of different pieces made from the same mold varied. These processes still depended too heavily upon human judgment and skill. At the same time, the demand for bells and cannon never grew high enough to justify additional research into cost cutting or process improvement. Revere continued these operations without any major procedural changes, and they provided him with a steady income.

Bolts, Spikes, and Fasteners

Revere started producing bolts and spikes in his Canton mill shortly after buying his Canton property. The high opinion in which Revere valued his bolts and spikes, as well as his notion of honor, is evident in his response to a rare complaint from Mess. Beck and Harvey in Philadelphia, who complained that Revere's bolts and spikes were too brittle and out of proportion. His response speaks for itself:

> we were never so much astonished at any thing of the kind as at the contents of your letter ... That "the bolts" should be "extremely brittle" is <u>impossible</u>, for they are drawn hot, under the forge hammer ... the <u>spikes</u> are pronounced by judges here as good as ever was made, these sent you are exactly the same ... We have manufactured the Bolts and Spikes for more than twenty Merchant vessels and

[98] Revere to Levi Lincoln, February 26, 1802, Vol. 53.2 RFP.
[99] Joseph Carson to Revere, September 25, 1810, Roll 2 RFP.

> you are the first persons who have found fault with our bolts or spikes. ... We have but one rule to do our business by, the strictest rules of Honour; we have sent you Bolts & Spikes such as our Carpenters approve of here, had you sent us patterns we should litteraly have followed them. We are Gentlemen.[100]

Revere's next letter to these merchants was far less outraged, and indeed, almost humble. He discussed terms for reshipping the bolts and spikes back to Boston and clarified his defense of his bolts and spikes:

> ... that they are as smooth as English we do not contend but that they are as good we do. Our Manufactory is yet in its infancy. I think I told you when in Phila. that we finished ours with a hammer which is the reason they are rough, the English is Rolled ... we are improving & expect to finish our Bolts the same way.[101]

Revere concluded by referring these men to Joshua Humphreys for his opinion of bolt and spike quality.

Whether or not Beck and Harvey were correct about the quality of their bolts and spikes. Revere was not exaggerating his experience in this field. Throughout all his Canton operations, bolt and spike work proceeded with ever-increasing volume, eclipsing all other products in total sales. Any improvements he could make to this process would have a major effect on his balance sheet.

By 1805 he made the improvement he mentioned to Beck and Harvey. Revere either purchased or cast a special pair of rollers for the mill. He explained this system to Levi Hollingsworth in 1808 and implied that he made his own rollers. The rollers contained diagonal grooved indentations. If aligned properly, these rollers would produce copper cylinders out of flat copper passed through them: the flat sheet would be compressed where the rollers had no grooves, and would therefore get squeezed into the indentations of the rollers. This produced what Revere called "strings" of copper – long, bolt-sized rods between 4 and 10 feet long. Revere's reply to Hollingsworth answered his

[100] Revere to Beck and Harvey, October 29, 1803, Vol. 53.2 RFP.
[101] Revere to Beck and Harvey, November 20, 1803, Ibid.

questions and included a cross sectional diagram of iron rolls highlighting the diagonal indentations for bolt production.[102]

He still made other fastening products such as spikes at the forge, working them hot and finishing them cold to insure that the points remained hard. Revere claimed that his bolts and spikes were nearly as hard as iron and claimed his braces and pintles were the best in the State, because "we can give the metal a better heat and we cast the whole for one ship at one melting." He concluded with a discussion of the merit of copper bolts over composition metal, since copper is "tougher than iron," while a composition of metals is "easily broke."[103]

Revere produced large quantities of bolts and spikes throughout his operations. The applicability of the term "standardized output" to products of this sort is a matter of debate. Many historians restrict the "standardized" goods to complicated products such as mechanisms constructed from interchangeable parts: for example, rifles or bicycles. However, simpler items can be standardized in the same way that they can be heterogeneous. Revere's use of his rolling mill to produce copper bolts represents a major milestone in his manufactory, because he shifted a previously handmade item into the realm of machine production. As he offered products in several fixed sizes and weights, and as he offered to repurchase unused quantities, he increasingly treated them as uniform commodities. For example, a memorandum in his 1806-1812 bankbook lists the weights of one foot long copper bolts of different diameters: 1.5 inch diameter bolts weigh four pounds, 1 inch diameter bolts weigh three pounds, and so on.[104] This calculation clearly assumes constancy among his output. In any early industrial endeavor the potential for irregularities still existed, but Revere's manufacturing and managerial policies indicated he wished to make them infrequent exceptions to a standardized rule.

[102] Revere to Hollingsworth, September 1, 1808; Hollingsworth to Revere, May 10, 1809, Roll 2 RFP.
[103] Revere to Hathaway and Davis, March 1, 1805, Vol. 53.2 RFP.
[104] Bank Book Boston 1806-1812, Vol. 52, RFP.

