Robert J. Schneller, Jr. THE DEVELOPMENT OF DAHLGREN'S HEAVY CAST-IRON SMOOTHBORES AND THEIR ADOPTION BY THE NAVY. (Under the direction of William N. Still, Jr.) Department of History, June, 1986.

The purpose of this thesis is to present an in-depth study of John A. B. Dahlgren's heavy guns, their development and adoption by the navy. When first placed on board ships in 1856, Dahlgren guns were considered to be among the world's most powerful ordnance. They remained in service nearly until the end of the nineteenth century, by which time they were obsolescent.

Shell guns were adopted by the French and British navies early in the second quarter of the nineteenth century. At this time, naval officials considered them to be controversial and they served as auxiliaries to guns capable of firing solid shot. Prior to this time, ordnance design was based on tradition and experience. The second quarter of the nineteenth century witnessed the application of scientific methods and experimental procedures to both ordnance design and metallurgy.

Dahlgren guns were characterized by their unusual "soda bottle" shape. Dahlgren chose this shape because he believed it resulted in a stronger, more powerful gun and a higher safety factor for a given weight of metal than more conventional designs. His guns had sufficient strength to fire solid shot as well as shells.

Dahlgren's design, however, was a synthesis of existing ideas rather than a product of innovation. A more unique aspect of the guns was their metallurgy. The first Dahlgrens produced for shipboard use were cast by methods that had been in use for centuries. Many of these

guns exploded when test fired. Dahlgren's solution to this problem did not involve changing the design; instead, he modified the casting technique. Later, the larger caliber Dahlgrens were cast by a new technique developed by Thomas J. Rodman, an army ordnance expert.

Dahlgren believed that his IX- and XI-inch guns should arm ships' batteries entirely, supplanting other types of ordnance. He argued that a battery of a smaller number of heavy guns was superior to a battery of more numerous, lighter guns. Naval officials were willing to use the IX-inch gun in conjunction with other types of ordnance in ships' batteries, but at first, adamantly opposed the XI-inch gun because they believed that its sixteen thousand pound weight was excessive. The IX-inch gun received general approval in 1854, but the XI-inch gun was not fully approved until Dahlgren demonstrated its feasibility for shipboard use in 1857. Dahlgren's system of ordnance was never accepted as a whole: his guns were rarely used to arm ships' batteries to the exclusion of other types of ordnance other than on board the Monitors.

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DAHLGREN'S HEAVY CAST-IRON SMOOTHBORES
AND THEIR ADOPTION BY THE NAVY

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Robert J. Schneller, Jr.
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TABLE OF CONTENTS

Page

LIST OF FIGURES

INTRODUCTION

American historians have called John Adolphus Dahlgren the father of modern ordnance and gunnery.[1] Although the United States Navy traditionally imitated rather than initiated new trends, Dahlgren introduced in the 1850s a new type of heavy ordnance considered to be among the world's most powerful.[2] These guns were cast-iron, muzzle-loading smoothbores. Dahlgren borrowed ideas that existed independently either in the minds or guns of other inventors, refined them, and incorporated them into his own ordnance. Designed so that the metal's thickness along the bore increased with the change in internal pressures, these guns had a unique shape. Critics referred to them as "soda bottles." Dahlgren believed that his guns were safer and could fire heavier projectiles than any other contemporary gun of the same weight. Although his guns were capable of firing solid shot, he favored firing exploding shells because he believed that they could inflict far more damage on wooden ships. Despite the resistance of conservative senior naval officers, he also arranged for the adoption of his new ordnance on board naval vessels. He based his new system of ordnance on the belief that a ship armed with fewer heavier guns had more firepower than a ship armed with more numerous lighter guns. His ordnance became the principal armament of United States naval vessels during the Civil War and remained in service until the end of the nineteenth century.

Little has been written about the history of Dahlgren guns. In works such as Naval Gun by Ian Hogg and John Batchelor, The Evolution of Naval Armament by F. L. Robertson, Sea Power in the Machine Age by Bernard Brodie, The Introduction of the Ironclad Warship by James P. Baxter, III, and Battleships in Transition by Andrew Lambert, Dahlgren guns are only briefly mentioned in the context of either the transition from wooden to ironclad ships or the transition from smoothbore to rifled ordnance. They are described briefly to differentiate them from other types of ordnance in works such as Civil War Naval Ordnance by Eugene B. Canfield and Warren Ripley's Artillery and Ammunition of the Civil War. Works such as Round-Shot to Rockets by Taylor Peck and Admiral John A. Dahlgren, Father of U. S. Naval Ordnance by C. Stewart Peterson exaggerate the importance and effectiveness of the Dahlgren guns because they are based largely on Memoir of John A. Dahlgren by Madeleine V. Dahlgren. This latter work is more or less the standard on the subject of Dahlgren guns and may be considered a primary source. However, it was written by Dahlgren's second wife who based it on his papers and diaries. This work is clearly biased and does not present analysis using other sources.

The purpose of this thesis is to present an in-depth study of the heavy cast-iron Dahlgren smoothbores; their development and their adoption by the navy. Using a variety of primary and secondary resources including Dahlgren's papers, this thesis attempts to take a more objective look at the subject than other works. Additionally, this paper focuses more than others have on the technological aspects of Dahlgren's ordnance in the developmental years. This is not intended to be an exhaustive study as there are many more primary sources to use and much more technical information to include. It is intended to be a learning experience and a basis for further study.

Chapter I outlines the history of shell guns prior to the Dahlgrens. Shells were first used on land as early as the sixteenth century. They were originally fired from mortars, heavy weapons that fired shells at high angles with low charges because in their primitive state, shells were dangerous. High-angled, low-charged firings minimized the danger to the mortar crews and yielded an adequate range. Mortars were found to be too heavy for field use so light mortars called howitzers were invented. Shells were first used on board ships at a much later date because their unstability often caused fires which had dire consequences. The story of horizontal shellfire in naval warfare remains obscure, but that tactic was firmly in place by the mid-nineteenth century. The debate about the merits of heavy and light guns had been raging between their respective advocates for centuries. By the mid-nineteenth century, most navies favored using lighter guns. The rate of progress in ordnance innovations was increasing during the second and third quarters of the nineteenth century. Many of the aspects of ordnance design incorporated in the Dahlgren guns were developed in the eighteenth and early nineteenth centuries.

Chapter II explains how Dahlgren arrived at his soda bottle design and the rationale behind it. His early career provided him with a wealth of ordnance experience and mathematical knowledge that he applied to his guns. He made rapid progress while Lewis Warrington was chief of the Bureau of Ordnance and Hydrography. Warrington supported Dahlgren's ideas whereas his successor, Charles Morris, did not. Dahlgren's dogged persistance finally paid off. His experiments eventually convinced the critics that his beliefs were sound and his guns were chosen to arm the Merrimack class of frigates in 1854.

Chapter III examines the metallurgy of Dahlgren's guns from his own and modern perspectives. Metallurgical and chemical knowledge in the mid-nineteenth century was primitive by today's standards, but it was a time when many experiments were being conducted that yielded a wealth of new information. Dahlgren utilized pieces of this information when constructing his guns. A crisis arose when many of the new guns cast for the Merrimack class of ships exploded when test fired. Many of Dahlgren's original views about casting guns were in error, but his solution of changing the casting technique solved the problem.

Chapter IV explains how Dahlgren managed to overcome senior naval officers' resistance to his ordnance, eventually having it approved for shipboard use. His plan included arming newly constructed ships entirely with his own guns and eventually replacing the ordnance of older ships with his guns. Senior naval officers approved his IX-inch gun in 1854, but adamantly refused to adopt the XI-inch gun because they believed its sixteen thousand pound weight to be excessive. Dahlgren battled long and hard for the adoption of his entire plan of armament, but was never fully successful. The XI-inch gun received approval only after he made a special cruise on board the Plymouth in 1857 to test its capabilities at sea. Dahlgren guns became the standard ordnance by 1860, but Dahlgren's plan of armament was never fully adopted.

The following stylistic form is used throughout this thesis. The caliber (diameter of the bore) of guns used by the United States Navy has been designated in accordance with the common usage of the 1850s. Roman numerals were normally used for Dahlgren guns while the calibers of other guns were designated by Arabic numbers. Finally, the 1850s marked the beginning of an era in which guns took the names of their inventors in order to distinguish some particular feature. In this thesis, therefore, Dahlgren guns are often referred to simply as "Dahlgrens."

ENDNOTES

[1] Ralph Earle, "John Adolphus Dahlgren,"United States Naval Institute Proceedings LI (1925): 435, hereinafter cited as Earle, "Dahlgren;" C. Stewart Peterson, Admiral John A. Dahlgren, Father of U. S. Naval Ordnance (Cynthiana, KY: Hobson Book Press, 1945), p. 1, hereinafter cited as Peterson, Father.

[2] Richard Dwight Glasow, "Prelude to a Naval Renaissance: Ordnance Innovation in the United States Navy During the 1870s," (Ph. D. dissertation, University of Deleware, 1978), p. 9; hereinafter cited as Glasow, "Prelude."

CHAPTER I

BEFORE THE SODA BOTTLE

Although the United States Navy had officially adopted shell guns in 1845, many officers and men still mistrusted and misunderstood them in 1850. Percival Drayton, an ordnance officer who later had a distinguished career in the United States Navy during the Civil War, summarized his perception of the current feeling toward shell guns in a letter to Dahlgren that year:

> I cannot speak for other people, but my experience entitles me to say that gunnery may be considered an occasional divisional exercise, where the guns are run in and out with the least possible trouble to officers and men. Target firing is a tradition, and shells a mystery which it is supposed will be explained some of these days. In the mean time poor Jack looks upon them with a mixture of fear and awe, and a Lieut. not very long ago, asked me privately, what composition was inside to cause the explosion, not seeming to dream, that so simple an agent as gunpowder could be used and I heard a very warm argument in a ward room as to which part of the shell should go into the gun first, the majority I think being of the opinion that unless the fuse was next to the cartridge, it could not ignite. . . .[1]

Students of naval ordnance will not find this attitude surprising. Exploding shells did not appear until approximately two centuries after the earliest recorded use of cannon, and were generally unreliable as late as the early nineteenth century.

Two distinct types of cannon emerged in Europe early in the fourteenth century. The first type, shaped like a vase, was designed to fire stout, winged, metal arrows in imitation of the crossbow. These pieces were probably cast in bronze, a technique developed from the bell founding industry. The second type was designed to fire large, heavy stones in imitation of ancient siege engines. These were large, clumsy pieces made by placing strips of iron lengthwise around a form so that they lay along the barrel's axis. The iron strips were heated and hammered to weld them together, then reinforced with either rope or iron hoops wrapped around the barrel. This method fell out of use in the mid-sixteenth century. The earliest manuscripts yet discovered which mention guns reveal that in 1314, cannon were being manufactured in Ghent and exported to England. The manuscripts do not reveal which type of guns these were. The earliest picture yet discovered of a gun is from an illuminated manuscript belonging to Christ Church, Oxford, dated 1326. The manuscript depicts an arrow-throwing vase-shaped piece.[2]

Artillerists soon discovered that arrows were unsuitable projectiles for use in conjunction with gunpowder. They realized the difficulty in preventing gases generated by the ignited powder from escaping through the windage space between the arrow shaft and the vase neck. Arrows were soon entirely supplanted by stones or metal spheres and the windage space was reduced so that the projectile diameter was nearly that of the gun's bore.[3]

The Venetians were probably the first to mount cannon on board ships. In 1378, a fleet of Venetian galleys armed with cannon attacked the Austrian port of Zara. The Venetians and others had previously mounted catapults, ballistae, and slings on the forecastles of their galleys, and substituting cannon for these was a logical step. These first cannon were probably installed specifically to bombard Zara, but the practice of mounting cannon to fire over the bow soon became standard practice in the Venetian fleet. Breech-loading guns with removable chambers were used as anti-personnel weapons and were mounted on board English ships as early as 1412. During the fifteenth and much of the sixteenth centuries, guns were used on board ships primarily as anti-personnel weapons. The dominant tactics of the day involved either ramming or boarding the enemy vessel. In the latter case, naval battles resembled land battles: opposing ships were lashed together and soldiers determined the outcome. Advances in gun founding and gunpowder chemistry in the sixteenth century changed cannon from defensive into offensive weapons. Tactics changed from ramming and boarding to sinking an enemy vessel from a distance with gunfire.[4]

Artillerists also began using exploding projectiles in the sixteenth century. The Turks used bombs or hand grenades during the siege of Rhodes in 1522.[5] The shell, a hollow metal projectile filled with gunpowder designed to explode near its target, emerged at this time. Early shells were unstable and prone to exploding prematurely or catching fire, often inflicting more damage on the side that employed them than the enemy. Because of their sensitivity, shells were only considered safe if fired with small propelling charges at high angles. Mortars, short, squat, heavy pieces originally developed to throw large stones over the walls of enemy fortifications in siege warfare, became coupled with shells because of their high-angled fire. Artillerists soon discovered that mortars were too heavy to be used in the field, so light mortars called howitzers were developed. Mortars and howitzers were more difficult to aim and less accurate than guns that fired projectiles horizontally. As a result, artillerists attempted to develop guns which could safely fire shells horizontally. Renaud Ville, a French engineer, developed a gun which successfully fired shells horizontally at the siege of Ostend in 1602.[6]

Shells first appeared on board ships, where the danger from explosion or fire is much more acute than on land, at a later date. Naval officers in general believed that the risks inherent in explosive projectiles far outweighed any tactical advantages gained from using them. Some were willing to take chances, but the development of shell guns as a naval armament was characterized by slowness or an unwillingness on the part of world navies to exploit successes. A few individuals attempted to develop guns that could safely fire shells horizontally from ships, but shell fire at sea was initially confined to mortars. Prior to the nineteenth century, mortars were usually mounted on board specially constructed boats which could absorb the recoil and in which special care was taken in handling the projectiles. Mortars were thought to be inappropriate on board ships of the line because these vessels had far less space for magazines to store shells safely.

In 1682, a French fleet under Admiral Abraham DuQuesne bombarded pirates in the city of Algiers. Among DuQuesne's fleet were five bomb ketches designed by a Basque named d'Elicagaray. Each of these boats had two masts, was armed with at least one short-barreled, high-angle, muzzle-loading mortar, and was specially reinforced to absorb the mortar's recoil. Algiers was devastated by these weapons.[7]

Several years later, Richard Leake, master gunner of England, invented a gun intended to be placed on a ship's forecastle that fired incendiary shells. Two such pieces mounted on an English bomb vessel set fire to a French ship during the battle of Bantry Bay in 1689.[8] In 1690 a French inventor named Deschiens devised a way to fire bombs horizontally from long guns which were successfully used against two

Dutch ships.[9] A council of officers on board H. M. S. Triumph in 1701 approved a proposal to shoot shells and incendiary shot from cannon provided precautions were taken to prevent their own ships from catching fire.[10]

In 1760 the British navy experimented with shells fired from 12- and 24-pounders to test their suitability for use on board ships. They concluded that shells were too dangerous to be fired from ship-mounted ordnance because they frequently burst in the guns.[11] Nevertheless, during the siege of Gibralter in 1779, the French army successfully fired 5½-inch shells with short fuses from 24-pounder guns.[12] Henry Shrapnel developed the shell that bears his name in 1784. This shell contained lead balls hardened with antimony and zinc. The spaces between the balls were filled with molten sulphur which solidified around them, forming a solid mass. A portion of the cavity in the shell was then partioned off by a diaphragm of sheet iron and the bursting charge inserted. Shrapnel's shells were first successfully used against the French in the Peninsular War.[13]

In 1788, Sir Samuel Bentham, an ex-shipwright from Deptford who was then a lieutenant colonel in the Russian army, equipped a fleet of small boats with long 36-pounders, 48-pound howitzers, and a 13-inch mortar. These boats were furnished with shells, carcasses, which were lightweight spheres filled with incendiary material, and solid shot for their guns. The Russian fleet defeated a much larger Turkish force in the Sea of Azov. Shells from the Russian ships were fired horizontally or at elevations never exceeding ten degrees. They tore holes in the sides of the Turkish ships and started fires which spread rapidly.

Yet very few in European naval circles took note of this event. The British at this time possessed what was arguably the most powerful navy in the world, but displayed a real or feigned indifference to advances in projectile technology.[14]

The British ignored technological advances in naval ordnance to maintain the status quo. One English historian, writing in 1837, observed that "so long as foreign powers did not innovate by improving their guns, . . . above all, by projecting shells horizontally from ships; so long it was our interest not to set the example of any improvement in naval ordnance . . . ."[15] Although it has been said that the guns Nelson fought with were little better than those Drake fought with, late eighteenth and early nineteenth century developments would eventually force the British into adopting shell guns.[16] Meanwhile, despite Royal Navy resistance, Englishmen continued experiments to improve ordnance.

Prior to the mid-eighteenth century gunnery was based on practical experience, not theory. Gun design was an empirical process that followed tradition, because deviations often led to failure. There was no established theory of internal ballistics and no theory relating stress to gun tube thickness. Some textbooks had been written, but these were largely based on hearsay and speculation.[17]

During the mid-eighteenth century, an Englishman named Ben Robins set out to verify or disprove established theories by actually firing guns. He invented a device which made possible calculating the differences in projectile velocity stemming from various gun lengths, charges, and distances to targets. In 1747 he published a paper in which he proposed redistributing a gun's metal so that it would be thicker where the strain on the gun was greater. This proposal would make guns safer, and for a given weight of metal, he believed, larger caliber guns could be produced. Robins pointed out that a larger, heavier shot would have a greater range, have a greater striking force, make a larger hole, and have superior penetrating power. The Royal Navy became interested in Robins' work when it discovered that the French shared his ideas. But when the French showed little enthusiasm for advancing these theories, the Royal Navy lost interest.[18]

A private individual took the first step away from conventional cannon. In 1774, Robert Melville designed a short gun with an 8-inch bore that weighed 3,472 pounds and fired a 68-pound ball with five and one-half pounds of powder. Windage, the clearance between the bore wall and the shot diameter, was kept to a minimum. Melville's design was based on Robins' theories. He contracted with the Carron company to make a speciman cannon that he called the "Smasher." This piece was the first carronade.[19]

The Smasher's short barrel, small charge, reduced windage, and heavy ball developed excellent muzzle velocity, accuracy, and fine penetration. Its defect was its low range in comparison with longer guns. This mattered little, as the tactics of the day emphasized close combat.[20] Carronades broke new ground in the form of mounting, as well. Slide mounts and carriages that resembled the later Marsilly pattern were used instead of the traditional truck carriage.[21] Melville's first offer of his weapon to the Royal Navy was ignored. The Carron company further shortened the barrel, however, and when it sold widely to privateer and

and merchant vessel owners the Royal Navy decided to experiment with carronades by placing them on forecastles and poop decks of some of its ships.[22]

The carronade proved successful. H. M. S. Rainbow was armed with a variety of carronades as a trial ship in 1782. On one cruise she engaged a French frigate, the Hébe, which was armed with conventional long-barreled guns. Had the Hébe's captain known better, he could have defeated the Rainbow by staying out of carronade range and pounding her with his longer range conventional guns. But since standard tactics dictated close-in combat, the Hébe was forced to surrender after receiving one broadside from the Rainbow's carronades.[23]

Many British ships carried carronades that successfully fired Shrapnel and regular shells during the American Revolutionary War and the wars against revolutionary and Napoleonic France.[24] The British phased out carronades after the War of 1812 because of their short ranges. There was little interest in non-traditional cannon until shells were adopted as standard projectiles.