In December of 1803 Revere wrote to Joshua Humphries, to discuss his sheet rolling process and how he learned by doing:[105]

> I agree with you that the manufacturing of copper in this country is a new thing & that every allowance ought to be made & every encouragement given to [so] usefull a Branch for tis by Experience that the Manufacturer becomes perfect & experience will not be gained without encouragement is given. We are dayly gaining experience. I have had & now continue to have the whole to feel out, for I have not been able to get any information from any person. Should I live & be able to take care of the Business for seven years to come, I should not get to the Zenith ... I cannot help acknowledging that I have done better than my expectations. Our sheets are as well finished and as soft & as free from scales & cannot be distinguished from English.[106]

His final claim was not completely accurate . Revere continued his learning process on the job, and made his fair share of mistakes. As mentioned earlier in this chapter, he informed Robert Smith of some consistent errors in his first shipment of sheet copper in May of 1802. Instead of producing sheets measuring 14 inches by four feet, a "small part" of the shipment measured 13 ¼, 13 ½, or 13 ¾ inches wide by four feet long. Revere also mentioned that he consulted with some shipbuilders, and was informed that many of the sheets on a ship are cut down to a narrower size anyway. In other words, he believed his error would not have any harmful impact.[107]

This problem with the roller alignment was only one of hundreds, if not thousands of mistakes he and his workers must have made in their early years. His success in this field testifies to his ability to adapt his process, and continue perfecting it. This in large part resulted from his vast experience with silver, iron, brass, and copper, which gave him a great instinctive awareness of metallurgical processes. He demonstrated this in various letters to the Navy Department or other questioners, on subjects such as annealing, work

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[105] "Learning by doing" is the process of on-the-job experimentation and practice. It is particularly valuable where theoretical knowledge and practical experience are lacking. Paul David, *Technical Choice Innovation and Economic Growth*, pp. 101-111; 163-165.

[106] Revere to Joshua Humphreys, December 19, 1803, Vol. 53.2 RFP.

[107] Paul Revere to Robert Smith, May 24, 1802, Ibid.

hardening, and the finishing process. Although his contract asked him to roll his sheets cold, he asked for permission to roll them hot, which would make them softer. This would allow nails to pass through them easily and would form a tighter seal with the ship hull. He knew this through practical experience, and not from a study of the chemical and physical theories behind the process. Captain Preble agreed with Revere's advice, and Navy Secretary Smith asked for more information. Revere responded:

> The nature of copper is such that when it is in its pure State it is nearly as soft as Lead. It cannot be wrought till it is in that state, hammering it, pressing it, or Roleing it makes it hard & stiff; then heating it red hot, or Annealing it, brings it to its natural State again.

He then mentioned that bolts and spikes are often finished while cold, to harden them enough to drive into wood, while British sheet copper is "finished as soft as the Annealing makes it." Revere then described his own method: "I think we have made an improvement, for after it is annealed and cleaned, we pass it once thro the Roles, which finish each sheet flat, smooths it, and adds a little to their stiffness." Presumably, this described his process for handling finished copper sheets.[108] Smith adopted all his suggestions.

In addition to drawing upon his past knowledge, Revere tried to learn from the state of the art practitioners in Britain. Since British authorities did their best to prevent any technology transfer, he had to be creative. In 1802 he wrote to Mr. Bennoch, a former Bostonian who now lived in England. This long, detailed, mouse-eaten letter paints a vivid picture of Revere's limitations and concerns. He started with a summary of his product line, and mentioned that he had failed to find any information about the "English Method of Roling" in books or other information sources. And even though he had already rolled over 2,000 sheets which the "Inspectors appointed by our Government" declared "equal in quality to the English," Revere confessed that he still could not "finish it in the high stile that they do." Revere hypothesized that this might be attributable to his iron rolls, which he cast and turned himself, and which he believed were too soft for the

[108] Revere to Robert Smith, July 1, 1803; Robert Smith to Revere, July 22 1803; Revere to Robert Smith, October 29, 1803, Vol. 53.2 and Roll 2 RFP.

task at hand. Revere asked Bennoch to procure rolls from Bristol, Liverpool, or anywhere he believed he could find quality workmanship. Furthermore, Revere specifically sought more information about the British copper rolling process, such as:

> the size & thickness of the pieces when first put into the Roles; what kind of Furnace or Oven they Aneal their Copper in; wether they role it single, or double; to what length they role it hot; & when they role it cold, wether they role it in water, and particularly how they clean it for finishing.[109]

These questions illustrate Revere's progress in his industry: he had a basic knowledge of the equipment and procedures, but had many questions about specific details. Most of these questions were answered three years later when Joseph Warren returned from his European espionage mission.

Revere's letter to Bennoch alluded to one critical component of his early rolling success. He not only had to learn the rolling process without any assistance, but also had to procure the necessary equipment. Waterwheel technology was well understood in America but iron rollers presented a particular challenge since they had to be hard, durable, perfectly round, and free from blemishes. While other metalworkers might have been forced to try to sneak rollers out of Britain, Revere cast and turned his own. They were not perfect, but they functioned. His familiarity with ironworking techniques was a vital component of his copper rolling success in the period before machine-making shops made specialized equipment widely available.[110] Over the years, Revere ordered rollers from firms in Plymouth Massachusetts, Liverpool England, and other locations. He did this whenever he needed to produce wider sheets, and also when he had to replace worn or broken rollers. His instructions to each of these firms emphasized the need to match his exact specifications and use the highest quality iron.

The importance and scarcity of rollers was illustrated in an 1810 correspondence with H. M. Salomon, a Philadelphia silver plating mill owner. One of Salomon's cast steel rollers broke, forcing him to shut down his operations. He learned that no firm in

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[109] Revere to William Ben[noch], May 12, 1802, Vol. 53.2 RFP.

[110] According to historian of technology Nathan Rosenberg, an identifiable American machine-tool or machine-producing sector appeared between 1840 and 1880. Rosenberg, "Technological Change in the Machine Tool Industry," pp. 416-417.

Philadelphia or New York could make rollers, but heard from a merchant that Revere might be able to help him. Revere responded that he no longer made his own rollers although he did turn them in his lathe, and "everything depends on their being turned true." Revere also told him "the breaking of roles is more from want of attention than accident, they must be constantly greased," and added that cast iron was as good as cast steel. Salomon responded with a grateful two-page letter that illustrated some of the differences between himself and Revere. Salomon knew nothing of the business apart from what his workers and his superintendent (who shared all profits) told him, revealing himself to be an owner lacking in technical experience, a prevalent category by the end of the 19th century. Salomon's workers repeatedly attempted to make their own iron rolls but could not remove the small holes from their surfaces, resulting in pitted, pockmarked sheeting. Based solely upon Revere's first letter, Salomon trusted him enough to ask him to procure a pair of rolls "such as you think in regard to quality." Salomon's rollers were only one foot long, much smaller than Revere's.[111] In spite of Revere's help, Salomon soon closed his shop doors forever.

Revere's willingness to help strangers and potential rivals such as Levi Hollingsworth and H. M. Salomon illustrates the small size and embattled camaraderie shared by would-be manufacturers at this time. In addition to his confidence in his mill's technical sophistication, Revere would not feel threatened by producers in other cities. He had never been threatened by any manufactory on his side of the Atlantic, and they might serve as allies in his battle for tariff protection against the true enemy, cheap imports from British facilities. Serving as kindred spirits and potential sources of future advice or support, these men worked together to improve the technical skill of American workshops as a whole.

In the same way Revere eventually treated bolts in a standardized way, he also came to view all copper sheets as interchangeable. As early as 1802, he mentioned that his sheets weighed "34 ounces to the superficial foot," or 34 ounces per square foot. This served as a measure of the thickness of the copper sheets, since the density of the raw copper would not vary much. But he told Robert Smith that copper sheet inspectors

[111] HM Salomon to Revere, May 2, 1810; Revere to H.M. Salomon, May 8, 1810; and Salomon to Revere, May 31, 1810, all in Roll 2 RFP.

recommended one fourth of his sheets should weigh 30 ounces per square foot, which he was happy to provide if asked. Not only was he more in touch with the needs of the actual shipbuilders than the navy secretary, but he also began to consider the utility of producing different grades of sheeting for different uses. His 1806-1812 bankbook reflected this division of sheet thicknesses in a memorandum listing the weights of different densities of sheet copper.[112] This method allowed Revere to verify the uniform quality of his sheets with a well understood and easily used measuring device, his scale. He did not mention whether he also used gauges to measure the width of his sheets, but this seems highly likely considering his use of measurements on the surface area of his sheets, as well as the increasing mention of sheet width in his correspondence with clients such as Robert Fulton. In spite of Revere's move toward standardization, his output occasionally suffered from imperfectly machined rollers. He was still a bit ahead of his time, and only when other industries perfected the machining processes that created his own equipment could he truly establish standardized production.

Robert Fulton, Boilerplate, and Other Products

Throughout his life, Revere sought new applications for his equipment and workforce. He had a remarkable ability to simultaneously perform established processes, perfect new ones, and research further opportunities. By 1808, Revere's facilities could produce a diverse product line. But he still wanted more. By this point his reputation had spread throughout much of the New England merchant community, and a lucrative new opportunity was about to knock on his door.

New York State showed an avid interest in steamboat building from an early date, and used its ability to grant corporate charters – in this case, using the early version of corporations to grant monopolistic privileges in pursuit of societal benefits – to inspire different entrepreneurs to perfect and operate franchises. John Fitch received a 14-year corporate monopoly in 1787, but failed to perfect a steamboat by 1798. At this point the legislature revoked his grant and gave influential merchant Robert Livingston a 20-year

[112] Paul Revere to Robert Smith, May 24, 1802; Bank Book Boston 1806-1812, Vol. 52 RFP.

charter, provided that he build a working boat within one year. By 1803 he had not succeeded, but managed to receive a new 20-year charter as long as he could build a working boat within two years. Once again, he had failed to live up to his end of the contract by 1807, when he and his partner, inventor Robert Fulton, renewed the 20-year charter as long as they succeeded in the next two years. And succeed they did.[113]

Fulton and Livingston's earliest attempt failed for many reasons, one of which was their dependence upon steam engine equipment from Nicholas Roosevelt's Soho plant in nearby New Jersey. Their successful attempt relied upon designs and parts that they ordered from Britain, including a Bolton and Watt steam engine. But these parts were hard to remove from the country, not to mention expensive. Fulton and Livingston required a cheaper source of parts for their later steamboats, particularly the giant copper sheets used in their boilers. Eventually they discovered Revere.