The shell idea, generally ignored in the eighteenth century, eventually interested the French. The outbreak of war in 1792 accelerated ordnance experiments with hopes that the French navy could supplant the English as masters of the seas. In June 1795, at Toulon naval base, Lieutenant General Count Andréossy test fired shells horizontally from 18-, 24-, and 36-pounders at targets built to represent ships of the line. Ranges varied between 400 and 600 yards. The same type of experiment was repeated on a larger scale at Meudon in 1798. The shells had a devastating effect on the oak targets and the French considered them successful. In a similar experiment performed at Cherbourg in April 1797, 24-pound shells were fired against a vessel of lighter scantling. The results indicated that the heaviest ships of the line, if struck by shells of this caliber at the waterline, would sink in less than fifteen minutes.[25]

Impressed by these tests, the French in 1795 began issuing shells and other incendiary projectiles to their ships. Unfortunately, these proved to be more dangerous to their own ships than to the enemy's. French ships frequently caught fire by spontaneous combustion and other accidents. Fires on board ships caused by battle damage often reached stores of shells, causing explosions. One of the better known examples was the loss of the French flagship Orient during the battle of the Nile in 1798. The following year, twenty 36-pounder and fifty 18-pounder shells captured from a French prize exploded on board H. M. S. Theseus killing thirty-one officers and men. These results confirmed the beliefs of more conservative British naval officials that shells were too dangerous to be permitted on board ships. Undaunted, the French continued experimenting with shells and arming ships with them. Choderlos de Laclos fired shells from a 24-pounder at a range of 512 yards and demolished an earthwork at Vincennes in 1799. Experiments would continue into the nineteenth century.[26]

French experiments with horizontal shell fire did provoke some interest in England during the Napoleonic Wars, but no major innovations were forthcoming. Having returned from Russia, General Bentham in 1798 proposed to mount 24-pounder carronades, which threw shells, carcasses, and solid shot, in small coasting sloops. Other experiments with shells yielded some successes with both horizontal-firing guns and mortars, but in July 1813, the Admiralty again rejected a plan to fire shells from shipboard guns of carronades.[27]

In the United States, the shell concept caught on more rapidly. Lieutenant Colonel Louis de Tousard published a work in 1809 that called attention to the earlier French experiments in firing shells horizontally from guns.[28] Prior to the War of 1812, only one American naval officer, Stephen Decatur, was known to have experimented witn explosive shells. He designed shells having four holes in them for admitting air to facilitate the explosion. Decatur claimed that he had fired these shells at a wooden target which was torn to pieces at a 400 yard range, but in the interest of fair play he said he would not use them if the United States went to war with its British cousins.[29]

The major American contribution to shell gun development during the War of 1812 was the introduction of the Columbiad, a long-chambered piece combining characteristics of the gun, howitzer, and mortar, and capable of firing both solid shot and shells. All guns capable of firing solid shot could also fire shells: it was the American's willingness to use shells in the Columbiad that classified it as a shell gun. Because shells were lighter than shot, smaller charges could be used to fire them. Later guns designed to fire shells exclusively often were not capable of firing solid shot because for a given caliber, the shell guns were made lighter than shot-firing guns. If shot were used in such a shell gun, the larger charge necessary to produce adequate muzzle velocity would probably rupture it. The Columbiad's origin is obscure. Most historians agree that it was designed by Major George Bomford, who later became the

United States Army's Chief of Ordnance, but while some claim that Bomford designed it during the War of 1812, others date it as early as 1810. Even the name's origin is confused; some suggesting that it was named after a patriotic poem by Joel Barlow, others claiming it derived from being manufactured at the Columbian foundry of Georgetown, District of Columbia. The name "Columbiad" was also applied to smaller guns cast at the Columbian foundry as well as coastal defense and shipboard guns. One version, a 50-pounder of 7.4-inch diameter was mounted on American privateers, enabling them to outrange British ships relying on carronades. After 1840, the name was usually applied to coastal defense weapons.[30]

The late eighteenth and early nineteenth centuries witnessed the first successful adaptations of steam power to ships as well as further experiments with shells and shell guns. The first steamships to be commercially successful were driven by paddle wheels. Naval officials at first objected to steam propulsion for warships for a variety of reasons: the large, fragile paddle wheels provided an easy target for the enemy; if the cumbersome steam machinery were damaged, the steamship would be at the mercy of an enemy sailing ship; early boilers often exploded; and the machinery and fuel would take up room required for guns, ammunition, and crew quarters. With the development of the propeller in the 1830s, naval officials became more amenable to steam propulsion. When the Crimean War began in 1853, England and France possessed only a few steam propelled frigates and ships of the line, but the war convinced the critics of steam power of its value.

In 1814, Colonel John Stevens and his sons Robert and Edwin Stevens of Hoboken, New Jersey developed an elongated shell. When fired at a target representing the side of a ship, the shell caused extensive damage. The Stevenses predicted that their shell would revolutionize naval architecture. Both the army and navy ordered Stevenses' shells, and the navy evidently experimented with them in the period from 1818 to 1823 to acquaint as many officers and seamen as possible with their use. The Stevenses also proposed that shell guns and armored steamers be adopted by the United States Navy, but their suggestions fell on deaf ears.[31]

In France, one of Napoleon's artillery officers shared the Stevenses' belief that shells would revolutionize naval architecture. Formerly an army general, Henri-Joseph Paixhans began his work with naval guns in 1809. He experimented with firing solid cast-iron 24-pounder shot against an armored target.[32] Inspired by the Americans' Columbiad, Paixhans experimented with hollow projectiles and the effects of bursting shells from 1809 to 1819. In 1822 he published the results in a treatise, Nouvelle Force Maritime.[33] In this work, Paixhans argued for mounting shell guns on board steam-powered, armored vessels. He believed that the wooden walls of ships of the line protected them adequately from solid shot, but were hopelessly vulnerable to attack by heavy shells, which would tear great holes in them. Mortars, he pointed out, could only be used for high-angle fire and were practical only on board vessels specially designed to carry them. Paixhans declared that horizontal firing of heavy shells would not only be feasible on board ships, but, compared to mortar fire, would greatly increase the chances of striking the target. Believing that shells would render wooden walled vessels obsolete, Paixhans suggested armoring ships with iron. He argued that affixing iron thick enough to resist shells to the large surface area of a ship of the line would severely hinder its sailing qualities. On the other hand, he believed that smaller steam-powered vessels could be easily armored and would not need to rely on changing winds. He believed that a fleet of such vessels would require fewer skilled seamen, and that in the future a nation's naval power could become proportional to its total poputation, instead of remaining proportional to its seafaring population.[34]

Paixhans also suggested that the French navy adopt shell guns of standardized calibers. He argued that the policy of arming ships with different calibers caused supply problems. During battle, a ship would occasionally run out of one caliber of ammunition, naturally reducing its firepower for the remainder of the engagement. Adopting one standard caliber for a ship's entire battery would solve this logistical problem. By varying the weights of the guns and charges in a battery of one caliber, the same effect could be achieved as with a battery of mixed calibers. Thus, if eight inches were chosen as the standard caliber, the main battery would be heavy 8-inch guns fired by powerful charges and the lighter guns would be fired with smaller charges. Only one caliber of ammunition need be carried and the main battery would not run out of ammunition in battle. Since the standardized caliber would be the largest possible, the firepower of the ship, expressed as projectile weight, would increase. Paixhans did not recommend his plan of standardized caliber for shot-firing guns, because the lighter pieces would be fired at such low velocities as to lose the range and especially the penetration capabilities required for solid shot to be effective. Shells, on the other hand, could be fired at the lower velocities resulting from lighter charges. A shell needed to be fired with only enough velocity to be lodged in a ship's timbers; penetration through the hull would not be necessary. The ensuing explosion would inflict far more damage on the hull than the mere penetration of solid shot. Since shells could be fired at lower velocities than solid shot, guns designed to fire shells exclusively could be made lighter than shot-firing guns. Thus, a shell gun would recoil less than a heavier shot-firing gun. Shell guns could therefore be reloaded faster and have a faster rate of fire. A ship armed with a battery of shell guns could fire a greater volume of projectiles than a ship armed with a battery of guns capable of firing solid shot.

Besides theorizing about shell guns, Paixhans designed them. His first "cannon-obusier" or shell gun weighed the same as the French naval 36-pounder long gun, about 8000 pounds, yet it had the same caliber as the French 80-pounder, twenty-two centimeters. It threw a hollow shell that weighed 62½-pounds empty, and could be filled with four pounds of black powder. It was a plain, tapering, smooth-surfaced gun without the fancy ornamentation characteristic of the period.[35] In January 1824 at Brest, this new gun was tested successfully. Le Pacificateur, an old eighty-gun ship of the line, was used as a target. The sixteenth shell caused so much damage that those present believed a similar explosion near the waterline would probably have sunk the ship. The government officials in charge of the experiment concluded that Paixhans' gun was effective. They believed that with improvements, Paixhans guns could be as easy to handle as ordinary guns and would be suitable to arm ships of the line.

Paixhans published the results of the test in Experiences faites sur une Arme Nouvelle in 1825. Together with Nouvelle Force Maritime, this work summed up his arguments and caused some commotion in naval circles. Several of Paixhans' arguments were at fault. He advocated armoring the sides of ships and arming them exclusively with shell guns. Should such vessels encounter armored enemy ships armed with shot-firing guns, they would be at a disadvantage because shells fired at low velocities could not penetrate armor while solid shot could. He opposed using elongated projectiles, although these were destined to increase artillery's power enormously. He declared that the day of the large, expensive ship had passed. Nevertheless, Paixhans guns were first introduced on board French warships on a limited basis in 1827. Two years later, the French army adopted Paixhans' idea of standard calibers and adopted a selection of 6-inch guns of varying weights for service. In 1837, the French adopted shell guns for the entire fleet but retained shot-firing guns.[36]

Meanwhile, the British were making their own experiments with shell guns. Captain Frank Abney Hastings mounted shell guns on board the British steamer Karteria. This vessel served effectively with the joint British, French, and Russian fleet that supported the Greek revolt against Turkey in 1827. Two years later, the Admiralty ordered tests with 10- and 12-inch guns. Experiments continued throughout the next decade before the British in 1839 adopted shell guns for service in their navy. The British followed the French practices of retaining solid shot guns and standardizing the calibers of their guns.[37]

Although both the British and French navies had adopted shell guns, they were still considered controversial. In both navies, shell guns were meant to supplement, not supplant, solid-shot firing guns. The latter type was still considered a ship's main armament. There were a number of drawbacks to shell guns. Their range was limited by their small charges. Because shells were still considered dangerous, increasing the charge to increase the range was thought to heighten the danger of the shell exploding before it exited the barrel. The flight of shells was not as certain as solid shot because, among other reasons, shells were not as uniformly cast. Many naval officers believed that battles between steam-powered warships might be fought at distances beyond the reach of shell guns, where solid shot would prove more effective. Many still believed that it was simply unsafe to carry shells on board wooden ships, because of the dangers of fire and explosion.[38]

Despite these conservative views, some naval officers, such as Captain T. F. Simmons, even stepped beyond Paixhans in their thinking. Simmons, an Englishman, published his theories in 1837 in *Ideas as to the Effect of Heavy Ordnance*. He argued that larger guns would in time mean fewer guns mounted on board ships. He wrote:

> Instead of determining the armament of a ship from the length of her decks and crowding as many [guns] together as possible . . . it might be safer to place on board a few of the most powerful guns which [the ship's] construction would admit . . . making the *number* and not the *nature* of the guns depend on what is inevitably fixed: the capacity of the vessel.[39]

His arguments foreshadowed the development of the pivot gun.

The impetus to improve United States naval ordnance stemmed from the visit of a French 26-gun warship, whose battery included shell guns, to American ports in 1838. American naval officers who toured her deemed that the French ship was equal to two old line of battle ships, and reported that the United States lagged behind Europe in naval armaments. In May 1839, the secretary of the navy instructed Captain Matthew Calbraith Perry to conduct experiments with hollow shot, which were projectiles similar in construction to shells but having no powder inside. Perry also experimented with shells and shell guns, finding them to be effective and nearly as safe and precise as solid shot guns. Later in 1839, Perry experimented with "Paixhans guns and shot" on board the steamer Fulton. He continued these experiments until 1841 when a small number of 8-inch Paixhans guns were introduced into the fleet. The navy then contracted with private American firms for fifty 10-inch and two hundred 8-inch Paixhans guns with shells to be delivered by January 31, 1843.[40]

As in other navies, American officers and men distrusted shells. Captain William Harwar Parker commented about four shell guns placed on board the Columbus in 1842:

> The shells were a great bother to us, as they were kept in a shell room and no one was allowed to even look at them. It seemed to be a question with the officers whether the fuse went in first, or the sabot, or whether the fuse should be ignited before putting the shell in the gun or not. However we used to fire them off, though I cannot ever say I saw them hit anything.[41]

John A. Dahlgren, a lieutenant on board the Cumberland in 1844, wrote of his first experience firing shell guns: "It was amusing to-day, when about to fire, to notice that the crew had left the gun, as if desirous of avoiding any accident from the shell, which is new to them and seems alarming. . . . Shot they do not mind, but shell they dread."[42]

Nevertheless, shell guns were adopted by the United States Navy. On May 29, 1845, a board of captains submitted a formal report on naval armament to the secretary of the navy. The report noted that the ships of the line Pennsylvania, Delaware, and Columbus were each equipped with eight 8-inch shell guns besides their other armament, and some of the navy's frigates and sloops carried four 8-inch shell guns apiece. The board proposed that the number of shell guns on board ships of all classes be doubled and that new ships should be similarly armed. The navy responded by adopting shell guns as standard armament for naval vessels, but as auxiliary armament to shot-firing guns in the same manner as the French and English navies.[43]

ENDNOTES

[1] Drayton to Dahlgren, June 23, 1850, Box 2, General Correspondence, John Dahlgren Papers, Library of Congress, Washington, D. C., hereinafter cited as Dahl Gen Corres, LC.

[2] Frederick Leslie Robertson, *The Evolution of Naval Armament* (London: Harold T. Storey, 1968), p. 62, hereinafter cited as Robertson, *Naval Armament*; Ian Hogg and John Batchelor, *Naval Gun* (Poole, England: Blanford Press, 1978), p. 7, hereinafter cited as Hogg, *Naval Gun*.

[3] Robertson, *Naval Armament*, p. 63.

[4] Hogg, *Naval Gun*, p. 7; Robertson, *Naval Armament*, p. 63; John A. Dahlgren, *Shells and Shell Guns* (Philadelphia: King and Baird, 1856), p. 1, hereinafter cited as Dahlgren, *Shells and Shell Guns*; Louis A. Bolander, "The introduction of Shells and Shell Guns in the United States Navy," *Mariners' Mirror* XVII (April 1931): 105, hereinafter cited as Bolander, "Shell Guns."

[5] Dahlgren, *Shells and Shell Guns*, p. 1; Bolander, "Shell Guns," p. 105.

[6] James P. Baxter III, *The Introduction of the Ironclad Warship* (Cambridge: Harvard University Press, 1933), p. 19, hereinafter cited as Baxter, *Ironclad Warship*; Bernard and Fawn M. Brodie, *From Crossbow to H-Bomb* (Bloomington: Indiana University Press, 1962), pp. 115-116, hereinafter cited as Brodie, *Crossbow*.

[7] Baxter, *Ironclad Warship*, p. 18; Hogg, *Naval Gun*, pp. 24-25.

[8] Baxter, *Ironclad Warship*, p. 18

[9] Philip Cowburn, *The Warship in History* (New York: The Macmillan Company, 1965), p. 206, hereinafter cited as Cowburn, *Warship*.

[10] Baxter, *Ironclad Warship*, p. 19.

[11] Bolander, "Shell Guns," p. 106.

[12] Baxter, *Ironclad Warship*, p. 19; Brodie, *Crossbow*, pp. 115-116.

[13] Baxter, *Ironclad Warship*, p. 19; Brodie, *Crossbow*, pp. 115-116; John D. Bartleson, Jr., *A Field Guide for Civil War Explosive Ordnance* (Washington, D. C.: Government Printing Office, 1972), p. 5.

[14] Baxter, *Ironclad Warship*, p. 20; Cowburn, *Warship*, p. 205; Hogg, *Naval Gun*, p. 25; Bolander, "Shell Guns," p. 107.

[15] Quoted in Hogg, *Naval Gun*, pp. 25-26.

[16] Robertson, *Naval Armament*, p. 7

[17] Hogg, *Naval Gun*, p. 17

[18] Hogg, *Naval Gun*, p. 17.

[19] Hogg, *Naval Gun*, p. 20.

[20] Hogg, *Naval Gun*, p. 21.

[21] Hogg, *Naval Gun*, pp. 21-22.

[22] Hogg, *Naval Gun*, p. 21.

[23] Hogg, *Naval Gun*, p. 24.

[24] Baxter, *Ironclad Warship*, p. 20.

[25] Baxter, *Ironclad Warship*, pp. 20-21; Hogg, *Naval Gun*, p. 26; Cowburn, *Warship*, p. 206.

[26] Hogg, *Naval Gun*, p. 26; Baxter, *Ironclad Warship*, p. 21; Bolander; "Shell Guns," p. 106.

[27] Baxter, *Ironclad Warship*, p. 22.

[28] Lieutenant Colonel Louis de Tousard, *American Artillerist's Companion*, 2 vols. (Philadelphia, 1809).

[29] Bolander, "Shell Guns," p. 107.

[30] Hogg, *Naval Gun*, pp. 28-29; Bolander, "Shell Guns," p. 108; Baxter, *Ironclad Warship*, pp. 22-23.

[31] Hogg, *Naval Gun*, pp. 28-29; Bolander, "Shell Guns," p. 108; Baxter, *Ironclad Warship*, pp. 22-23.

[32] Hogg, *Naval Gun*, p. 26; Baxter, *Ironclad Warship*, p. 21; Bolander. "Shell Guns," p. 106.

[33] Bolander, "Shell Guns," p. 109; Hogg, *Naval Gun*, p. 29; Baxter, *Ironclad Warship*, pp. 23-24.

[34] Baxter, *Ironclad Warship*, pp. 24-25.

[35] Hogg, *Naval Gun*, p. 29.

[36] Baxter, *Ironclad Warship*, pp. 24-25; Hogg, *Naval Gun*, p. 29.

[37] Baxter, *Ironclad Warship*, pp. 24-25; Hogg, *Naval Gun*, p. 29.

[38] Cowburn, *Warship*, p. 207.

[39] Quoted in Cowburn, *Warship*, p. 207, italics are as used in source.

[40] Bolander,"Shell Guns," p. 111.

[41] Quoted in Bolander, "Shell Guns," p. 111.

[42] Madeleine Vinton Dahlgren, *Memoir of John A. Dahlgren* (Boston: James R. Osgood and Company, 1882), p. 87, hereinafter cited as Dahlgren, *Memoir*.

[43] Bolander, "Shell Guns," p. 112.

CHAPTER II

EVOLUTION OF THE SODA BOTTLE

Late in his career, John A. B. Dahlgren's second wife asked him what specific thought led him to invent his heavy ordnance. He replied: "I observed a law of nature, and making a mathematical application of it, made a gun which was an invention, and in no wise a result of experiment."[1] Dahlgren developed his new system of ordnance because he believed that the navy ordnance then in use was neither accurate or powerful enough to justify its weight. He also believed that the navy's heavy ordnance at that time was unsafe. He believed that his design would result in greater accuracy, penetration power, and safety for a given weight of metal than conventional designs. Critics strongly objected to his ordnance's soda bottle shape. Dahlgren arrived at his design with the aid of mathematical knowlege and ordnance experience acquired early in his career.

Dahlgren was born on November 13, 1809, in Philadelphia. He received his early education in a Quaker school and from his father, becoming proficient in Latin and mathematics by age fifteen. Raised within sight of the Delaware River's shipping, Dahlgren early conceived a longing for the sea. He visited the ship of the line Pennsylvania at the Philadelphia Navy Yard, read James Fenimore Cooper's sea tales, and decided at age fifteen to apply for a midshipman's warrent. Despite recommendations from his schoolmasters, a judge, a doctor, his representative in Congress, and other influential friends to the secretary of the navy, his first request was denied. He persisted in his efforts, meanwhile sailing on board the merchant brig Mary Becket, and was finally appointed acting midshipman on February 1, 1826.[2]

Dahlgren's first naval cruises were on board the frigate Macedonian and the brig Ontario. In 1832, he was appointed passed midshipman. Because of his skill in mathematics, Dahlgren was ordered to duty with the United States Coast Survey in February 1834 under R. F. Hassler, who was considered one of the foremost mathematicians of his time. Hassler recognized Dahlgren's ability by assigning him increasingly difficult tasks involving triangulation, base-line measurements, astronomical observation, and testing new surveying devices. Dahlgren was promoted to lieutenant on March 8, 1837.

Dahlgren worked so hard on his assignments that he was threatened with blindness and compelled to enter the Naval Hospital in Washington, D. C. Finding no relief, he received permission to seek treatment in Paris under a famous oculist. While in Paris, Dahlgren became familiar with Paixhans' work and translated his pamphlet on shell guns into English, having it printed at his own expense for distribution in the United States Navy. Upon returning from Paris, Dahlgren was advised to continue his leave of absence until 1843, when he returned for duty at the Philadelphia Navy Yard, his vision fully restored.[3] Later that year he sailed on board the Cumberland for a cruise in the Mediterranean, where he had his first hands-on experience with shell guns. Dahlgren was assigned to command the Cumberland's battery of four shell guns. During this cruise, he tested a percussion lock that he had designed several years earlier.[4]

In January 1847, Dahlgren was ordered to the Washington Navy Yard, where his initial task was to investigate and introduce into the navy a system of rockets developed in England by William Hale. The Washington Navy Yard had been one of the navy's most important shipbuilding facilities since the early nineteenth century. The principal inspector of ordnance had resided there since the mid-1820s. Due in large part to its proximity to the Bureau of Ordnance and Hydrography's headquarters, the yard would eventually become the center of ordnance experiments. Most of the ordnance design work and all of the bookeeping on financial matters took place in the offices of the chief of the Bureau of Ordnance and Hydrography and his assistants. The staff usually numbered less than a dozen. At this time, however, the bureau devoted itself largely to the administrative duties arising from the Mexican War, paying little attention to improving naval armaments.[5]

When Dahlgren arrived, there was no ordnance establishment at the Washington Navy Yard. Fuse stocks, cannon locks, and shells produced there were made and fitted in the plumbers' shop, and Dahlgren's workshop was housed in the end of a timber shed.[6] Lewis Warrington, Chief of the Bureau of Ordnance and Hydrography until November 12, 1851, for reasons that are unclear, treated Dahlgren coldly at first and refused to see him during his first two weeks of duty.[7] Despite this chilly reception, Dahlgren soon gained Warrington's confidence and in August 1847 Warrington placed him in charge of all ordnance matters at the yard. At this time, the only ordnance facility at the yard aside from Dahlgren's workshop was the laboratory. Eventually, he set up foundries and machine shops and established a firing range which soon became an experimental battery. Within a few years, the yard's emphasis shifted from shipbuilding to ordnance work. This establishment became the famous gun factory that supplied much of the ordnance used in the Civil War.[8] In addition to his duties at the yard, in 1847, Dahlgren was appointed professor of gunnery at the new Naval Academy at Annapolis.[9]

In 1845, a board of captains had established an ordnance system to arm ships' batteries with guns of uniform caliber, so that vessels only had to carry two sizes of projectiles. The system used six classes of 32-pounders capable of firing both shot and shell: 57 cwt., 51 cwt., 46 cwt., 42 cwt., 32 cwt., and 27 cwt.[10] Several classes of 8-inch shell guns were also used. This system simplified life in the shot locker, but with each class of 32-pounder using a different charge, life in the magazine remained complicated.[11]

A first class frigate carried twenty-six 32-pounders of 57 cwt. and four 8-inch shell guns of 63 cwt. on its gun deck. Depending on the frigate's size, its spar deck was armed with either two 32-pounders of 51 cwt., two 32-pounders of 46 cwt., or two 32-pounders of 42 cwt. The gun decks and spar deck of a ship of the line were equipped like those of a frigate. Sloops were armed according to their size, the largest having 32-pounders of 42 cwt. and 8-inch shell guns of 55 cwt., and the smallest sloops mounting 32-pounders of 27 cwt.[12] The navy's pivot guns were 10-inch shell guns of 86 cwt. introduced in 1841 and 64-pounders of 105 cwt. introduced in 1849. The largest steamers carried 64-pounder pivots and 8-inch shell guns of 63 cwt. in broadside, while inferior classes carried 10-inch shell guns in pivot and 8-inch shell guns of 55 cwt. in broadside.[13]

The United States Navy shell guns were of two patterns. The 10-inch of 86 cwt. and the 8-inch of 63 cwt. cast before 1851 were similar

FIGURE 1

DIMENSIONS OF UNITED STATES NAVAL GUNS FROM 1852 BUREAU OF ORDNANCE REGULATIONS

Class	Weight (in cwt.)	Year Introduced	Tube Length* (inches)	Bore Diameter (inches)	Weight of Shot (pounds)	Weight of Loaded Shell (pounds)
32-pounders	27	1846	76.6	6.4	32½	26¼
	32	1846	84.0	6.4	32½	26¼
	42	1847	101.2	6.4	32½	26¼
	46	1846	107.4	6.4	32½	26¼
	51	1846	113.4	6.4	32½	26¼
	57	1846	117.6	6.4	32½	26¼
8-inch Shell Gun	55	1846	105.7	8.0	-	51½
	55	1841	111.5	8.0	-	51½
	63	1851	112.1	8.0	-	51½
10-inch Shell Gun	86	1841	117.0	10.0	-	106
64-pounder	105	1849	137.0	8.0	63 3/4	51½

SOURCE: John A. B. Dahlgren, *Shells and Shell Guns* (Philadelphia: King and Baird, 1856): 26.

*Tube length designates the distance from the muzzle to the rear of the breech plate, excluding the cascabel.

to Paixhans' guns and had a straight-tapering muzzle, no sights, and a rough appearance since they were not turned on the exterior. The 8-inch of 55 cwt. introduced in 1846 and the 8-inch of 63 cwt.introduced in 1851 had the same length bore as the other patterns, but were turned on the exterior to give them a smooth finish.

In 1848, Dahlgren was assigned the task of fitting a new type of sight to the 32-pounders by actually firing the guns and plotting the fall of the projectiles using sighting and triangulation techniques adapted from coast survey methods.[14] While working on this assignment, he realized the need for suitable guns for ships' boats; he proposed equipping the navy with lightweight, accurate boat howitzers which would be useful for both field and naval service. Dahlgren developed bronze 12- and 24-pounders in 1848 and 1849. They were finally adopted by the navy in 1850 after he overcame opposition to their design.[15]

Dahlgren's work with boat howitzers along with testing, sighting, and ranging the 32-pounders continued in 1849. His ordnance curriculum vitae was growing rapidly and he began to suspect that the guns he was working with were inadequate. While observing 32-pounders, he noted that the larger, more powerful pieces lacked accuracy and the smaller, more accurate pieces lacked power. Heavier 32-pounders used a larger charge than lighter ones, but they all fired shot weighing 32.5 pounds. The heavier 32-pounders fired projectiles at velocities that approached the speed of sound. These projectiles were not aerodynamically shaped or spun by rifling. When such a projectile's velocity nears the speed of sound, the atmospheric resistance to it increases, causing it to wobble from its trajectory, thus reducing accuracy. The lighter

32-pounders' projectiles met less atmospheric resistance because they travelled at lower velocities and were therefore delivered to their targets more accurately, but with less momentum and force. In September 1849, Dahlgren presented to the Bureau of Ordnance and Hydrography the idea that in firing shot there is a certain velocity that cannot be exceeded without adversely effecting accuracy. If the projectile's momentum was insufficient in ship-damaging power at this maximum velocity, he believed that the projectile's weight should be increased, not its speed. In his opinion, United States naval ordnance increased projectile speed, not weight, at accuracy's expence.[16]

On November 13, 1849, the event that stimulated Dahlgren to design his own heavy ordnance occurred. He was testing the accuracy of a 32-pounder of 57 cwt. at the experimental battery when it exploded. He wrote:

> . . . I said, "Fire." An unusual explosion took place instantly. The battery was filled with smoke, and a great crash of timber was heard. Behind me I heard the ground ploughed up, and of the things that fell, something grazed my heel which afterwards, proved to be a part of the breeching, a piece weighing two thousand pounds. Much stunned by the noise and concussion, I turned to the battery. Amid the smoke, yet lifting slowly, the first object was the body of the unfortunate gunner, stretched out on the deck and quite dead.[17]

After the accident, Dahlgren asked Warrington's permission to design a new gun that would incorporate his ideas of power, accuracy, and safety. He believed that he could "exercise a *greater* amount of *ordnance power with a given weight of metal*, and with more safety . . . than any other piece then known of *like weight*."[18] Warrington assented and Dahlgren commenced. Not knowing what the optimum ratio of projectile weight to speed would produce the ideal momentum and accuracy, he designed two pieces to ascertain this relationship by experiment. One was a 50-pounder solid-shot firing gun weighing eight thousand pounds, and the other was a IX-inch shell gun weighing 9,080 pounds.[19] Dahlgren was not satisfied with Paixhans' shell guns because he believed that they were not designed for great penetration or accuracy at long ranges. In the French, British, and American navies, shell guns were secondary armaments because they lacked the range of solid-shot guns. Dahlgren objected to a mixed battery of shot- and shell-firing guns. He hoped to arm a ship's entire battery with one type of gun that could fire shells far and accurately and had the strength to fire solid shot when necessary.[20] Dahlgren finished his plans on January 8, 1850 and he submitted them to Warrington the next day. Highly confident that the IX-inch gun would be successful, he wrote:

> . . . I have no doubt that both will add materially to the present broadside means of offence. . . .
>
> I am aware that the principle now evolved, if established, would lead to an entire reorganization of the ordnance, and to great changes in the arrangement of ships which are to receive new metal.
>
> But neither of these considerations ought to be of weight in view of the advantages attributable to superior efficiency, especially if it not be overlooked that, with the exception of a single frigate, we have not a model of a liner or frigate less antique than the third of a century.[21]

The IX-inch shell gun's design was a departure in form and thickness from standard naval ordnance. Dahlgren believed that the only factors that mattered in developing maximum power from a gun were the length and diameter of the bore. He reasoned that the distribution of metal about the bore had no effect on a gun's power, accuracy, or range; the only function of a gun's exterior form was to provide safety for the gun crew. In a report to the Bureau of Ordnance and Hydrography, he wrote that "the distribution of the material which is to produce the desired thickness at the several parts, and the exterior form, concern only the safety of those who may be about the piece. . . ."[22]

Army ordnance specialists had proven that the strain on a gun diminished rapidly as the projectile travelled down the barrel. The rate of diminished strain was first demonstrated scientifically in the United States by George Bomford of the United States Army Ordnance Department in the first quarter of the nineteenth century. He drilled several holes along the length of a cannon, perpendicular to its axis. A pistol barrel was screwed securely into each hole and a bullet inserted in each barrel. The bullets' speeds as they were blown out of the pistol barrels by firing the cannon were measured and recorded. These speeds were greatest at the seat of the charge and decreased down the length of the gun towards the muzzle. Major Thomas J. Rodman later verified this finding using a similar test. He also drilled a series of holes down the length of a gun barrel, but instead of inserting pistol barrels, placed pistons having punches at one end into these holes. The pistons were arranged so that when the gun was fired, the punches were driven by the force of the blast into copper blocks secured outside each hole. Rodman compared the indentations made in the copper blocks to indentations made later in the same blocks by similar punches driven by a machine that measured the amount of pressure applied. These experiments showed that the seat of the charge received the greatest stress during firing. Although ordnance experts had been designing tapered guns for nearly two hundred years, Bomford and Rodman confirmed this principle experimentally. Their experiments generated the curve of pressure that Dahlgren incorporated into his design.[23]

Dahlgren's first IX-inch gun, as well as his subsequent models, were designed with thickness of the metal along the bore increasing correspondingly to the change in internal pressures, in hopes of fitting strength to stress at the critical points. This produced the unique and characteristic shape of the Dahlgren guns, which amused English critics later labelled "soda-water bottles." Dahlgren designed his gun to fit strength to strain because of the manner in which previous army and navy heavy guns burst on firing. The section behind the trunnions would fracture, often having lethal effects on the crew while the chase, the part between the trunnions and the muzzle, remained intact. Dahlgren knew that in battle, casualties were often greater from ships' own guns bursting than from enemy fire. He cited several instances of this in a report. He wrote: "It may easily be imagined that such an occurrence is very disheartening to the men."[24]

Dahlgren conceded that current English and American guns were thick enough to prevent explosions. He believed that if the guns then in use were cast from good quality metal, they would be strong enough to endure service without bursting. At that time, however, there was no way of knowing what the quality of a gun's metal was without actually firing the piece. Dahlgren attributed the explosion that nearly killed him in November 1849 to faulty metal. His new design's purpose, he wrote in a report to the bureau, was:

> . . . to ascertain if it were possible by a certain distribution of metal so to proportion the thickness in front and rear of the

> trunnions always to precede that of the part about the charge: could this be done, then whatever might be the quality of the metal, whether good or bad, the rupture would occur in such a manner as to expose the men at the guns but very slightly to its fatal consequences. . . .[25]

Dahlgren knew of no data to support his belief that an exaggerated breech would promote safety and endurance, yet he was convinced that his ideas would be accepted. He thought that the navy should spare no expense to improve the safety of its ordnance.[26]

On January 10, 1850, Warrington contracted with the West Point foundry to cast two experimental guns, a IX-inch shell gun and a 50-pounder of Dahlgren's design. This first design of the IX-inch gun had the same exterior form as the type later adopted by the navy and was cast with lock lugs for two vents. When the gunfounders and conservative naval officers first viewed this design, they were appalled by its slender chase. They asserted that if such a gun were fired, the chase would certainly rupture. For this reason, they objected to casting a gun with this design.

Dahlgren was as concerned about testing his theory of projectile momentum as he was with safety at this point. In order that a IX-inch gun be cast at all, he modified his design. Without changing the shape or amount of metal around the breech, he reduced the gun's length and thickened the chase, keeping the overall weight at about 9,000 pounds. The resulting gun had a somewhat more angular outline, shorter barrel length, and a thicker chase than subsequent models and used a single vent. This modified IX-inch model satisfied critics and along with the proposed 50-pounder, it arrived at the Washington Navy Yard in May, 1850.

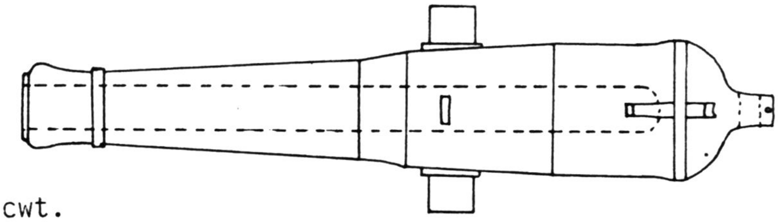
The carriages and equipment for the two experimental guns were constructed as the barrels were being cast, and they were promptly mounted at the experimental battery. A single day's practice with the two guns confirmed Dahlgren's preference for the IX-inch design. He believed that its 9,080 pound weight was manageable, not excessive as critics had charged, and found its performance superior to the 50-pounder.[27]

During the summer of 1850, Dahlgren experimented with several classes of ordnance, firing them from different elevations and ranges using various amounts of gunpowder in the charges. He fired 120 rounds from the IX-inch gun, using charges ranging from eight to ten pounds. After comparing the performances of the IX-inch gun with the others, Dahlgren was convinced that the ideas he had presented to the bureau in September 1849 were correct. He found that the 32-pounder of 57 cwt. firing shot at a higher velocity was less accurate than the 32-pounder of 32 cwt. and the 8-inch shell gun of 55 cwt., both of which had a lower muzzle velocity. When firing the 32-pounder of 57 cwt. and the IX-inch shell gun at an oak target from 1,300 yards, he found that the IX-inch gun, with its lower muzzle velocity and greater projectile weight, was more accurate. Additionally, although failing to explode, the IX-inch shell was more destructive to the target. Reporting these results to the bureau in January 1851, Dahlgren wrote:

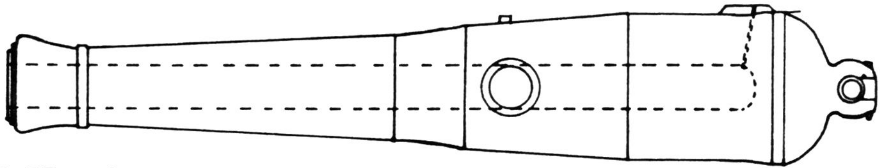
> I believe therefore that nothing is hazarded in saying that the true direction for future experiment should be to ascertain whether the most effective ordnance for ships is not:-
>
> 1st The heaviest pieces that can be manoeuvered on truck carriages, and those throwing the heaviest projectiles that can be conveniently handled.