On October 8, 1808, Robert Livingston's brother John asked Revere for a price quote on copper sheets weighing 12 pounds per square foot and what sizes he could produce. Revere responded immediately, explaining that he previously had rolled only sheathing copper of 14-inch width but he could roll sheets as wide as three or three and a half feet (the width of his rollers), and any length desired. He offered this copper at 55 cents per pound, and estimated that he could roll a ton in approximately 10 or 15 days.[114]

Livingston soon accepted, and sent a draft diagram that carefully listed the dimensions of the different sheets he required. These sheets differed from everything Revere had previously produced. All three boilerplate dimensions dwarfed naval sheathing, which measured fourteen inches by four feet by 1/16 of an inch thick and weighed no more than 34 ounces per square foot. Boilerplate measured three feet wide by five feet, and between 1/6 and ¼ of an inch thick, weighing 12 pounds per foot. In addition, several of the pieces required curved cuts along the sides to facilitate the construction of round portions of the boilers.[115] Despite the novelty of this order, Revere completed over 16,000 pounds of boilerplate early in 1809. Fulton placed a second order

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[113] John S. Morgan, *Robert Fulton* (New York: Mason/Charter, 1977); Cynthia Owen Philip *Robert Fulton* (New York: Franklin Watts, 1985); Horwitz, *The Transformation of American Law* p. 122.
[114] John Livingston to Revere, October 8 1808, Roll 2 RFP; Revere to Livingston, October 12, 1808, Vol. 53.3 RFP.
[115] John Livingston to Revere, November 25, 1808, Roll 2 RFP.

for five more tons of plates in 1810, and Revere sent it in 1811. Fulton continued ordering more sheets from Revere well into 1814, well after Joseph Warren had taken over the business.[116]

The steamboat contract had advantages and disadvantages. The dimensions of the boilerplates required altered production methods: bigger copper pigs were needed, more men were needed to lift and feed them through the rollers, and the cooling rate of the thicker sheets affected the details of the annealing process. These challenges led to delays and errors, and Fulton's satisfaction decreased rapidly in 1811 as he complained about excessive delays as well as brittle plates that cracked frequently. In spite of these complaints, he continued placing orders with Revere.

On the other hand, the Fulton contract provided Revere with tremendous copper orders requiring relatively less processing per pound. Since each sheet was far larger than naval sheathing, Revere's workers had fewer sheets to process for an equal weight of copper. Since he sold by the pound, this contract promised major profits. Revere worked hard to encourage further sales, and by December of 1810 he informed Robert Fulton that he learned to make six foot long sheets of any thickness, although he could not circumvent the three foot width of his rollers.[117]

The Fulton contract prepared Revere for a host of creative new copper sheeting applications that foreshadowed the business growth Joseph Warren would experience after he took over the business. Many of these new opportunities first appeared in 1809. Revere supplied local coppersmiths with heavy plate copper for stills, which required 3 by 4 and 3 by 5 foot sheets. The efforts of Joseph Carson, his factor, turned up a long list of copper requests for still, sheet, "raised bottom," and "flat crown" copper from Philadelphia braziers. And Revere was asked to comment on the possibility of sheathing gigantic piles in copper to prevent them from corroding and accumulating barnacles, a proposal that he wholeheartedly endorsed.[118]

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[116] Robert Fulton to Revere February 24, March 8, and July 28, 1814, Roll 3 RFP.
[117] Revere to William Torrey, February 10 1810, and Revere to Robert Fulton, December 15 1810, Roll 2 RFP.
[118] Revere to Joseph Carson, March 6, 1809, Vol. 53.3 RFP; Joseph Carson to Revere, June 6, 1809 Roll 2 RFP; Revere to George Cabot, September 11, 1809, Vol. 53.3 RFP.

Old and New

Revere's transitional state between craftsman and proto-industrialist is more evident during his Canton operations than ever before. From 1802 until his retirement in 1811, he juxtaposed old and new methods in all aspects of his business. For example, he adopted many of the most current managerial advances, such as double entry accounting and billing, credit and cash discount policies, warrantees, using a factor to solicit work and raw materials in distant markets, and drawing up a legal and binding partnership agreement that quantitatively divided company assets and ownership. At the same time he still allowed his laborers many of the privileges of skilled craftsmen (such as control over their time and free board), avoided incorporating or requesting patents, allowed fellow copper rollers access to his techniques and facilities, relied upon verbal agreements with laborers and in important transactions, and continued to conflate his personal sense of honor with the affairs and reputation of his business. This also applied to his technological practices: he moved towards standardization on several of his product lines and increased his use of machinery, but still had far to go before his products were truly interchangeable, partly because of his continuing reliance on skilled labor.

Revere made many choices concerning methods and technologies throughout this period, and moved forward quickly on some issues while hesitating on others. His career illustrates his willingness to adopt new technologies if conditions seemed right, so his decisions to remain with older methods either represented ignorance of new possibilities or approval of the status quo. In assessing his choices it is important to remove value judgments from the classification of new and old techniques. In many cases older practices made more sense and served him better than alternatives we would consider more advanced. For example, his old fashioned manner of dealing with his workers probably averted some of the labor disputes faced by other manufacturing concerns, and he had little to lose from treating potential competitors as colleagues.