FIGURE 2

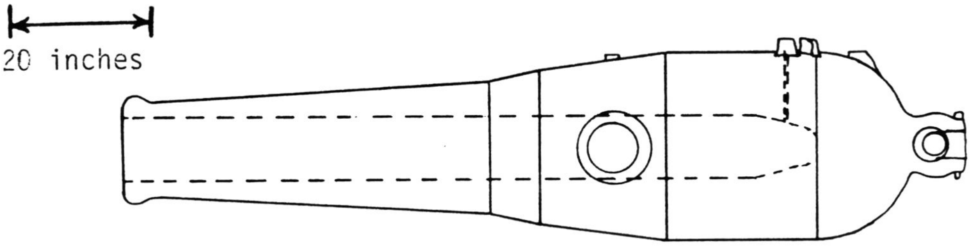
THE DAHLGREN GUNS



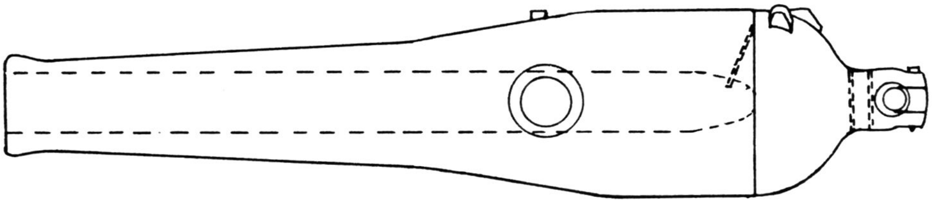
32-pounder of 42 cwt.



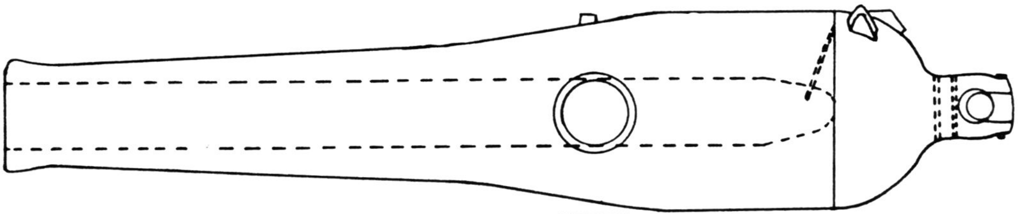
32-pounder of 57 cwt.



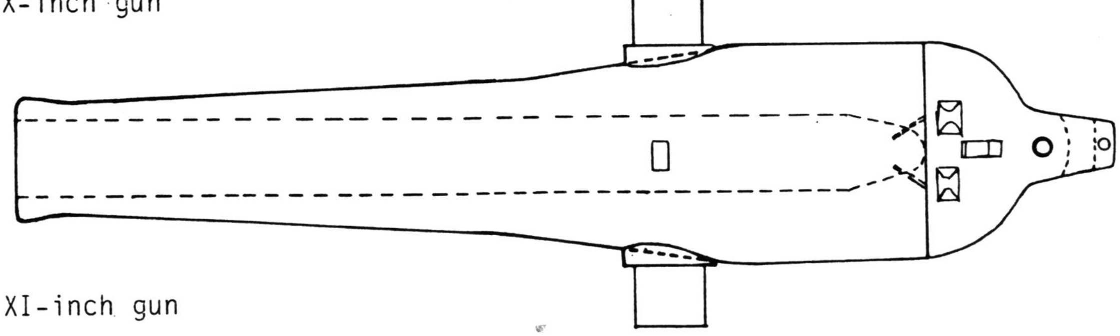
First IX-inch gun



IX-inch gun



X-inch gun



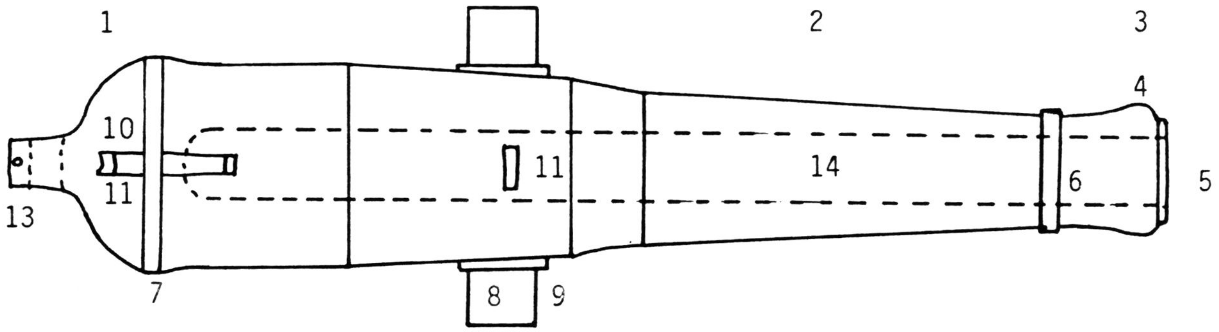
XI-inch gun

SOURCE: Drawing by Kevin Foster from Eugene B. Canfield, Civil War Naval Ordnance (Washington: Government Printing Office, 1969).

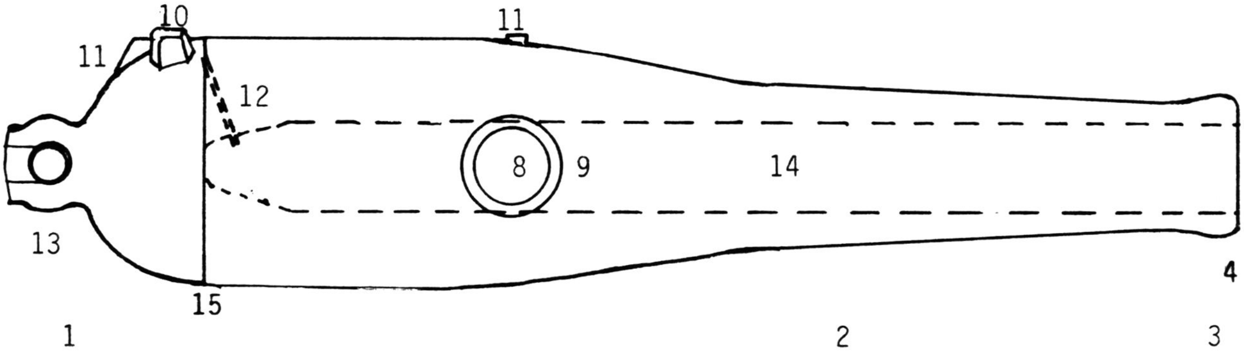
FIGURE 3

PARTS OF A GUN
(not to scale)

32-pounder



Dahlgren gun



KEY

1. breech
2. chase
3. muzzle
4. swell of muzzle
5. muzzle molding
6. muzzle astragal
7. reinforce ring
8. trunnion
9. rim base
10. lock lug
11. sight mass
12. vent
13. cascabel
14. bore
15. base line

SOURCE: Hogg, Naval Gun.

> 2d The weight of projectiles is to be distributed in the form of a shell - shot only to be used in exceptional cases and then with low charges.
>
> 3d To ascertain the precise term of velocity that ought not to be exceeded with these calibres in order to attain the greatest practicable accuracy. . . .
>
> The times seem propitiousto the development of our naval force hinted at in the foregoing lines - the system which 30 years ago was one step in advance of all, is now behind the progress of England and even of France in naval affairs. . . .[28]

Dahlgren also asked in this report if he could submit plans for an XI-inch shell gun to test his theories further. If adopted, this piece would be placed in pivot mounts on ship's spar decks. He believed that shells would replace shot and that future naval battles would be fought at longer ranges.[29]

On March 18, 1851, with Warrington's approval, Dahlgren submitted plans for an XI-inch shell gun weighing 15,600 pounds. He wrote:

> All the mouldings and the protrusion of the Base-Ring were discarded from the exterior surface as unnecessary: the swell of the muzzle was also reduced to a very small limit; it may answer a useful purpose in fortifying the muzzle end against the consequences of striking the port in recoil, though this consideration has not prevented Paixhans from dispensing with it altogether. . . .[30]

In the letter accompanying the draft, Dahlgren explained that the distribution of metal in the XI-inch gun was similar to the IX-inch piece, but the principle of construction was more fully developed. The XI-inch piece would have the same shape for this caliber as those later adopted by the navy - with a slim, elongated chase similar to the one critics had strongly objected to in the original IX-inch gun design. The IX-inch gun had safely withstood two rounds of 93-pound shot charged with eighteen pounds of powder, and Dahlgren asserted that this justified making the XI-inch gun's chase slimmer and breech thicker. He believed that if a gun did rupture, the crew would be safer if the chase failed rather than the breech. Warrington then granted Dahlgren's request to prepare equipment, shot, and shells for the XI-inch gun and to make changes in the experimental battery platform, ostensibly to simulate a slide mount.[32]

The bureau placed the order for the XI-inch gun with Cyrus Alger and Company of Boston in April, 1851. Alger was critical of the design's slim chase, just as others had objected to the original plan for the IX-inch gun. Naval officials and gun founders still believed that even the modified version of the IX-inch gun's chase was too slender. Alger informed Warrington that unless the chase was thickened, he believed the gun would burst when fired. Warrington apprised Dahlgren of Alger's opinion, but this time Dahlgren refused to modify his design as he had done when critcs had raised objections to the original IX-inch gun design. Dahlgren intended to verify his theory that the best naval ordnance was the heaviest manageable gun firing the heaviest manageable shell at the optimum muzzle velocity by comparing his XI-inch gun with a navy 64-pounder of 105 cwt. Although still concerned with safety through sound design, Dahlgren now considered proving this to be of secondary importance. Warrington, pleased with the IX-inch gun's performance, backed Dahlgren fully on his refusal to modify this design.[33]

The critics, however, remained wary of casting the XI-inch gun with such a slim chase. In lieu of modifying his design, Dahlgren proposed two alternatives to demonstrate the safety of a slim chase on June 17, 1851. The first was to cast an 8-inch shell gun similar in shape to his proposed XI-inch gun. The navy rejected this proposal. The second alternative was to modify an existing service 8-inch shell gun of 55 cwt. by turning it on a lathe until its dimensions were proportional to the XI-inch design. The navy assented. Dahlgren fired the modified 8-inch piece at the experimental battery eith charges ranging from seven to nine pounds. The rounds initially consisted of single shells and later of two shells, or one shot and one shell. Since no evidence of fracture appeared in the chase, skeptics were forced to agree that if the XI-inch gun's metal were as sound as that in the modified 8-inch gun, it stood a reasonable chance of being able to withstand firing. The navy approved Dahlgren's slim chase, and the first XI-inch gun was cast in July 1851.[34]

Near the end of August, the XI-inch gun was ready for inspection. As with every other gun cast for the navy, several rounds were fired to detect flaws in the metal before the gun left the foundry. This was called "proof." Dahlgren suggested ten rounds consisting of one shell charged with fifteen pounds of powder. In October, Dahlgren finally went to Boston to inspect and prove the gun. After firing the ten proof rounds, Dahlgren reported that the gunmetal displayed unusual characteristics, such as a high degree of porosity along the bore and a high density. He was not sure whether these characteristics indicated sound or unsound metal. Either he had stumbled onto a new gunmetal of superior quality or the gun was cast poorly. Since the gun was experimental and precautions could be taken in case it burst, Dahlgren decided to accept it on one condition. If the gun failed to withstand five hundred rounds, Alger would have to pay for it. Despite Alger's objections to the design, he agreed and the gun was sent to the experimental battery, arriving there on March 25, 1852.[35]

Testing of the XI-inch gun was delayed for several months. Much of this delay can be attributed to Warrington's death in November 1851. Warrington's successor as Chief of the Bureau of Ordnance and Hydrography, Charles Morris, was far less receptive to Dahlgren's ideas. Finally, on October 16, 1852, Dahlgren first practiced with the XI-inch gun at the experimental battery. The few rounds he fired that day were to determine if the carriage worked properly. Rather than the standard slide mount or truck carriage, the gun was mounted so that the recoil was absorbed only by a pair of yellow pine skids. The first regular practice began early in November. Dahlgren tested the XI-inch gun using the same methods and instruments he had used when ranging 32-pounders several years earlier. When filled with five pounds of rice, the XI-inch shells weighed about 131 pounds. Dahlgren found that it took an average of two and one-half minutes to sponge, load, and run the piece out for each firing. Detecting no movement of the breech in recoil, he was satisfied with the gun's balance. He found no ill effects from recoil on the elevating screw or the corresponding female threads cut in the cascabel.[36]

The XI-inch gun's performance boosted Dahlgren's confidence and on May 3, 1853, he resubmitted his original plan for the IX-inch gun to the Bureau of Ordnance and Hydrography. He argued that since the

XI-inch gun and the 8-inch gun he had modified in the spring of 1851 had been successfully fired without bursting, it was now safe to lengthen the IX-inch gun's chase and make it slimmer while maintaining the weight at about nine thousand pounds. He requested that two of these guns be cast and that they be tested at sea.[37]

Morris, however, would agree to cast only one gun, and ordered that it be tested at the experimental battery. At the end of May 1853, Morris placed the order for the second IX-inch gun with the West Point foundry. As before, objections to the slender chase arose. Robert P. Parrott, West Point's chief founder, believed that a gun so designed would be difficult to cast. Dahlgren assured Parrott that the design would present no problems. Soon after Morris placed the order, Dahlgren received reports that the first IX-inch gun's motion in recoil was violent when the gun was double shotted. He moved the position of the trunnions forward .35 of an inch relative to the center of gravity on the new IX-inch gun's design so that it would weigh about one hundred more pounds in the breech than the first IX-inch gun, making the new piece steadier. He asked that Parrott complete the gun as soon as possible, and it was cast with the adjusted preponderance (the excess weight of the breech over the muzzle) later in the summer of 1853.[38]

Dahlgren continued testing the first IX-inch gun and the first XI-inch gun in 1853 and began testing the second IX-inch gun in 1854. By May 24, 1854, the XI-inch gun had fired 121 rounds, each of one shell charged by fifteen pounds of powder. On this date, Dahlgren asked Morris' permission to bring the total number of firings up to five hundred.

Satisfied with the gun's interior construction, Dahlgren was interested the fitness of the gun's unusual metal for service. Dahlgren justified his request by stating that if the gun did stand up to protracted firing, he could prove his theories that heavier guns were more powerful and accurate than lighter ones because they fired heavier shells at lower velocities. If the gun did not last five hundred rounds, he reminded Morris that Alger would be obligated to pay for it and cast a new one. At the end of June, 1854, Morris granted Dahlgren's request. The tests were to take place on the grounds of an insane asylum near the yard. Dahlgren received permission to fire rounds of one shell charged with fifteen pounds of powder. If the gun survived five hundred such rounds, it was to be fired five additional times with the same amount of powder. The last five projectiles, however, were to be loaded shells calculated to explode before exiting the barrel.[39]

By mid-July, 1854, Dahlgren had thoroughly tested the first IX-inch gun and fired the second IX-inch gun a few times. At this time, he suspended testing of the IX-inch guns so he could concentrate on testing the XI-inch gun. After firing the 134th round, he discovered a crack in the chamber in the vicinity of the vent. After the 254th firing, this crack extended nearly the whole length of the chamber. On August 17, Dahlgren asked Alger's permission to bore a new vent and continue the testing, remarking that Alger had "the greatest interest in the piece completing 500 fires." He noted that a Columbiad had endured 2,582 firings using three vents. Alger assented and Dahlgren sealed the old vent with zinc, boring the new one beside it.[40]

By October 16, Dahlgren had fired the XI-inch gun 475 times and a crack appeared at the new vent. Dahlgren finished the five hundred firings the next day, probably to Alger's relief. Dahlgren noted that the chamber was scarred by several cracks, the largest being the one that began at the 134th discharge through the original vent. He reported to the bureau that the second vent had become enlarged by fifty percent. By the end of the month, Dahlgren succeded in bursting three shells in the barrel with no apparent negative effects on the gun. Morris then gave Dahlgren permission to continue firing the gun until it burst. He began firing solid shot as well, and by November 4 he had fired a total of 506 shells and 270 solid shot, the latter projectile type inducing more stress on a piece than the former. The gun lasted until July 8, 1855, when it burst at the 1,959th firing. Alger happened to be visiting Washington that day and was present to witness the event. The gun split into three pieces: the right side of the breech flew ninety feet, the left side of the breech turned over with the carriage, and the chase broke off and fell down in front. No injuries were reported, although the breech did not behave exactly as Dahlgren had hoped. Nevertheless, he commented that he knew of "no other gun of its size, or near it, that has done so well."[41]

Meanwhile, in July 1854, Morris ordered Dahlgren to submit the plans he completed the previous month for a X-inch shell gun. This gun's shape resembled those of the XI-inch gun and the second IX-inch gun. Dahlgren noted that its weight would be the same as that of the service 64-pounder and two thousand pounds heavier than the service 10-inch shell gun. Recommending that its charge should be at least 12½ pounds, he stated that its accuracy and power would be superior to tnose of the service 10-inch guns. He believed the latter to be inadequate as pivot guns. A X-inch Dahlgren would not be cast until 1855.[42]

At the end of October, 1854, Dahlgren scored a victory in his battle for his soda-bottle shaped ordnance. On the 30th, Morris called a meeting of cannon founders at the Bureau of Ordnance and Hydrography to discuss Dahlgren's guns. All agreed with Dahlgren that the XI-inch gun's shape was workable and its slim, elongated chase was not to be altered. The successes of the first IX-inch gun and the lathed service 8-inch gun, the few firings of the second IX-inch gun, and the XI-inch gun's ability to endure over five hundred rounds despite its questionable quality gunmetal convinced them that Dahlgren's design was indeed safe. The navy decided to arm the six new steam frigates approved by Congress earlier that year with Dahlgren designed guns. In December, the navy placed orders with four private founders to produce a total of 156 IX-inch guns and fourteen each of the X- and XI-inch guns.[43]

ENDNOTES

[1] Peterson, *Father*, p. 68.

[2] Earle, "Dahlgren," p. 425; Allen Johnson, ed., *Dictionary of American Biography*, 10 vols. (New York: Charles Scribner's Sons, 1959), III: 29, hereinafter cited as *DAB*.

[3] *DAB* III: 30; J. T. Headley, *Farragut and our Naval Commanders* (New York: E. B. Treat and Co., 1867), p. 459, hereinafter cited as Headley, *Commanders*.

[4] Dahlgren, *Memoir*, p. 87; *DAB* III: 30.

[5] Pictorial Section, "The Bureau of Ordnance," *United States Naval Institute Proceedings* LXXV (February, 1949): 213; Glasow, "Prelude," pp. 314-315.

[6] Earle, "Dahlgren," p. 428; Robert V. Bruce, *Lincoln and the Tools of War* (New York: The Bobbs-Merrill Company, Inc., 1956), p. 5, hereinafter cited as Bruce, *Tools*.

[7] *DAB* III: 30.

[8] Bruce, *Tools*, p. 5; Earle, "Dahlgren," p. 428; *DAB* III: 30.

[9] *DAB* III: 30; Earle, "Dahlgren," p. 428.

[10] Dahlgren, *Shells and Shell Guns*, p. 23. For simplicity, the nomenclature of the period is used throughout this thesis. Solid-shot firing guns and the 32-pounders were designated by the projectile weight while the guns that fired only shells were designated by projectile diameter. Cwt. is an abbreviation for hundredweight, defined as 112 pounds. Thus, a 32-pounder of 32 cwt. weighed about 3, 584 pounds (32 cwt. x 112 pounds/cwt.) and fired a 32-pound shot. Heavier 32-pounders fired the same shot. An 8-inch shell gun of 55 cwt. weighed about 6,160 pounds and fired an 8-inch shell. Guns in the same class varied in weight; the cwt. designation was rounded off. Each piece had its exact weight stamped on it. Dahlgren guns were designated by projectile diameter using Roman numerals, their weights being recorded in pounds.

[11] Dahlgren, *Shells and Shell Guns*, pp. 272-273.

[12] Dahlgren, *Shells and Shell Guns*, pp. 23-24.

[13] Dahlgren, *Shells and Shell Guns*. p. 24. Pivot guns were mounted on a fixed carriage, usually on a ship's spar deck, enabling the gun to be fired from either side of the vessel.

[14] Untitled chronology of Dahlgren's career, 1862, Box 27, Dahlgren Naval Ordnance Papers, Library of Congress Manuscript Division, Library of Congress, Washington, D. C., hereinafter cited as Dahl Nav Ord, LC; Earle,"Dahlgren," p. 428.

[15] *DAB* III: 30; Earle, "Dahlgren," p. 428; Headley, *Commanders*, pp. 461-462.

[16] Dahlgren to Warrington, "Report to Bureau of Ordnance of Practice made with the experimental Nine-Inch Shell Gun 1850," January 30, 1851, Box 21, Dahl Nav Ord, LC; Headley, *Commanders*, p. 463; Dahlgren, *Memoir*, pp. 150-151.

[17] Dahlgren, *Memoir*, p. 134.

[18] Dahlgren, *Shells and Shell Guns*, p. 14, italics are as used in the source.

[19] Dahlgren, *Memoir*, p. 147.

[20] Eugene B. Canfield, *Civil War Naval Ordnance* (Washington: Government Printing Office, 1969), p. 4, hereinafter cited as Canfield, *Ordnance*.

[21] Dahlgren, *Memoir*, p. 147.

[22] John Dahlgren, "Notice of XI in Shell gun No. 1 cast by Alger from the design by Lieut J. A. Dahlgren 1852," Box 22, Dahl Nav Ord, LC, hereinafter cited as Dahlgren, "Notice of XI in Shell gun No. 1."

[23] Edward Simpson, *A Treatise on Ordnance and Naval Gunnery, Compiled and Arranged as a Textbook for the U. S. Naval Academy* (New York: D. Van Nostrand, 1861), pp. 76-77, hereinafter cited as Simpson, *Ordnance*: Hogg, *Naval Gun*, p. 29.

[24] Dahlgren, *Memoir*, p. 314; Bruce, *Tools*, p. 6; Joseph A. Gutierrez, Jr., "Confederate Naval Ordnance, 1861-1865" (Unpublished Master's Thesis: East Carolina University, 1977), p. 90, hereinafter cited as Gutierrez, "Ordnance;" Dahlgren, "Notice of XI in Shell gun No. 1."

[25] Dahlgren, "Notice of XI in Shell gun No. 1."

[26] Dahlgren, "Notice of XI in Shell gun No. 1;" Dahlgren, *Memoir*, p. 135.

[27] Dahlgren, *Memoir*, pp. 148-151; Dahlgren, "Notice of XI in Shell gun No. 1;" Hogg, *Naval Gun*, p. 52; Canfield, *Ordnance*, p. 4; John Dahlgren, "Report to Bureau of Ordnance of Practice made with the Experimental Nine-Inch Shell Gun 1850," January 30, 1851, Box 21, Dahl Nav Ord, LC; Dahlgren to Warrington, March 19, 1851, Box 2, Dahl Gen Corres, LC;

Dahlgren to Morris, May 3, 1853, Box 22, Dahl Nav Ord, LC; Dahlgren to Parrott, May 30, 1853, Box 2, Dahl Gen Corres, LC. The primary and seconary sources do not agree on the evolution of the Dahlgren gun's shape. Hogg and Canfield above agree that Dahlgren developed the shape later adopted by the navy after the first IX-inch gun arrived at the Washington Navy Yard in May 1850. The latter three primary sources cited above indicate that the famous shape was present when the design for the first IX-inch gun was submitted to Warrington on January 9, 1850. In response to criticism, Dahlgren then shortened and thickened the chase in order that a IX-inch gun be cast at all. In 1853, the shape Dahlgren originally intended for the first IX-inch gun manifested itself in the metal of the second IX-inch gun after he demonstrated the safety of a slim chase. The names of the critcs of the first design are not given in the sources cited above, but are presumed to have been older, conservative naval officers and the gun founders.

[28] John Dahlgren, "Report to Bureau of Ordnance of Practice made with the Experimental Nine-Inch Shell Gun 1850," January 30, 1851, Box 21, Dahl Nav Ord, LC; Dahlgren, *Memoir*, pp. 150-151.

[29] Dahlgren, *Memoir*, p. 151; John Dahlgren, "Report to Bureau of Ordnance of Practice made with the Experimental Nine-Inch Shell Gun 1850," January 30, 1851, Box 21, Dahl Nav Ord, LC.

[30] Dahlgren, "Notice of XI in Shell gun No. 1."

[31] Dahlgren to Warrington, March 19, 1851, Box 2, Dahl Gen Corres, LC.

[32] Dahlgren to Warrington, March 26, 1851, Box 2, Dahl Gen Corres, LC; Warrington to Dahlgren, March 27, 1851, Box 2, Dahl Gen Corres, LC; Dahlgren to Morris, "Reorganization of the US Naval Ordnance (XI inch gun) by Lieut. J. A. Dahlgren," May 31, 1853, Entry 201, Record Group 45, National Archives, Washington, C. C., hereinafter cited as RG 45, NA.

[33] Dahlgren, "Notice of XI in Shell gun No. 1;" Dahlgren, *Memoir*, p. 153; Dahlgren to Warrington, March 19, 1851, Box 2, Dahl Gen Corres, LC.

[34] Dahlgren, "Notice of XI in shell gun No. 1;" Dahlgren to Warrington, April 14, 1851, Box 2, Dahl Gen Corres, LC; Warrington to Dahlgren, April 15, 1851, Box 2, Dahl Gen Corres, LC; Dahlgren to Warrington, "Memorandum for Bureau of Ordnance and Hydrography in relation to new model of 8 in of 63 cwt.," June 17, 1851, Box 21, Dahl Nav Ord, LC; Dahlgren, *Memoir*, p. 153.

[35] Dahlgren, "Notice of XI in Shell gun No. 1."

[36] Dahlgren to Morris, "Reorganization of the U. S. Naval Ordnance (XI inch gun) by Lieut. J. A. Dahlgren," May 31, 1853, Entry 201, RG 45, NA; Dahlgren, *Memoir*, p. 161.

[37] Dahlgren to Morris, May 3, 1853, Box 22, Dahl Nav Ord, LC.

[38] Dahlgren to Parrott, May 30, 1853, Box 2, Dahl Gen Corres, LC; Dahlgren to Parrott, June 14, 1853, Box 2, Dahl Gen Corres, LC. The preponderance of a gun is the weight of the breech minus the weight of the chase, measured as the gun balances on its trunnions. Usually, the breech weighed more than the chase. This weight was critical because it effected the steadiness of the gun in recoil.

[39] Dahlgren to Morris, May 24, 1854, Box 22, Dahl Nav Ord, LC; Morris to Hiram Paulding, June 27, 1854, Box 2, Dahl Gen Corres, LC.

[40] Dahlgren to Parrott, July 14, 1854, Box 2, Dahl Gen Corres, LC; Dahlgren to Morris, October 19, 1854, p. 95, Vol. 15, Entry 19, Record Group 74, National Archives, Washington, D. C., hereinafter cited as RG 74, NA; John Dahlgren, "Memorandum for Bureau," August 17, 1854, Box 2, Dahl Gen Corres, LC; Peterson, *Father*, p. 49. The first IX-inch gun withstood five hundred shells and five hundred shot without bursting.

[41] John Dahlgren Diaries, October 16, 1854, J. A. B. Dahlgren Papers, Syracuse University Library, Syracuse, New York, hereinafter cited as Dahlgren Papers, Syracuse; John Dahlgren Diaries, October 17, 1854, Dahlgren Papers, Syracuse; Dahlgren to Morris, October 19, 1854, p. 95, Vol 15, Entry 19, RG 74, NA; John Dahlgren Diaries, October 24, 1854, Dahlgren Papers, Syracuse; John Dahlgren Diaries, November 4, 1854, Dahlgren Papers, Syracuse; Dahlgren, *Memoir*, p. 172; John Dahlgren Diaries, July 18, 1855, Dahlgren Papers, Syracuse.

[42] Dahlgren to Morris, July 20, 1854, p. 63, Vol. 15, Entry 19, RG 74, NA; John Dahlgren, "Ten-Inch Shell Gun," Box 25, Dahl Nav Ord, LC.

[43] Dahlgren, *Memoir*, pp. 168-169; John Dahlgren Diaries, November 25, 1854, Dahlgren Papers, Syracuse; Peterson, *Father*, p. 39.

CHAPTER III

METALLURGY OF THE SODA BOTTLE

In the fall of 1855, several Dahlgren guns cast by the Fort Pitt and Boston foundries to fill the December 1854 order burst when first fired. As a result, the navy refused to accept the entire initial order of guns from either foundry. Dahlgren, having spent years trying to convince critics that his designs were sound, attributed their failure to their iron and to founders' mistakes. Throughout the first half of the nineteenth century, gun founders attempted to change their art into a science in response to the frequency with which guns exploded, killing their crews. They experimented with steel, cast iron, and wrought iron to determine which was the best metal for cannon. They found that cast iron was the weakest of these metals and that cast-iron guns had to be made heavier to withstand firing. Naval officials favored cast iron because it was the least expensive metal. Naval gunners found that heavy cast-iron guns were easier to handle on board ships than on land and their weight reduced recoil.[1]

Cast-iron guns, however, suffered from inconsistant performance. In some cases, guns cast from the same batch of iron were not uniform. One gun would withstand hundreds of firings while another would explode after only a few. Gun founders knew the strength of an iron before pouring a gun, yet could not predict how long that gun would endure. They simply had not yet learned enough chemistry or metallurgy to produce ordnance that was uniform and predictable. In 1861, Thomas J. Rodman lamented:

> We do not know, for example, what qualities of iron are necessary to make the best gun; nor, if we did, do we know how, from any of its ores, constantly to produce iron which shall posess those qualities . . . we are at present far from posessing a practical knowlege of the properties of cast iron in its application to gunfounding.[2]

Dahlgren, among several Americans trying to unlock cast iron's mysteries by experimenting with guns, wrote:

> . . . I am yet unable to see my way clearly as to the nature of the relation that may exist . . . between properties of metal and its capacity to endure protracted and severe firing. There is such a wide difference between the nature of the forces applied—in one case a gradual and steadily applied traction, in the other a sudden and violent shock—that the problem presented seems almost as disconnected in its data as the boys' puzzle—if a pound of cheese costs ten cents, how much will a barrel of apples cost![3]

Dahlgren guns were among the last of the world's naval ordnance made entirely of cast iron. Their mechanical properties depended on a combination of the founder's techniques, the casting's shape, and the metal's chemistry.[4] Dahlgren believed that by manipulating the factors that affected the iron's properties, he could attain uniform ordnance with predictable endurance.

Nineteenth century ordnance experts knew that firing a gun subjected it to a variety of stresses. They learned eventually that cast iron's properties could not be manipulated in a manner that offered optimum resistance to each type of stress. At best, cast-iron guns suffered therefore from a compromise in performance. Dahlgren, however, never learned this. At present, ordnance experts know that as a material, cast iron is incapable of optimum resistance to each type of force that a gun is subjected to.

Cast iron is primarily elemental iron with carbon as the main alloying element. The amount of carbon in the iron and the presence of other elements, whether as additives or impurites, depend on the skill and knowlege of the founder. Although small amounts of other elements can influence the properties of cast iron, the amount of carbon has the greatest influence. Increasing the carbon content reduces the modulus of elasticity, tensile strength, and hardness of cast iron while facilitating machinability.

The majority of carbon in gray iron is present as graphite. Microscopically, the graphite is in the form of flakes dispersed in a silicon-iron matrix. Graphite flakes form in the matrix as the liquid metal solidifies in the mold. The length of these flakes influences cast iron's properties. Increasing flake length reduces the modulus of elasticity, tensile strength, and hardness of cast iron. Additionally, longer graphite flakes are better for thermal conductivity.

Flake length depends on cast iron's density, solidification rate (cooling rate) and wall thickness. Iron castings with high densities, slow cooling rates, or thick walls have large graphite flakes. Conversely, castings with low densities, fast cooling rates, or thin walls have smaller graphite flakes. As wall thickness and density in a casting increase, its cooling time increases. Longer cooling times reduce cast iron's tensile strength and hardness. A thick-walled casting has a lower tensile strength and modulus of elasticity than a thin-walled casting. Generally, flake length has a greater effect on tensile strength than hardness. For easier machinability, low hardness for a given tensile strength is desirable.

Castings in which cross sections vary in thickness, such as cannon, can have variable cooling rates. Variable cooling rates in a single casting can cause differences in graphite flake size between thick and thin cross sections. Thicker parts of a casting, which take longer to cool than thinner parts, will have longer graphite flakes. Although poured from one batch of metal, such a casting displays different properties at different points. This is called section effect. Thicker parts of a casting so effected have better thermal conductivety, a lower modulus of elasticity, less tensile strength, and less hardness than thinner sections. One can easily imagine that section effects were responsible for many ruptured guns throughout history.

The arrangement of iron crystals at the molecular level in a casting affects its strength. Iron crystals line up in the direction of heat waves that pass from or into a casting, perpendicular to its exterior surfaces. For example, as an iron cylinder cools the crystals line up radially outward from the center, perpendicular to the cylinder's exterior. Weak spots in a casting occur where the crystal arrangement is not uniform, or where the crystals are not nearly parallel to each other. Sudden changes in a casting's exterior surface cause crystals in the matrix to line up in non-uniform patterns or at angles to each other. In a cooling iron square, crystals lining up with one face are perpendicular to crystals lining up to adjacent faces. Planes of weakness occur along the square's diagonals. Trunnions, rim bases, and reinforce rings are examples of surface irregularities in cannon where planes of weakness occur. They cause the crystals to be arranged in non-uniform patterns, often perpendicular with one another. These features also interrupt vibration waves caused by firing the gun. The vibration then tends to settle where the crystal arrangement is irregular. Iron crystals in cannon are subject to rearrangement produced by the heat of repeated firing. Eventually, the entire piece is affected. As the crystal structure changes in response to firing, the modulus of elasticity increases, making the gun more brittle and more prone to bursting.[5]

Firing a cast-iron smoothbore subjects it to a variety of stresses. Because there is a space between the gun's chamber wall and the projectile known as windage, the ball virtually bounces down the bore. When a gun is fired horizontally, recoil forces are transmitted to the carriage, which moves as a result. When a gun is fired at elevated angles, many of the recoil forces are absorbed by the trunnions before they force the carriage to move. Thermal stresses result from the expansion and contraction of the gun during firing. For good resistance to thermal fatigue, iron should have high thermal conductivity, a low modulus of elasticity, and high tensile strength at a variety of temperatures, in addition to resistance to oxidation. High thermal conductivity and a low modulus are characteristic of iron with long graphite flakes whereas high tensile strength is found in iron with shorter graphite flakes. Since some of these properties are in opposition, a compromise in the iron is necessary to prevent thermal fatigue. When iron is not suited to this type of stress, crazing, or surface cracks appear.

Guns that are fired frequently are subjected to repeated alternation between tension and compression. These forces are applied to the trunnions during recoil, to the barrel as the projectile travels through (especially where windage is more pronounced), and to the barrel by expanding gases from ignition of the powder. This type of stress can fracture cast iron after a large number of load cycles (firings) even though the maximum stress of any individual cycle is well below the metal's tensile strength. Such a fracture is called a fatigue failure, and the gun's rate of fire or length of service is not a significant cause of it. Fatigue cracks are directly influenced by the maximum unit stress and the cumulative number of times it is applied to the gun. Fatigue cracks start in areas of high stress concentration, such as the vent, after a large number of firings. They are always brittle fractures. as with thermal stress, the properties of a given type of cast iron are often in opposition in preventing fatigue stress.