Revere's ability to make fundamental changes to his operations was certainly not unique. He was part of a widespread movement toward larger manufactories employing machinery and machine-operators in lieu of skilled craftsmen. However, the participants

in this widespread movement stood in contrast to a far larger proportion of the population who did not adopt new methods as quickly. According to labor historian Bruce Laurie, artisans followed three general career paths during this period of upheaval. Small, struggling shop owners and journeymen unable to raise large amounts of capital to keep up with changes lost economic and social status and became wage laborers. The most successful artisans, such as Revere, became businessmen, raising sufficient capital to employ others and prosper in the new world of mass output. The majority entered the "middling" class, continuing their craft work in any way possible, often supervising the labor of others in small shops or working as skilled laborers for larger employers while failing to achieve the financial stability of the growing middle class. This growing body increasingly embraced a meritocracy and promoted traits such as industry and frugality. The term "mechanic" was eventually identified with this community of middling men who were unified by their belief in the "dignity and utility of manual labor."[119]

Revere was no mechanic by this definition. He supported the importance of the mechanical arts as a vital component of national security, but saw his own role, the manager and technical pioneer, as the most essential position. Skilled laborers knew how to master complicated processes and equipment in order to complete a job. Revere was one step above that level. He designed the processes, he purchased the equipment, and he coordinated all the activity within his shop in order to finish his contracts. And here lay his true reward, something he considered more valuable than a comfortable income at the end of the working day. Revere's copper mill allowed him to help his community by providing goods that no other American could create. He could be a patriot once again, and this time he didn't have to ride a horse.

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[119] Jack Larkin, *The Reshaping of Everyday Life* (New York: HarperPerennial, 1989), p. 59; Bruce Laurie, "'Spavined Ministers, Lying Toothpullers, and Buggering Priests': Third-Partyism and the Search for Security in the Antebellum North," in *American Artisans: Crafting Social Identity,* ed. by Howard B. Rock, Paul A. Gilje, and Robert Asher (Baltimore: Johns Hopkins University Press, 1995), pp. 99, 105-6; Stephanie Grauman Wolf, *As Various as their Land* (New York: HarperPerennial, 1993), p. 275.

CONCLUSION

At some time around 1810, shortly before his retirement, Revere wrote "Cantondale," a poem celebrating his happy daily routine in his rural home. This poem repeatedly juxtaposed images of nature and industry without identifying any links between them:

Around my Cot, at break of day,
The robin pipe's his artless lay;
The yellow-Bird, with pleasing note,
Sings sweet, and trills his little throat.
Near to my Couch, congenial guest,
The Wren has wove Her mosey Nest,
Her hopes in safe repose to dwell,
Nor ought suspects the silvian dell.

At early morn I take my round,
Invited first by hammer's sound;
The Furnace next; then Roleing-Mill;
'Till Breakfast's call'd, my time doth fill;
Then round my Acres (few) I trot,
To see what's done and what is not.
Give orders what ought to be done.
Then sometimes take my Dog and Gun.

Revere wakes each morning to the songs of birds, and immediately proceeds to inspect his hammer, furnace, and rolling mill. He issues instructions to his workers, and then goes hunting with his dog and gun. At the end of his poem, he states,

Or ere the Sun sinks in the West
Or tunefull birds skim to their nests
To walk thro Groves, and grass'y Fields
Contemplating what Nature yealds.[1]

Revere's early romantic imagery, common in the late 18th century, labels him a supporter of the pastoral ideal. He preferred the gardenlike aspects of nature to its wilder

[1] "Cantondale" is an undated document in roll 2 of the Revere Family Papers, although "1810" was written in the corner at a later date. Emphasis is in the original.

components while keeping the comforts of civilization reassuringly close at hand.[2] Unlike many later 19th century writers (such as Twain, Thoreau, and Melville) who viewed machinery and technology as threats to pastoral fulfillment, Revere prominently included industrial elements in his catalog of Cantondale's delights. To Revere, his Canton property represented a "middle landscape," a harmonious meeting point of wild nature and civilization. It is tempting to apply the themes of his Cantondale poem to his final years and assume that he found happiness on his rural property, surrounded by nature and technological activity.

On March 1, 1811, at age 76, Paul Revere officially retired from the business he had founded. Although Revere and Son had only existed as a separate entity for seven years, it was the successor to the copper, brass, and iron work he had been performing for 22 years. For a man who defined himself by his achievements, retirement undoubtedly represented a difficult and momentous transition. But at least his business would live on, under the supervision of his son and partner.