Although his experiments revealed many of the shortcomings of cast iron, Dahlgren never abandoned it as a material for cannon. A few other ordnance experts, one of whom was Alfred Krupp, had been experimenting with steel guns since the 1840s. Dahlgren, however, seemed convinced that cast-iron ordnance could be uniform and predictable. His work in the 1850s demonstrated that stresses having the greatest effect on a cast-iron gun's endurance resulted from the founder's casting technique. A gun that was cast solid with the bore drilled after cooling was subjected to strain induced by unequal solidification and contraction of it's metal. As iron cooled, it shrank. Solid castings cooled from the exterior. As the exterior solidified, it shrank onto a liquid interior and induced strain, resulting in a weak center along the casting's length. Ostensibly, the gun's weak center would be removed when the chamber was bored. This was not always the case. The amount of stress placed on the interior of a casting by the exterior depended on how much the exterior contracted. Two factors that influenced the amount of contraction were the cooling time and iron's strength prior to casting. Shorter cooling times caused greater shrinkage, inducing more strain and resulting in a weaker gun. Strong iron contracted more than weak iron with similar effects. Surprisingly, guns made of strong iron with higher tensile strengths were often not as reliable as guns made of iron lower in tensile strength because of greater shrinkage during cooling. By the Civil War, experiments indicated that because of shrinkage, highly elastic iron made better guns than iron with a higher density and tensile strength. Low density, soft, gray iron with moderate tensile strength made the best gun. High density, hard, close-grained iron made poor guns. In the 1850s, the mean specific gravity and tensile strength of pig-iron were 7.0 and 16,000 pounds per square inch, respectively. When pig-iron was cast in a gun, the average density increased slightly and the average tensile strength rose to between 25,000 and 30,000 pounds per square inch.[6]

In the 1850s, Dahlgren guns were cast solid and bored. The founders who cast the guns ordered in December 1854 for the steam frigates used the same general procedures as those who cast the first three experimental Dahlgrens. To prepare iron for casting, the founder first mixed freshly mined ore with wood or coal, then roasted it to remove water and impurities. Next, the ore was broken into smaller pieces and reduced in a smelting furnace, also called a blast furnace. A blast furnace was from thirty to fifty feet high, egg-shaped with the point at the tip, and built of brick. The top was open and the bottom had a receptacle for catching molten metal. To smelt the iron, the founder charged the furnace by first adding kindling, then alternating layers of fuel with layers of a mixture of ore and flux until the furnace was full. Fuel could either be coal, coke, or wood, and either oyster shells or limestone was used for flux. The founder then lit the fire and employed either steam or water power to produce the blast.[7] Founders debated whether a hot blast or a cold blast produced better iron. An 1844 experiment demonstrated that if iron was retained in the furnace for a certain time after it melted, then cast into pigs and later remelted to pour the gun, its quality improved.[8] This method was employed in casting all the Dahlgren guns.

The founder's first step in preparing the mold was making a model of the cannon. Although iron or copper models were preferred because they were easy to extract from the mold and left smooth surfaces, wooden models were generally used. A model had at least four parts - one section for each trunnion and at least one section for each barrel half. The barrel was divided lengthwise and each half section was further subdivided in heavier pieces. When all the sections were bolted together, the resulting model was the same size and shape as the cannon was intended to be, except for a square knob at the cascabel's end and an extra length at the muzzle. The cascabel knob was for holding the gun in a lathe during boring. The extra length at the muzzle end, called the sinking or sprue head, allowed impurities in the metal to collect in it. It also served as a reservoir. As the casting cooled, the metal contracted and excess liquid metal in the sprue head flowed back into the casting, filling gaps. The sprue head was cut off prior to boring the chamber.[9]

Two boxes, called flasks, were used to house the mold, each flask holding half. They were constructed from cast-iron plates and held together by bolts and screws. Each flask had a box bolted to it to hold the trunnion model. The two flasks could be bolted together and had rings, hooks, and bolts on the outside for lifting the whole structure by crane to move it about the shop.[10]

Iron guns were generally cast in molds made of a special type of sand. This sand was mixed with a specified proportion of clay to make it moderately adhesive when damp.[11] To make a mold, one of the flasks was placed on the ground with the trunnion box downward. A trunnion model was then set in place and sand was rammed compactly around it using iron bars with knobs on their ends. After the trunnion box was filled, a barrel-half model was bolted to the trunnion model and sand rammed around it until the flask was filled. Parting sand, a kind of white sand, was sprinkled on the surface to keep the two mold halves from sticking together. The other barrel-half model was then placed on top of the first. The second flask was bolted on top of the first flask with the upper plates removed. Sand was rammed around the second barrel half until the top flask was nearly full, leaving space for the second trunnion. The second trunnion model was bolted in place and the upper plates of the top flask screwed on. When the top trunnion box was full, a plate closing the trunnion box was bolted in place.[12]

The flasks, each containing holf of the mold, were separated with each half-model remaining in its respective flask. The model sections were then removed from the mold. The mold's surface was smoothed with trowels, and if it was not deemed hard enough, it was coated with pulverized firebrick. However, molten metal was not poured into the mold through the open muzzle end. If it were, the first few tons of metal splashing down into the breech would probably have ruined the mold. Instead, the molten iron was poured into the breech through a narrow channel cut into the mold. This channel was cut in one flask parallel to the barrel along its whole length. The channel entered the mold at the cascabel block. Smaller channels were cut between the main channel and the mold along the barrel's length. Once the mold's interior was smoothed out, it was covered with a wash of charcoal, coke, or black lead to prevent hot metal from coming in direct contact with the sand. The mold dried in an oven for about twenty hours.[13]

When the founder was ready to pour the metal, he dug a deep pit near the blast furnaces, bolted the flasks together, and lowered the mold breech first into the pit with a crane. With the mold secured in an upright position, channels were cut from the furnaces to a reservoir dug near the mold pit's mouth. A cast-iron gutter coated with clay and black lead was placed between the reservoir and the long channel cut in the mold to transfer hot metal. The founder then put the pigs in the furnaces, plugged the furnace openings with clay, closed the reservoir gate, and kindled the fire. As the metal melted in the furnaces, the clay plugs were poked out with pointed iron bars and the metal flowed into the reservoir. When enough molten iron collected in the reservoir, the gate was opened and it flowed into the mold through the main channel along the barrel's length. The mold filled from the bottom or breech end. The smaller channels between the main channel and the mold caused the metal to swirl as its level rose. The founder agitated the surface of the rising metal with a pine stick to force some of the impurities to the top, so that they could eventually collect in the sinking head. The founder allowed the casting to cool undisturbed, then lifted the flasks from the pit, unbolted them, extracted the gun, chiseled off rough spots, and transferred the gun to the boring mill.[14]

In the boring mill, the gun was laid horizontally in adjustable collars which allowed it to rotate. Water or steam power was used to spin the gun, via a shaft connecting the power source to the cascabel block. With the gun spinning, the sinking head was sliced off. The gun could now be bored. A cutting tool similar to a drill was fixed to a boring rod. The rod, long enough to reach the end of the chamber, was fixed to a moveable car. Moving along the same horizontal axis as the gun, the car was powered down a track by a system of weights and levers similar to a ratchet. The gun rotated, the boring rod did not, and the ratchet moved the cutting tool down the barrel. Several passes with cutting tools of increasing diameter finished the job. In some cases, as the chamber was being bored a different type of cutting tool was applied to the gun's exterior surface to give it a smooth finish.[15]

After the boring operation, the gun's trunnions and rim bases were turned. The piece was secured in a turning lathe with the axis of its trunnions in a vertical position. The piece rotated on its trunnions as cutting tools pressed against them. While the gun was secured in the turning lathe, the vent was drilled. Several minor finishing operations followed, readying the piece for inspection and proof. In the case of navy guns, these operations were performed under the supervision of navy personnel. If the gun failed any of these tests, the navy would refuse to accept it. First, the naval officer carefully measured the gun's interior and exterior dimensions to ensure that it met the navy's specifications. After inspection came the powder proof, in which ten rounds of ammunition were fired with service charges. Following this, water was used to detect whether cracks had formed in the bore during the proof firings. Guns that passed inspection and proof were so marked and coated with a rust preventative, and the cascabel block was removed. Dahlgren later modified the founding techniques employed to manufacture his guns, but they were all cast solid until the first years of the Civil War.[16]

In 1851, Lieutenant Thomas J. Rodman of the United States Army experimented with a different casting method. He reintroduced coring - the practice of casting guns with hollow cores. This was not a new technique in gunfounding. The French had abandoned it in 1713 in favor of solid casting because coring produced an irregular interior surface. Rodman knew that iron shrank as it cooled and that when guns were cast solid, the exterior cooled first. He was aware that solid-cast guns were strained when the exterior compressed the liquid interior, forcing the liquid metal in the direction of the sprue head. When the interior finally cooled, its compression lowered its density in comparison to that of the exterior. His solution was to cast guns on a hollow core through which water circulated, cooling the interior as rapidly as possible. At the same time, heat was applied to the exterior so that it cooled slowly. The interior hardened first. Since the exterior cooled and compressed on an already hardened interior, the process induced far less strain on the gun. The iron had a more uniform density than it did if the solid casting technique were employed. At the moment of firing, the interior received the support of the exterior instantly, rather than after some distention of the metal occurred. Interior cooling significantly increased the overall strength of the gun. However, hollow casting's superiority was not effectively demonstrated until the method was perfected during the Civil War. Rodman's experiments were still at an early stage. He tested his method's effectiveness in 1851 by comparing the endurances of four guns cast from the same reservoir of high-density metal. Two were cast solid and two were cast by his method. The hollow-cast guns endured firing longer. A solid cast 10-inch Columbiad failed at the eighteenth firing while a hollow cast 10-inch Columbiad lasted for 246 rounds. Since the latter result was also considered a poor performance, Rodman blamed it on the iron's high density and the gun's exterior cooling too fast. His critics were not yet convinced that hollow casting was effective.[17]

Other experiments in 1852 yielded more knowledge about exterior cooling. Guns less than one year old were compared with guns more than six years old. Although the hypothesis that exterior cooling induced strain was verified, experimenters found that the longer a gun rests after casting without being fired, the greater its endurance will be. Guns made of strong iron (that is, with high tensile strength) and fired shortly after being cast, soon burst. Guns made of weaker iron that had a long interval between casting and firing endured longer. The explanation for this was that after a period of time, iron crystals will adjust themselves to the gun's shape. The strain induced by exterior cooling diminished with time as long as a gun was not further strained by firing. Experimenters found that because hard, strong iron contracts more than iron with a lower modulus of elasticity and tensile strength, it requires more time to relieve itself of the strain induced by exterior cooling. These experiments showed that the manner in which iron was treated after being poured was more critical to a gun's strength than the treatment of the iron before pouring.[18]

Although aware of these experiments, Dahlgren pursued a different line of thought. His major concern was the relationship between iron's density and tensile strength. If the iron's density was raised, he wondered, would the gun endure longer? He knew this to be the case in lighter guns, and was interested in whether it also applied to heavier guns with thicker barrels. The densities and tensile strengths of the first two IX-inch guns were considered unusually high. The first XI-inch gun's density and tensile strength were considered excessive. The XI-inch gun's specifications called for a density of at least 7.230 and a tensile strength of at least 33,000 pounds per square inch. The gun's actual density and tensile strength were 7.319 and 36,149 pounds per square inch, respectively. Previously considering 7.250 to be a high density, Dahlgren was unsure whether the gun was sound and made special provisions for its acceptance (see Chapter II). He assumed, though, that the higher the density, the better the metal.[19] Ignoring the effects of coring, Dahlgren attributed the comparative longevity of one of Rodman's guns from the

1851 experiment to its high density. He wrote:

> . . . the Specific Gravity of Rodman's guns was very high, and one of them burst after no great continuance of ordinary firing, while one stood extraordinarily well not bursting at 1500 fires. . . .
>
> Again the moderate density of 7248 has furnished a piece of excellent quality, which also resisted the severest efforts to burst it - and what is more remarkable this piece was one of the heavy calibres (X-inch of 10,000 lbs) and therefore goes in the teeth of commonly asserted dogma that such pieces are not so trustworthy as others, by reason of the large mass of its metal. . . .[20]

The XI-inch gun's performance appeared to bear this idea out.

In reality, the first three Dahlgrens endured despite their high-density iron rather than because of it. As was generally the case with cast-iron guns, each one suffered from strain caused by the compression of a solid exterior on a liquid interior during cooling - a problem compounded by high-density iron. Section effects arising from their soda-bottle shape may have further weakened them. Yet these three guns survived. In fall 1854, Dahlgren stopped testing the two IX-inch guns so he could concentrate on the extreme proof of the XI-inch gun. He was satisfied with the first IX-inch gun's endurance. More conventionally shaped than the other models, it may have been less prone to section effects. The second IX-inch gun had only been fired a few times by then. Cast in July 1851, the XI-inch gun had fired a few proof rounds in October 1851 but was not fired regularly until October 1852. The long interval between its casting and its testing, due in part to Charles Morris' doubts about its safety, probably eliminated much of the strain resulting from unequal cooling. Because these three guns not only endured but performed admirably, Dahlgren guns were chosen to arm the six new steam frigates.

The conference of ordnance experts and cannon founders that Morris called on October 30, 1854, largely influenced this decision. Its purpose was to gather opinions about the best methods of casting and testing guns in general and to discuss the Dahlgren guns. The superintendents or owners of the principal cannon foundries in the United States were present: Cyrus Alger from Alger and Company in Boston; Robert P. Parrott from the West Point Foundry in Cold Spring, New York; John R. Anderson from Tredegar Iron Works in Richmond; and William Wade and Charles Knapp from the Fort Pitt Foundry in Pittsburgh. In addition, Charles W. Skinner, Inspector of Ordnance for the navy; Colonel H. K. Craig, Chief of Army Ordnance; and Dahlgren attended. Everyone apparently agreed with Dahlgren about the soundness of his guns and his ideas on how to cast them, but there was a disagreement not clearly explained in the records concerning the XI-inch gun. Whatever the dispute was, the navy settled it on November 25 by siding with Dahlgren. In December, contracts were issued to Alger and Company of Boston and Parrott's West Point Foundry to produce twenty-eight IX-inch, seven X-inch, and seven XI-inch Dahlgrens each. Knapp and Wade of Pittsburgh and Anderson of Richmond each received contracts to produce fifty IX-inch guns. "It has been considered good policy," wrote Morris, "to divide the making of guns among several different foundries, that they may be better able to readily supply any future wants of the country, with all the advantages for giving reliable guns, which frequent if not constant practice can secure."[21]

The foundries began casting the guns early in 1855. To each foundry the navy assigned an Assistant Inspector of Ordnance whose responsibility was to "attend [the foundry] daily, and to collect and communicate to the Bureau [of Ordnance and Hydrography] all the information attainable which is connected with the metal of which the Navy guns are made, and of its character and treatment, from the ore till the several guns are completed, ready for inspection and proof." Henry A. Wise, a friend and supporter of Dahlgren, was assigned this duty at Alger's foundry in Boston on January 8, 1855.[22] His correspondence with Dahlgren survives as an informative account of the progress and problems in manufacturing the initial order of Dahlgren guns. It shows that Dahlgren made changes and refinements in his designs in response to results obtained from experiments with existing guns. To some degree, it illustrates Dahlgren's theories of metallurgy.

On March 17, Wise reported that five IX-inch guns were in the boring shop. Based on the characteristics of the shavings and chips from the boring and finishing processes, he believed the gunmetal was high quality. The workmen thought that the density of each gun increased in the breech, but Wise did not offer his opinion. Dahlgren's specification that surplus metal be used in casting was implemented and sprue heads were raised to five feet. There appeared to be little shrinkage in the gunmetal as it cooled. Wise closed this report by describing Alger as a "charming sagacious old Son of Vulcan."[23]

For much of 1855, both Wise and Wade corresponded frequently with Dahlgren on the subject of preponderance (the excess weight of the breech over the muzzle).[24] Dahlgren's difficulty in establishing uniformity in his guns. On April 23, Wise reported that no limit on preponderance was specified on the IX-inch plans supplied to Alger and asked what it should be. Later that month, Wise admitted that his method of measuring preponderance might not have been accurate. In June, Wise tried a different method and achieved a different result. Preponderances varied by as much as sixty pounds in the guns cast in Pittsburgh. "Slight variations in finishing the peculiar forms," Wade wrote, "and in the density of the metal are sufficient to account for the variations in preponderance."[25] The preponderance of the first XI-inch gun was 950 pounds, and a later XI-inch gun's preponderance was 832 pounds. Dahlgren ordered that the cascabel lips should be strengthened on his XI-inch guns so they could better withstand recoil. Wise, expecting this to add to the preponderance, expressed surprise when the opposite happened. He wrote that preponderances "certainly hop up and down very strangely, for here is this piece, - the first that had the cascabel and lips enlarged, whereby I presumed we should get at least 20 lb more preponderance, than any of its predecessors; not varying materially either in Density, - when lo! it drops down. . . ."[26]

While filling the navy's order for Dahlgren guns, Alger's foundry was producing guns for the army. Early in July 1855, Wise reported that five 10-inch Columbiads cast for the army at Boston had burst during proof. "To all human vision," wrote Wise, "this. . . metal has excellent qualities in fibre, color, and crystal, and the only doubt there has yet been discovered for these accidents is the rapid falling off of density from the new iron that fused."[27] Dahlgren reported this to Morris, stating that if the same iron were used to cast the IX- and XI-inch guns, they would not be acceptable. In June, six Columbiads failed at West Point. Alarmed, Dahlgren requested "a course of extreme proof at each foundry for the new guns." He wanted to take action "before too many pieces are vitiated by inferior metal or other causes, to ascertain fully the general character of the metal used for the new shell guns that have been cast. . . ."[28] His request was granted.