Revere prepared a new set of Articles of agreement to formally establish a new partnership between Joseph Warren, Paul Revere the Third, and Thomas Eayres Jr. This partnership received all company assets (totaling over $40,000) and maintained the name "Paul Revere and Son." Paul Revere the Third was Paul Revere's grandson and the oldest son of Paul Revere Junior, who still managed the original silvershop. Thomas Eayres Jr. was also Paul Revere's grandson, the son of Revere's daughter Frances and Thomas Eayres Sr., a promising young silversmith who apprenticed with Paul Revere, started his own shop, and eventually lost his sanity. Joseph Warren became the new senior partner of this family venture, responsible for 4/6 of all expenses and entitled to a similar percentage of all profits, while the other two owned 1/6 each. Revere loaned Joseph Warren the use of all of his property and in exchange Joseph Warren agreed to pay him $900 a year and reserved to his father the exclusive use of his house.[3] This new partnership united Joseph Warren with two members of the next generation, including the oldest son of Paul's oldest son. The thought of a thriving family business must have

[2] The pastoral ideal is discussed at great length in Leo Marx' *The Machine in the Garden* (New York: Oxford University Press, 1964).
[3] Indenture documents, March 1, 1811, Roll 2 RFP.

pleased Revere in his old age, as he could now become a family patriarch and the founder of a successful manufacturing dynasty.

Compared to the voluminous correspondence that characterized his working career, Revere's life in retirement is relatively unknown. Revere suffered several heartbreaking losses before the end of his life, as his oldest son Paul Junior and his beloved wife Rachel both died in 1813. Only five of his 16 children outlived him: Mary from his first marriage, and Joseph Warren, Harriet, Maria, and John from his second. He had at least 51 grandchildren.

Paul Revere died on May 10, 1818. His last will and testament reveals the great trust he placed in Joseph Warren's honesty and competence, since he appointed him the guardian for all grandchildren under the legal age. In a later codicil to the will, Joseph Warren also received the money previously given to Revere's three daughters and was instructed to pay them the interest from that money in quarterly installments. Revere did not grant all of his business property and equipment to Joseph Warren, but rather asked him to purchase it from the estate over a period of four years, at "lawful" interest. However, after all of Revere's bequests to children and grandchildren were made, Joseph Warren received the remainder of his father's personal property and money.[4]

Joseph Warren oversaw the operations of Revere and Son until his death in 1867. He could not have been better prepared to carry out the business. In his youth he worked under his father's supervision for many years before he was entrusted with management of the Boston foundry while his father ran the Canton operation. Immediately after becoming a full partner he traveled to Britain and Europe in search of the latest manufacturing technologies. Joseph Warren shared his father's ability to grasp both the technical and managerial details of his operations, and this versatility was directly responsible for the company's continuing success. Although he had big shoes to fill, the company thrived under his management. He received an early boost during the War of 1812 when naval copper demands increased sales to three tons of copper sheathing a week. Joseph Warren spearheaded the establishment of a manufacturing complex at Point Shirley Massachusetts in 1844, which used the "Continental process" to refine copper ore. A series of mergers, eventually including the descendent of Levi

[4] Paul Revere's last will and testament, dated March 14, 1818, Roll 3, RFP.

Hollingsworth's company, helped Revere and Son continue growing, and versions of the firm survive today as Revere Copper and Brass Incorporated and the Revere Ware division of Borden Inc.

Revere's legacy extends beyond the corporate descendants of his business. His career offers many insights into early American manufacturing and business. A final analysis of Revere's accomplishments rests upon two broad questions: what factors helped him accomplish his goals, and how did these goals evolve throughout his life?

Tools of the Trade: The Components of Revere's Success

Revere's career trajectory makes too much sense when viewed in its entirety. His different business endeavors seem to fit perfectly into a seamless plan. After all, he started as a well-positioned silversmith and built a good reputation, patron network, and stockpile of capital. Ironworking allowed him to learn and practice his casting skills while earning a steady income from cast iron sales. The ironworking furnace enabled him to enter the field of bell and cannon casting, which familiarized him with copper and government contracts. Malleable copper production such as bolt and spike drawing easily followed, which introduced him to new metallurgical techniques and a much larger scale of production. After mastering that line of work he had the technical and organizational qualifications required for copper rolling, his most advanced endeavor. All in all, a most excellent strategy.

Of course this is false. Revere did not possess oracular powers, and could not chart such a fortunate string of events. But he does deserve credit for fostering the components of success throughout his career. With three powerful entrepreneurial tools in his repertoire he was always poised to exploit any opportunity that arose, and Revere's America was a growing and evolving land of opportunity. Revere's skills focused upon the areas of management, capital collection, and technical expertise, three fields in which America was particularly deficient.

His first tool was **managerial savvy**. This ambiguous quality is easy to overrate, but in colonial and postrevolutionary America it was not common. Colonial America did

not offer many opportunities for a business education. Over 90% of the population worked on small farms and relied primarily upon barter and credit interactions within close kin and community networks. Urban craft shops had far more access to the expanding market economy, but these establishments were still quite small and traditional. Despite the short supply and high value of skilled labor many craft shops failed, often because of managerial incompetence. The apprenticeship tradition focused on technical art and mystery, not upon accounting, pricing, advertising, or the many other important business elements.

Why was Revere different? From the beginning he believed in careful recordkeeping. His methods certainly changed over time, becoming more comprehensive, more quantitative, and better subdivided, but even his earliest records reveal his attempt to document his major transactions. This recordkeeping was one aspect of his desire to analyze and perfect his operations, both technical and otherwise. He was never satisfied with the status quo, but looked for new ways of expanding his business or increasing his efficiency. Historian Jayne Triber discusses Revere's ambition primarily in terms of his desire to improve his social standing, but he applied the same enthusiasm and ambition to the details of his many endeavors. He was a good manager because he was always looking for new ways to improve his business.