On July 18, the first XI-inch Dahlgren burst on the 1,959th firing. In a letter to Dahlgren, Wade compared the XI-inch gun's long endurance with the Columbiads' failures. He acknowledged that the XI-inch gun's longevity may have been attributable to its high density. Wade noted, however, that the higher the iron's density, the more it contracts in cooling, thus placing a greater strain on the gun. This strain, he believed, would relieve itself if the gun were allowed a sufficient amount of time to set before being fired. That opinion concurred with the results of the 1852 experiments. Wade reasoned that the Columbiads burst because they were fired too soon after being cast. He argued that the XI-inch gun's endurance was probably due to sufficient time elapsing between casting and extreme proof for the strain to relieve itself. He indicated that another factor in the XI-inch gun's performance may have been its rounded breech. A Columbiad's breech was square in comparison to Dahlgren's design and Wade believe that a hemisphereical breech could better withstand firing. He agreed with Parrott's opinion that the high density of the Columbiads' iron caused their failure since they were tested soon after being cast.[29]

Late in the summer of 1855, many of the new guns were ready to undergo the thorough testing that Dahlgren had called for. Problems surfaced immediately. On August 29, a IX-inch gun cast in Pittsburgh burst, with one of its trunnions snapping off at the 206th firing. Dahlgren, considering this a poor performance, attributed the failure to a combination of low-strength iron and bad casting techniques. Wade had erred in casting the trunnions, allowing impurities in the metal to concentrate there. Dahlgren, forced to reject thirty-nine guns cast similarly, considered this to be a "shocking mistake to be made by so experienced a person as Major Wade."[30] Parrott attributed the gun's failure to its high density iron.[31]

A similar incident occurred in Boston on September 18. Wise reported:

> We began to prove last Saturday on Castle Island. The very first pop of a IX in, by the Holy Maker the very sky was hung with black. It broke nearly square off at the rim base, leaving a portion of one trunnion. . . . Now what do you think of that caper.[32]

Both the Boston and Fort Pitt foundries used the same type of iron to cast their first lots of Dahlgren guns. After firing ten proof rounds from many of the IX-inch guns cast in Boston, Wise reported that the iron was "extremely darn bad," but could not offer an explanation why. On October 8, Commodore Morris ordered another Boston gun to be fired until it burst.[33] Morris and Alger selected IX-inch gun number 973. Dahlgren meanwhile had ordered that no guns cast for the navy under the December 1854 contracts from Pittsburgh and Boston be accepted until he could determine why many of them were failing. After the ten proof firings, number 973 had a small crack in the chamber near the vent.[34] On October

31, number 973 exploded on the 950th firing. Wise reported:

> . . . the post mortem shows a very diseased state of constitution. The main aorta, where the shells lay, was honeycombed and eaten away to 4 tenths of an inch, while the chamber shows several fine cracks of long standing and the surface generally is rough and corroded by the powder. She split nearly in halves, as clean as a whistle. . . .[35]

Because of the failures of the Fort Pitt and Boston guns, Morris ordered Dahlgren to write a new list of specifications which would guarantee good quality guns. Dahlgren complied, forwarding the list in November 1855. He specified that only pig iron be used to cast the guns, no scrap metal was to be remelted. The castings were to cool slowly, remaining in the pit for ten days. The most interesting specification was that the guns were to be cast nearly in the form of a cylinder with protruding trunnions, then turned to their soda-bottle shape after cooling:

> The casting shall have a diameter of 24 inches at the plane of the muzzle and its form to the cylinder of the gun is to be obtained by right lines, so as to produce a section of a right cone, the greater base of which shall have the diameter of the cylinder and the lesser base that of 24 inches at the muzzle. The proper shape of the gun is to be had afterwards by removing this superflous metal.[36]

This technique produced reliable guns and was used for all caliber Dahlgrens until early in the Civil War.[37] Before this method was adopted, Dahlgrens were cast as close as possible to their finished shape. Cylindrical casting greatly reduced section effects during cooling. Much of the exterior metal that caused strain by compressing the interior was turned off. Rodman's method later proved more reliable, but Dahlgren did not believe interior cooling increased a gun's strength. Anderson, Knapp, and Parrott were also dubious about interior cooling. Rodman's method was adopted for XI-inch guns during the Civil War but it was never adopted for the IX-inch guns.[38]

Before the cylinder casting method was proven effective, Dahlgren's anxiety over the future of his heavy guns increased as he considered the fate of the initial order at the four foundries. At Pittsburgh, a total of forty-three guns were rejected, two-thirds having trunnions so defective that they broke before the guns had a chance to explode. All of the Boston guns were rejected. Three of the Richmond guns had defective iron and were rejected. All of the West Point guns were accepted.[39]

In January 1856, Dahlgren accepted the fact that the Pittsburgh and Boston guns failed because the densities of their iron were too high. He began experimenting with other approaches to gunfounding, including the cylinder casting method. He specified that a cylindrically cast test piece had to withstand 1000 rounds for the method to be proven. He became more interested in the treatment of the iron before it was poured, as well. He compared products of the warm blast and cold blast smelting methods to determine which produced better metal. From each experiment, he demanded reports on "every possible criterion."[40] In addition, he experimented with different types of iron that varied in carbon content.[41]

Although the initial lots of guns cast in Boston and Pittsburgh were rejected, the founders still hoped to fulfill the contract. In February 1856, manufacturing guns at these foundries was suspended until the results of the several experiments were known. Dahlgren was especially interested in the cylinder casting method. This method was originally intended only for the XI-inch guns. On the sixth, Dahlgren requested that it be adopted for the IX-and X-inch calibers as well. Charles Morris had died the previous month and Dahlgren's request was granted by the acting chief of the Bureau of Ordnance and Hydrography, Joseph Smith. Unlike Morris, Smith approved of Dahlgren's theories and methods. Morris had only allowed one vent in the Dahlgren guns cast during his tenure as Bureau chief. Dahlgren had always preferred two vents, and Smith allowed him to add another lock lug for the second vent on subsequent guns to be cast. Experiments with warm and cold blast iron began in April. In July, Dahlgren received a report that the experimental XI-inch gun cast by the cylinder method at West Point had withstood 1,000 rounds "without apparent injury." In September, the Boston foundry resumed casting IX-inch guns using the cylinder pouring method and two vents. On December 20, Dahlgren received a report of two guns cast by the Rodman method that performed poorly. His comment in his diary, "What a precious pair of bad guns," seems to sum up his doubts about the Rodman method. The apparent glee with which Dahlgren received news of the failure of ideas he did not approve of may account for some of his unpopularity among naval officers. Of all the experiments made in 1856 with metals for guns, Dahlgren considered the cylinder casting method to be the most effective.[42]

Further tests supported this belief. Every gun produced in Boston in 1857 by the cylinder casting method and selected for extreme froof endured. Some achieved 1,600 rounds. Parrott considered the changes in the casting technique to be "substantial improvements." In 1858, a IX-inch gun produced in Boston withstood 1,509 rounds. Twenty-two rounds of shells calculated to explode before exiting the barrel were then fired. The round that finally burst the gun consisted of twenty pounds of powder and ten shot weighing ninety pounds each. This nearly filled the gun to the muzzle. With critics convinced by shipboard tests that Dahlgren's guns were indeed safe and reliable, this test was like icing on the cake.[43]

ENDNOTES

[1] Simpson, *Ordnance*, p. 33.

[2] Alexander L. Holley, *A Treatise on Ordnance and Armor* (New York: D. Van Nostrand, 1865), p. 314, hereinafter cited as Holley, *Ordnance*.

[3] Dahlgren to Parrott, July 14, 1854, Box 2, Dahl Gen Corres, LC.

[4] The sources consulted for current metallurgical knowlege are: Charles F. Walton and Timothy J. Opar, eds., *Iron Castings Handbook* (Iron Castings Society, Inc., 1981); Dudley C. Gould, ed., *Metalcasting Dictionary* (Des Plaines, Illinois: American Foundrymen's Society, 1968); and Roland I. Curtin and Thomas J. Johnson, *Naval Ordnance* (Baltimore: The Lord Baltimore Press, 1917). Sources contemporary with Dahlgren are footnoted separately. The following terms are taken from the above sources:

tensile strength - the maximum load in tension which a material will withstand prior to fracture. A gun can only bear an internal pressure per square inch equal to the tensile strength of a square inch of the metal, the wall thickness is not significant.

specific gravity - the numerical value representing the weight of a given substance as compared with the weight of an equal volume of water at 39° F., for which the specific gravity is defined as 1.0000.

density - the mass per unit volume of a substance. For the purposes of this thesis, density and specific gravity are interchangeable.

pig-iron - cast iron generally produced by the reduction of iron ore in a blast furnace; also the iron in the foundry melted and poured into pig molds. so-called because they were runoff molds from a large central reservoir which in appearance resembled a sow with suckling pigs. Founders recognized two types of cast iron: gray and white iron. Gray iron, the type used for guns, is softer, less brittle, has a lower melting point, and contracts less when cooled than white iron.

modulus of elasticity - the ratio of the unit stress to the unit deformation or strain of a metal, provided fracture does not occur. The higher the modulus, the stiffer or more brittle the iron. Lower modulus irons are more elastic.

stress - forces applied to an object which cause it to move or be altered. In the case of ordnance, stress results from thermal forces as the gunpowder ignites and mechanical forces resulting from the expansion of gases and recoil produced by projectile motion.

strain - the change in an object as a result of stress.

hardness (of metal) - a metal is called soft when it yields readily to stress without fracturing or returning to its original form when the stress is removed. A metal is called hard when it does not yield readily to stress or when it requires a great deal of stress to produce permanent strain or change.

[5] Simpson, Ordnance, pp. 104-110.

[6] Simpson, *Ordnance*, pp. 41 and 110; Holley, *Ordnance*, pp. 309-323; "Strength of Guns and How to Cast Them," *Scientific American*, 15 November 1862, p. 307.

[7] Simpson, *Ordnance*, pp. 38-39.

[8] *Reports of Experiments on Strength and other Properties of Metals for Cannon, with Description of Machines for Testing Metals, and of Classification of Cannon in Service* (Philadelphia: H. C. Baird, 1856), p. 32, hereinafter cited as *Reports on Metals, 1856*.

[9] Simpson, *Ordnance*, pp. 45-46.

[10] Simpson, *Ordnance*, p. 47.

[11] Simpson, *Ordnance*, pp. 44-45.

[12] Simpson, *Ordnance*, pp. 47-48.

[13] Simpson, *Ordnance*, p. 48.

[14] Simpson, *Ordnance*, pp. 49-52.

[15] Simpson, *Ordnance*, pp. 52-54.

[16] Simpson, *Ordnance*, pp. 72-75; "Armament of United States Vessels of War and Ordnance Regulations for the Navy of the United States," November 13, 1849, Box 21, Dahl Nav Ord, LC.

[17] Bruce L. Simpson, *History of the Metalcasting Industry* (Chicago: Edward Keogh Printing Co., 1969), p. 111; Thomas J. Rodman, "Explanation of the differences in the endurance of the Experimental 8 and 10 in guns, cast and proved at Pittsburgh, PA, in the fall of 1851," Box 21, Dahl Nav Ord, LC; Lieutenant Chas. C. Turner to Warrington, October 20, 1851, Box 21, Dahl Nav Ord, LC.

[18] *Reports on Metals, 1856*, pp. 217-220.

[19] Dahlgren, "Notice of XI-inch Gun No. 1;" Dahlgren, *Memoir*, p. 150; Dahlgren to Morris, May 24, 1854, Box 22, Dahl Nav Ord, LC; Morris to the secretary of the navy, August 19, 1852, p. 248, Vol. 1, Entry 1, RG 74, NA; Dahlgren to Parrott, July 14, 1852, Box 2, Dahl Gen Corres, LC.

[20] Dahlgren to Parrott, July 14, 1854, Box 2, Dahl Gen Corres, LC.

[21] Dahlgren, *Memoir*, pp. 168-169; John Dahlgren Diaries, October 30, 1854 and November 25, 1854, Dahlgren Papers, Syracuse; Morris to Dobbin, November 13, 1854, p. 347, Vol. 1, Entry 1, RG 74, NA.

[22] Morris to Dobbin, May 25, 1855, pp. 372-373, Vol. 1, Entry 1, RG 74, NA; Morris to Hiram Paulding, June 9, 1855, Box 1, Dahlgren Papers, Syracuse.

[23] Wise to Dahlgren, March 17, 1855, Box 1, Dahlgren Papers, Syracuse.

[24] Preponderance is defined as the excess weight of the breech over the muzzle determined by measuring the pressure sustained by the elevating screw when the gun rests horizontally on its trunnions. The usual preponderance was one-twentieth the weight of the gun. The position of the trunnions determined preponderance. Its proper adjustment kept the gun steady during recoil. Simpson, Ordnance, pp. 87-88.

[25] Dahlgren to Morris, June 13, 1855, p. 20, Vol 18, Entry 19, RG 74, NA.

[26] Wise to Dahlgren, September 5, 1855, Box 1, Dahlgren Papers, Syracuse; Dahlgren to Morris, June 2, 1855, p. 13, Vol. 18, Entry 19, RG 74, NA; Dahlgren to Morris, June 13, 1855, p. 20, Vol. 18, Entry 19, RG 74, NA; Wise to Dahlgren, April 23, 1855, Box 1, Dahlgren Papers, Syracuse; Wise to Dahlgren, April 25, 1855, Box 1, Dahlgren Papers, Syracuse; Wise to Dahlgren, June 20, 1855, Box 1, Dahlgren Papers, Syracuse.

[27] Wise to Dahlgren, July 5, 1855, Box 1, Dahlgren Papers, Syracuse.

[28] Dahlgren to Morris, July 9, 1855, p. 41, Vol., 18, Entry 19, RG 74, NA; Dahlgren, Memoir, p. 172.

[29] Wade to Dahlgren, July 28, 1855, Box 1, Dahlgren Papers, Syracuse.

[30] John Dahlgren Diaries, August 29, 1855, Dahlgren Papers, Syracuse.

[31] Parrott to Dahlgren, October 4, 1855, Box 1, Dahlgren Papers, Syracuse.

[32] Wise to Dahlgren, September 18, 1855, Box 1, Dahlgren Papers, Syracuse.

[33] Wise to Dahlgren, October 8, 1855, Box 1, Dahlgren Papers, Syracuse.

[34] Wise to Dahlgren, October 12, 1855, Box 1, Dahlgren Papers, Syracuse.

[35] Wise to Dahlgren, October 31, 1855, Box 1, Dahlgren Papers, Syracuse.

[36] Dahlgren to Morris, November 24, 1855, Box 3, Dahl Gen Corres, LC.

[37] "Strength of Guns and How to Cast Them," *Scientific American*, 15 November 1862, p. 307.

[38] Warren Ripley, *Artillery and Ammunition of the Civil War* (New York: D. Van Nostrand Reinhold Co. 1970), p. 98; Charles Dew, *Ironmaker to the Confederacy* (New Haven: Yale University Press, 1966), pp. 45-46.

[39] Dahlgren, *Memoir*, pp. 172-173; Duncan N. Ingraham to James C. Dobbin, May 2, 1856, p. 411, Vol. 1, Entry 1, RG 74, NA.

[40] Dahlgren to Alger, January 29, 1856, Box 3, Dahl Gen Corres, LC.

[41] Dahlgren to Parrott, January 29, 1856, Box 3, Dahl Gen Corres, LC; Wade to Morris, January 17, 1856, Box 3, Dahl Gen Corres, LC; Dahlgren to Morris, November 24, 1855, Box 3, Dahl Gen Corres, LC; Dahlgren to Parrott, January 24, 1856, Box 3, Dahl Gen Corres, LC; Dahlgren to Alger, January 29, 1856, Box 3, Dahl Gen Corres, LC.

[42] William Downes Austin to Dahlgren, February 4, 1856, Box 3, Dahl Gen Corres, LC; Dahlgren to Joseph Smith, February 6, 1856, Box 3, Dahl Gen Corres, LC; Peterson, *Father*, p. 44; Austin to Dahlgren, April 15, 1856, Box 3, Dahl Gen Corres, LC; John Dahlgren Diaries, July 21, 1856, Dahlgren Papers, Syracuse; Austin to Dahlgren, August 4, 1856, Box 3, Dahl Gen Corres, LC; John Dahlgren Diaries, December 20, 1856, Dahlgren Papers, Syracuse.

[43] Dahlgren, "Report to Bureau of Ordnance on thirty-one IX-inch Guns Cast at Algers Foundry 1857," March 9, 1858, Box 24, Dahl Nav Ord, LC; "Casting Heavy Guns," *Scientific American* 30 October 1858, p. 60.

CHAPTER IV

ADOPTION OF THE SODA BOTTLE

In a letter to Samuel F. DuPont soliciting support for his ordnance, Dahlgren complained that he had been "most closely scrutinized upon every point and compelled to prove the work of the New Guns in detail . . . . the records of the department will show that no change hitherto made in our Batteries, has been submitted to a like ordeal."[1] One of Dahlgren's supporters offered an explanation for this, writing that he was "fast being forced to the conclusion that we will never be freed of old fogyism, except through the grave. Railroad collisions and retiring boards seem alike inadequate to the task. . . ."[2] Dahlgren argued that a smaller number of heavy guns with increased range and striking power better armed a ship's battery than a larger number of lighter guns. T. F. Simmons, an English naval officer, had espoused this idea in 1837. Dahlgren believed that the regulations of 1820 armed ships adequately. Because they were provided with a tier of 42-pounders, in his opinion, ships' batteries were capable of firing broadsides that had an acceptable projectile weight and penetrating power. The regulations of 1845 removed 42-pounders from service, replacing them with 32-pounders and "virtually emasculating the power of the ship."[3]

Dahlgren concluded in 1849 that 32-pounders were inadequate. In his opinion, the heavier 32-pounders lacked accuracy and the lighter 32-pounders lacked power. His authorization to design and experiment with the IX- and XI-inch shell guns was due in large part to the influence of his friend and patron, Lewis Warrington. During Morris' tenure as chief of the Bureau of Ordnance and Hydrography, Dahlgren was hampered by official inertia and organized opposition to his plans. He first had to convince the navy that his ordnance was superior to 32-pounders and Paixhans-like shell guns. He then had to prove that his guns could be safely and easily used on board ships.

Dahlgren began experimenting with the first IX-inch gun during the summer of 1850, firing it a total of 120 times. Among the experiments' objects were demonstrating the gun's safety, testing its accuracy, range, and power, and comparing its performance to two classes of 32-pounders and the 8-inch shell gun of 55 cwt. The targets were either muslin screens or oak timbers constructed to represent a ship's hull. The former were used for testing range and accuracy and the latter were used to test power of penetration. Dahlgren believed that the chief purpose of naval ordnance was to penetrate ships' wooden hulls and scatter splinters from the interior planks. He agreed with Ben Robins, the eighteenth-century British ordnance expert, that "whatever operations are to be performed by artillery, the least charges of powder with which they can be effected are always to be preferred." He believed that the muzzle velocity should not exceed 1900 feet per second. Greater velocities reduced accuracy because of increased atmospheric resistance to the projectile. If a projectile moving at a high velocity did strike a ship's hull, it would probably punch a clean hole which the crew could easily patch. Conversely, projectiles fired at too low a velocity might not penetrate the target at all. To increase a projectile's momentum, Dahlgren argued that its weight, not its velocity, should be increased.