A second component of Revere's success was his ability to procure **government contracts and support**. At first, this was related to his ambition and self-confidence. Most Americans had a very limited amount of interaction with the federal government, perhaps through the postal service, Army recruiters, or through articles in the highly partisan newspapers. The same revolutionaries who resented Britain's attempts to intrude upon their freedoms went to great lengths to insure that the new American government would not do the same. A good degree of initiative was needed to find ways to receive specific help in the form of loans or contracts from such a small and limited national organization. Revere did not lack initiative.

Even after he failed to become the director of the mint or a customs inspector, he still believed the government had a place for him. When he shifted his full attention to his manufacturing endeavors, his place became clear. At that point, all that was required was years of frustrating correspondence and administrative delay, as he patiently

convinced the government to hire him for different jobs and then politely asked for his fees. No private contract gave him this much trouble, but no private contract was remotely as lucrative. In particular, the $10,000 loan provided him with the most vital resource required for entrepreneurial success in early America: capital. Where other entrepreneurs relied upon family wealth or alliances with moneyed men, and where future businessmen formed corporations to raise their funds, Revere and a small number of contemporaries made the government work for them.

The third component of Revere's success was his **technological versatility**. To phrase this differently, Revere excelled at finding ways to transfer technologies from other fields and locations into his operations. Although the concept of technology transfer does not truly apply to a well-established field such as silverworking, Revere's communal practices illustrate the importance of cooperation within the local culture. Individual practitioners undoubtedly competed with one another for clients, but as a whole they used the division of labor principle to work together. Subcontracting allowed them to divide work and maximize skill.

American ironworking also involved cooperation between firms, and in this case it involved technological sharing. The different establishments within the iron field developed symbiotic relationships: blast furnaces needed forges and fineries to buy their products, and the finishing industries depended upon furnaces for raw materials. In a nation with seemingly unlimited natural resources and a growing consumer demand, competition was not as large a concern as efficiency or specialization.

Revere's real experience with technology transfer occurred during his copperworking career. He was now one of the first if not *the* first American to learn to make malleable copper into bolts, spikes, and sheets. He used the knowledge of all his earlier endeavors to help him reproduce the high quality British goods that he would be competing against. His activities centered on reinventing British techniques by applying lessons from casting and silverworking, and he received all the help he could through the illegal importation of iron rollers, the critical element of British technology unavailable in America. The issue of cooperation arose in later years when Revere was joined by two other American copper rollers. Once again, he seemed unconcerned with the threats

posed by potential competitors, allowed others to visit his rolling mill, and offered extensive technical advice and diagrams to help Levi Hollingsworth and H. M. Salomon.

In the political sphere, American statesmen had recently created a new government that attempted to improve the British model upon which it was based. American manufacturers lacked this luxury. Finding themselves years behind their British counterparts, cut off from British processes and equipment, and lacking Britain's surplus population of cheap laborers, supply networks, and investment capital, American entrepreneurs had a lot of catching up to do. Although not an inventor in the strictest sense of the term, Revere brilliantly mastered the skill of reinvention, or the duplication of preexisting processes. And this is what America needed most at this point. Reproduction is a far faster process than invention, and is a necessary precursor to the advancement of knowledge – how can a backward nation create something that will push it past the leader? Revere borrowed from other metallurgical fields, and used the modern concept of reverse engineering to learn or perfect a production method from the study of advanced British products. He would never push his country past Britain's control of technology, but he closed the gap substantially during his career.

One feature underlying Revere's success in shifting between technical fields was his command of technology and metallurgical processes at both a practical and a theoretical level. He used a methodical research method to expand his repertoire and had a command of the scientific and technical vocabularies of the time. Correspondence with scientists indicated his interests infringed upon his personal time. He also loved new machinery and tools, and understood them well enough to be able to envision new uses for existing devices, or determine flaws and postulate solutions.

But although he loved the process of perfecting technical processes, he definitely did not want to be the person who performed the actual labor. As a master craftsman, Revere wore all the hats: he was worker and teacher and manager and marketer and researcher. As his career progressed, he tried to separate these job duties. He still wanted to be the manager (before we had such a term or official position) and he still wanted to learn the new processes and instruct his men (more like a researcher than a practitioner) but he needed to eliminate the labor from his job description.

Unpacking Success: Revere's Goals and Values

Summarizing a person's goals is a risky business, because a lifetime of decisions cannot be fit to a single theoretical model. Revere did not formulate a plan when he first entered the silverworking trade and patiently follow it until he retired. Instead, his goals evolved quite naturally in accordance with changing external conditions and as a response to the success or failure of his different endeavors. With this in mind, several primary patterns emerge from all of his career shifts and business practices.

In the beginning, Revere had the same direct and immediate concerns that anyone would have at the start of their life. He worked hard under his father's supervision and did his best to support his family when his father died. His apprenticeship inaugurated him into an ancient tradition of skilled labor and exclusive knowledge. His work as a silversmith verifies his consummate skill as an artisan, and his correspondence illustrates that he was very proud of his skills. This pride gave him the confidence to undertake new endeavors, and indeed, his pride was well founded, because he was exceptionally intelligent and perceptive, quick to learn. However, his pride also illustrates his colonial upbringing, which separated him from the postrevolutionary generation. As a pre-revolutionary silversmith, he interacted with the gentry on a regular basis and observed and envied their privileges.

Revere's high rank among the artisans and his high visibility among upper class buyers of silver items led to a very important role in the Revolutionary War. The Revolution had an interesting effect upon him. He started thinking bigger, and felt he deserved a more prominent role in society. For one exciting night's ride, he was the commander, the instigator, waking the countryside and rallying support. Throughout the rest of the war he performed other important services, interacted with many of the traditional leaders of society, and liked it. He had paid his dues in the patriot movement, his side won, and he expected some form of recognition. But he was confronted with an uncrossable barrier: gentry privileges almost always resulted from birthright, and he would never gain them by getting his hands dirty.

Fortunately, the times were changing, and national events opened new possibilities. During the postrevolutionary period, the hierarchical social stratification became a hated reminder of British oppression and restriction. A growing meritocracy arose in which one's skills and ambition replaced the importance of birthright. Classes persisted in the form of economic stratifications, in which the rich held the status and power, backed by an almost Darwinian justification of their privilege. Postrevolutionary ideology gave Revere a chance to enter the upper crust of society on his own terms, by earning his place in their ranks. This actually accorded with Federalist principles, in which society elected its most prominent – or its most talented – members for public service. Revere subscribed to the notion of a meritocracy, but not to any version of democracy. The gifted deserved power and status, and Revere counted himself in this elite assemblage. Apart from motivations of personal gain, he did not believe that public service required a personal sacrifice. He wanted to do his part to improve America's political, military, and economic position while helping himself. In fact, he believed that he could most help America by becoming a successful businessman and attaining positions of authority.

At first he tried to be a merchant, and funded his efforts with proceeds from his silvershop and early casting endeavors. This failed for many reasons: he did not have a good sense of purchasing habits, his timing was awful, his capital was insufficient, and he lacked the necessary personal contacts or reputation. He tried to arrange a government appointment, but this also failed because of his lack of connections and reputation. As a card-carrying Federalist he was completely frustrated: the qualified men should rule and he was qualified, but nobody believed him.

In the process of arriving at this dead end, an epiphany took place. Somehow the means to the end became the end; the manufacturing activities that funded his attempts to improve his status became his road to status. In part, these pursuits succeeded because of the growth of his operations and the vast changes that impacted on craftsmanship. With expanding markets and increasing consumerism, the production of goods was no longer exclusively associated with small craft shops owned by the most skilled worker. These shops still existed, but the more visible production facilities were comparatively large manufactories managed and owned by entrepreneurs. As a manufacturer he made money

and provided a valuable public service without getting his hands dirty. He was the boss, he commanded respect, and he used his mind to solve problems. It helped that he devoted most of his efforts to the technical issues that fascinated him and perfectly suited his talents.

The culmination of this epiphany was the opportunity to roll copper. At last, all the pieces fell into place. Copper rolling related to the United States navy, a federal institution intimately associated with the national welfare. Copper rolling also related to America's prestige: if he succeeded he would strike a blow for America's technological independence, and help build a fleet to assert and defend its political independence. This was his mission; this was his chance to be a hero. The $10,000 loan from Stoddert became an embodiment of his important contribution. In addition to representing a vital financial benefit, the government loan represented his mandate from government, tangible proof that the nation's leaders needed and sought his help. He certainly focused on the financial aspects of the loan at first, but in the years to come he repeatedly mentioned it as an example of his manufactory's importance. He was becoming a man of affairs and gained recognition as he finally began to play a role in national events by providing a vital service that nobody else could manage.

With his success, Revere believed the good times had only just begun. As a Federalist he felt he had just been admitted into the ranks of the elite and expected good treatment in the future. He anticipated the continuation of major government contracts and support, and certainly a monopoly, since he was the only American to provide sheeting and Stoddert wanted to buy from Americans. Of course, that was when the Federalists lost their grip on power. He was stunned by the Jeffersonians' withdrawal from his business, and fought them at every step. He wanted his loan, he wanted his manufactory to provide copper for all the government's needs, he wanted a protective tariff that provided special protection from foreign competition, and he could not understand why he never received these well-earned rewards. He won the battle to receive the funding Stoddert promised him, but lost the war. To the Jeffersonians, the loan was only a monetary transaction, and he was merely another government contractor. He would never be a public servant.

But he was a manufacturer, and in the end that meant something after all. For starters, labor had lost its servitude-based connotations in favor of the growing image of the "self-made man." And Revere was not a skilled laborer, but a manager, a property owner, an entrepreneur. More important than his net worth was the magnitude of his accomplishments, the technological secrets he wrested from Britain to strengthen his country. The appearance of other copper rollers did not hurt his fame, but enhanced it: he now knew his discoveries had borne fruit and could consider himself the founder of what we now call a national industry. And on the eve of his retirement from the shop he even accepted a new ideal, that of Cantondale. He could find contentment in the pastoral harmony of his operations and natural surroundings. Property ownership, a manufacturing legacy, societal prestige, and napping in a hammock represented different forms of success and happiness. At the end of his life, Revere could appreciate them all.