The 32-pounders fired a projectile that he believed was too light. Heavier 32-pounders increased muzzle velocity at accuracy's expense. Dahlgren reasoned that the most effective gun would fire a heavy projectile at a low velocity with sufficient accuracy to hit the target and sufficient momentum to penetrate the hull. If the projectile were a shell, it need only penetrate the hull planking. Upon exploding, a shell would drive large splinters from the interior planking and tear a large hole in the hull.[4]

In January 1851, Dahlgren presented his first report to the Bureau of Ordnance and Hydrography on his experiments with the IX-inch gun. Satisfied that his ideas were correct, he wrote, "the old system of hard shot with short distances have [sic] been superseded by shells and appliances which must decide the day at a longer range and far more speedily than has hitherto been the case. . . ."[5] He suggested that the navy replace its 32-pounders and shell guns with his own guns. Realizing that the navy probably would not change its ordnance on the basis of 120 firings from an experimental gun, he asked if he could arm a frigate with his IX-inch and proposed XI-inch guns to further demonstrate his beliefs. The navy did not give Dahlgren a ship, but Warrington considered the IX-inch gun successful enough to allow him to proceed with his experiments.[6]

Probably because of Warrington's influence, Dahlgren's work was brought to the secretary of the navy's attention. In his annual report of 1851, Secretary William Alexander Graham wrote:

> Improvements and discoveries in ordnance and gunnery have been

> Introduced by means of which, in the opinion of well informed officers a ship of inferior rating, say, of 32 guns, may be so built and rigged, and armed, as to prove more than a match for the stoutest line-of-battle ship of the old construction and armament.[7]

The secretary's report, however, called for more testing before the proposed system of ordnance could be adopted.

When Charles Morris became chief of the Bureau of Ordnance and Hydrography, the pace of Dahlgren's experiments slowed abruptly. One consequence of this was that the first XI-inch gun which arrived in the Washington Navy Yard in March 1852 would not be fired until the following October. Dahlgren was forced to renew his effort to justify his ordnance to a far less receptive bureau chief than Warrington had been. Fortunately Dahlgren had established ties with Fred P. Stanton of Tennessee, who sat on the Committee on Naval Affairs in the House of Representatives. Dahlgren convinced Stanton that his new ordnance would be more effective yet less expensive to maintain than the navy's current ordnance. Stanton brought this matter before the Committee on Naval Affairs in February 1851, giving the Dahlgren guns a good recommendation.[8]

In August 1852, Stanton requested that Dahlgren write a paper concerning the best type of ship to test his ordnance. Dahlgren responded with "Reorganization of the US Naval Ordnance No. 1," the first in a series of four papers he produced to defend his new guns. He wrote:

> The paramount consideration which presents itself in relation to the efficiency of ships of war is their armament.
>
> That the batteries of our vessels are susceptable of important improvements.
>
> By an entirely different distribution of the metal contained in these pieces (the cannon), I propose to increase, in a high degree-
>
> 1st. The weight of the projectile discharged.

> 2d. Their Accuracy.
> 3d. Their force.
> And fourthly, to preserve due range.[9]

He stated that his IX-inch gun was superior in accuracy, range, and power of penetration to the 32-pounders and 8-inch shell guns. He believed that the best guns in the English and French navies, along with the United States Navy's 32-pounders, were "constructed in entire violation of the law which controls the accuracy of military projectiles."[10]

Dahlgren's proposed solution was to re-arm ships with batteries of Dahlgren guns. In the paper he presented to Stanton, he spelled out his plan to re-arm the Congress as an example. On each side of the Congress' main deck by regulation, there were two 8-inch shell guns and thirteen 32-pounders of 57 cwt. The projectile weight fired from a broadside was 530 pounds, fired by 97,400 pounds of cannon. Dahlgren proposed replacing them with eleven IX-inch guns on each side, increasing the projectile weight of a broadside to 790 pounds fired by 99,000 pounds of cannon. By regulation, the Congress' spar deck was armed with four 8-inch guns of 52 cwt., four 32-pounders of 57 cwt. and twelve 32-pounders of 42 cwt. weighing a total of 107,000 pounds. The broadside projectile weight fired from the spar deck guns was 366 pounds. Dahlgren would instead mount six XI-inch pivot guns on the spar deck, so that four could be brought to bear at one time on either side of the vessel. The weight of the proposed spar deck battery would be 96,000 pounds, firing a broadside of projectiles weighing 700 pounds. By using smaller numbers of heavy guns in the proposed battery the total weight of cannon carried by the Congress would be reduced by almost four tons, while the weight of the projectiles fired from a broadside would increase dramatically.[11]

On August 17, Stanton delivered a speech to the House of Representatives on upgrading the navy. He proposed that when the cost of repairing a ship was expected to exceed two-thirds of its original price, it should be sold and a new one constructed to take its place. The new ships were to be sailing vessels with auxiliary steam power driving screw propellers, constructed of white oak timbers, and armed with Dahlgren's new system of ordnance. Stanton read much of Dahlgren's first paper in defense of these arguments. Although ships armed with Dahlgren's battery would carry fewer guns, they would have more firepower than ships armed with a larger number of lighter guns. Since the new ships would carry fewer guns, they would be less expensive to maintain. The result in the long run would be an improved and more economical navy.

The type of vessel Stanton referred to would later be built as the *Merrimack* class. Sailing frigates with auxiliary steam power had been discussed in the House since 1850, and Dahlgren's experiments provided a fresh impetus to the idea of building them. However, the Department of the Navy offered no encouragement to Dahlgren's scheme. Some officers, especially Morris, opposed his plans and the *Merrimack* class was delayed until 1854. Dahlgren's work received little attention in the secretary of the navy's annual report of 1852.[12]

On May 31, 1853, Dahlgren submitted "Reorganization of the US Naval Ordnance No. 2" to the Bureau of Ordnance and Hydrography. This paper was based largely on experiments with the XI-inch gun, and was more or less a continuation of the arguments presented in his first paper. Dahlgren proposed mounting six XI-inch guns on each frigate's spar deck in place of their regulation batteriesof 32-pounders and 8-inch shell guns. From experiments performed in October 1852, he calculated that the XI-inch gun could fire one round every two and one-half minutes. He admitted that 32-pounders and 8-inch shell guns, with their rate of fire of one round per minute, could deliver projectiles faster than a battery of XI-inch guns. He implied that high rates of fire would only occur in close-quarter battles. Quickly disregarding short ranges, Dahlgren claimed that future naval battles would be fought at longer ranges. This would necessitate slower rates of fire because it took longer to point guns at more distant targets. Using formulae derived by French ordnance experts, he calculated that the XI-inch gun was more effective at longer ranges than 32-pounders and 8-inch shell guns because its projectiles penetrated ship timbers better. Experiments showed that the XI-inch gun was more accurate than the 32-pounders or the 8-inch shell gun. This was the only section of the paper in which Dahlgren quoted experimentally obtained data. Based on mathematical calculations, he concluded that:

> 1st. Wherever the spar deck 32 pdrs and 8 in shell guns were operative, the XI-in shells would be so in a far higher degree and decisively
>
> 2nd. That the XI in shells would be accurate and destructive at distances where the 32 pdr. shot and 8 in shells would be nugatory.[13]

The previous February, Morris had instituted a change in armaments on frigates and ships of the line which added an obstacle to the adoption of Dahlgren's plan. The 32-pounder of 51 cwt. and the 8-inch shell gun of 55 cwt. were taken out of service. In their place, each gun deck was armed with ten of the heavier 8-inch shell guns of 63 cwt. Morris then removed all the shell guns from ships' spar decks. Since Dahlgren's overall proposal called for XI-inch guns in pivot mounts on spar decks, he would have a more difficult time receiving approval for his plans.[14]

In the summer of 1853, Morris replied to Dahlgren's first two papers with a list of objections to the new ordnance, primarily the XI-inch gun. He stated that if six XI-inch guns were mounted on a ship's spar deck, there would not be enough room for boats large enough to take out a bower anchor, transport provisions to the ship, or mount artillery for boat expeditions. If the problems with the boats could be solved, he believed that there would not be enough room between the fore and main masts for more than two pivot guns if the hatchways to reach the hold remained in place. Even two pivot guns mounted between the fore and main masts would take up much of the space required to stow spare spars. The slide mounts themselves were bulky and would restrict the movement of men fore and aft, making it difficult to sail the ship. Pivot gun crews would be vulnerable to enemy grape, canister, and musket fire. Morris doubted that the XI-inch guns could be fired safely in rough weather. He stated that the change in armaments he had instituted the previous February for ships of the line and frigates brought the broadside weight of projectiles to weight of guns ratio up to an acceptable level.[15]

Morris questioned many of Dahlgren's experimental proceedures. He pointed out that Dahlgren's tests of comparative accuracy among the

32-pounders, the 8-inch shell gun, and the IX-inch shell gun were conducted on shore. The results at sea would differ, he argued, because it was more difficult to estimate distances and because a rolling ship was not as stable a gun platform as the experimental battery. Morris stated that the "advantages which have been sometimes claimed for heavier and for lighter calibres by their respective advocates, in consequence of the different effect produced in actions between ships, seem to have been more properly due to the skill and accuracy with which they were used rather than to their relative calibres and weights." He attributed American success in the War of 1812 to better gun crews, not heavier guns. He pointed out that during the Napoleonic Wars, the French had had heavier guns while the British had had more successes in naval battles. Dahlgren had concluded in his papers that his IX- and XI-inch shells were more destructive than 8-inch or 32-pounder shells. Morris called attention to the fact that Dahlgren had reached this conclusion by comparing the amounts of powder in each shell, not by actual experiments with the latter two types. Morris conceded that Dahlgren's guns were more powerful than 32-pounders, but he believed that two 32-pounder hits could inflict as much damage on a target as one XI-inch shell. He believed that the more guns a ship carried, the better its chances of hitting its target would be despite Dahlgren's comparative accuracy tests. Morris concluded that Dahlgren had not shown sufficient experimental evidence to justify re-arming ships by his plan.[18]

Later that summer, James Cochran Dobbin, the new secretary of the navy, reopened the question of building a new type of naval vessel along the lines of Stanton's 1852 proposal. Dobbin asked several officers, including Morris, John Lenthall, Chief of the Bureau of Construction, and Joseph Smith, who had previously worked in the Bureau of Ordnance and Hydrography, to suggest a type of vessel that could replace the Franklin, a ship of the line. The officers agreed that the ship should be frigate built, should have the best possible sailing qualities, and should have auxiliary steam power to drive a screw propeller. The screw propeller was to be designed so that it would not interfere with the ship's sailing qualities. Under steam the ship should be capable of seven knots. Her gun deck would be armed with twenty-eight IX-inch Dahlgrens. The spar deck was to be armed with twenty 8-inch shell guns mounted on carriages and two or three pivot guns of an unspecified type. Dahlgren's IX-inch gun was accepted, but opposition to the XI-inch gun remained firm.[17]

Dahlgren responded with his third paper, "Reorganization of the US Naval Ordnance No. 3," which was based on comparisons of accuracy between his guns and the navy's current ordnance at 1,300 yards. Attempting to bypass Morris' objections, Dahlgren addressed this paper to Dobbin through the bureau. The paper began with Dahlgren's view of the world scene:

> . . . after a peace of nearly forty years there are signs of conflict among the great powers which may require us to defend the neutrality of our flag. Moreover we have now golden thoroughfares on the Ocean that we had not before, and which are at least worth the rate of an ordinary insurance. Hence any strengthening of our Naval force, especially if it afford a better return for a certain outlay, deserves consideration and I am assured will have it at your hands. . . .[18]

The tests outlined in the paper were designed to show the effectiveness of his guns at longer ranges. This time, he compared the 32-pounder of 57 cwt., the 8-inch shell gun of 63 cwt., and the 64-pounder with his IX-and XI-inch shell guns. He fired ten rounds from each piece at a muslin screen twenty feet high by forty feet long. Although the 64-pounder proved to be as accurate as the XI-inch gun, Dahlgren believed that the power generated by the former piece did not justify its weight. None of the other guns proved to be as accurate as Dahlgren's. He admitted that he did not fire as many rounds from each piece as he should have because of a lack of time and "circumstances." Despite this, he arrived at what he believed was a concrete conclusion based on two assumptions. First, he assumed that naval officers accepted his findings that his guns were more accurate than the navy's present ordnance. Second, he assumed that the newest American ships could attain the same maximum speeds as the fastest British and French vessels.[19]

He concluded that ships should carry the heaviest guns possible. He reiterated his proposal to arm new ships with IX-inch carriage guns mounted on the gun deck and XI-inch pivot guns mounted on the spar deck. If the new ships could choose more distant battle ranges by virtue of having speeds equal to their opponents, their more accurate guns would yield victories. For ships already afloat, he recommended replacing their present ordnance with batteries of IX-, X-, and XI-inch shell guns. Having fewer guns, the new batteries would reduce the vessels' maintainence costs yet would pack more of a punch. Dahlgren noted that British and French vessels still relied on larger numbers of lighter guns in their batteries, but the proportion of shell guns to shot-firing guns was increasing. He suggested re-arming the Franklin with fourteen IX-inch and six XI-inch shell guns. Envisioning a battle between the Franklin so equipped and the St. Jean d'Arc, a French ship armed with 101 lighter guns, he speculated that the battle would be a draw if fought at 1,300 yards.[20]

Morris' rebuttal of Dahlgren's third paper was a series of arguments concluding that ships armed with a larger number of guns were preferable to ships carrying fewer, heavier guns. He reiterated his position that because of the difficulties in aiming guns at sea, the greater accuracy of Dahlgren's guns was negated. With more guns, a ship's battery stood a better chance of hitting its target. One of Dahlgren's key points was that if American ships were capable of making the same speed as enemy vessels, they could choose to offer battle at longer distances where Dahlgren guns were more effective. Morris doubted that the United states could build a fleet in which every vessel could steam as fast as the best in foreign fleets. He also cited conditions under which American ships would be forced to fight at closer ranges. Morris admitted that Dahlgren guns were superior to regulation guns in terms of penetration and explosive force, but held that a larger number of guns still had a better chance of hitting the target. He believed that two lighter shells could inflict as much damage as an XI-inch shell. He backed this argument by calling attention to Dahlgren's admission that his guns had a lower rate of fire than the regulation ordnance. This was because XI-inch shells weighed 131 pounds, making them more difficult to load than 32-pounder projectiles. Additionally, the sixteen-thousand pound XI-inch gun was more difficult to maneuver than the lighter 32-pounder and 8-inch shell guns. Morris was willing to use the IX-inch gun in ship's batteries to compare their performance in action with 32-pounders and 8-inch ghell guns. He was not willing to try the XI-inch gun, arguing that it must be subjected to more experiments.[21]

Despite Morris' criticism, Dobbin acknowledged Dahlgren's efforts in his annual report of 1853, writing:

> The indefatigable efforts of Lieutenant Dahlgren to give accuracy and greater effectiveness to gunnery, and to improve the ordnance of the navy, have succeeded well, and none can doubt the advantages the service will experience therefrom.[22]

He then requested Congress to authorize the construction of six "first-class steam frigate propellers." His request was probably based in part on Dahlgren's efforts to upgrade naval ordnance.[23]

Dahlgren continued these efforts in January 1854 with his fourth paper to the bureau on reorganization of shipboard ordnance. This paper was largely a defense of his views in response to Morris' criticism of the first three papers. One subject that Dahlgren focused on was his proposed re-armament of the Franklin.[24] Later that month, Morris wrote Dobbin a letter outlining his objections to this proposal, Morris agreed to try mounting twenty-four IX-inch pieces on the gun deck as Dahlgren wished. They disagreed on how to arm the spar deck. Morris favored mounting twenty 8-inch shell guns on carriages which would be "worked through ports and covered by bulwarks," ostensibly to protect the gun crews from enemy grape, canister, and musket fire. Dahlgren favored mounting six XI-inch guns in pivot. Morris was willing to compromise, offering to allow two XI-inch pivot guns on the spar deck while retaining his twenty 8-inch shell guns. Dahlgren remained adamant, writing that his plan would be "marred by ingrafting upon it, armaments inconsistant with it" and that "the chances of success due to this modified armament are lessened. . . ."[25] Morris again objected to Dahlgren's plan on the basis that there was insufficient room on a ship's spar deck to mount six pivot guns. He reiterated his belief that a battery should consist of a larger number of guns than Dahlgren wanted. Dobbin chose twenty 8-inch guns and two XI-inch pivot guns for the Franklin's spar deck despite Dahlgren's protests.[26]

On April 6, 1854, Congress answered Dobbin's appeal by authorizing the construction of six "first-rate steamers" of the type ynder consideration since 1850. Five of these vessels, the Merrimack, Wabash, Roanoke, Colorado, and Minnesota, would be built by John Lenthall as sailing frigates with auxiliary steam power. Lenthall, Chief of the Bureau of Construction, was characterized by professional conservatism and a bearish personality. He looked with contempt on innovations that interfered with his own vision of stately sailing steamers. The sixth vessel, the Niagara, would be built as a sloop. Her designer, George Steers, who held a temporary position with the navy, was a private shipbuilder from New York famous for his fast clipper ships and yachts. Unlike the frigates, which would carry cannon on two decks, the Niagara would only carry guns on her spar deck. She was designed primarily for speed, and her length on the waterline would be 328 feet as compared to about 260 feet for the frigates.[27]

When Congress approved the construction of these vessels, the navy had not specified exactly what armaments they would carry. Despite Dobbin's enthusiasm for his guns, Dahlgren was not fully confident that they would be chosen. He continued experimenting. In May, 1854, he reported that in recent tests, the XI-inch gun had penetrated a target that 32-pounder shot and 8-inch shells could not. He testified that on one occasion during this experiment a twelve man crew had fired two rounds from the XI-inch gun at the rate of one round per minute. In his report, he wrote:

> . . . I attach little value, as the Bureau knows, to rapid firing and I only mention this to show to those who depend on it for the inferior calibres, that it would be nearly impossible to discharge the same weight of metal in equal time from the calibres now used. Still the fact is of interest, in as much as it marks the facility with which such pieces can be fired—the crew being one less than allowed to a 32-pounder. And it gives reasonable ground for anticipating that with a full crew, say 22 or 25 men, the motion of a ship in any weather that one would attempt to engage, need not prevent the handling of such a gun.[28]

In a similar test with the XI-inch gun, he fired six rounds at the rate of one round every forty seconds.[29]

While Dahlgren experimented that summer, work on the new ships commenced. Dobbin had not yet made a final decision concerning their armament. He was willing to mount IX-inch guns on the gun deck and place one pivot gun on each end of the spar deck but objected to placing pivot guns between the fore and main masts. Dahlgren pleaded to be allowed to use his entire plan on at least one ship and Dobbin suggested that he meet with the builders to discuss it. In July, Dahlgren met with both Lenthall and Steers. Lenthall, who had discussed armaments earlier with Morris, agreed to mount IX-inch guns on the frigates' gun decks but chose 8-inch guns and only one pivot gun for the frigates' spar decks. He preferred dispensing with the after pivot gun to make room for equipment to raise the propeller when the frigates were under sail. Steers was willing to mount twelve XI-inch guns on the *Niagara*'s spar deck, but did not want her gun deck armed at all.[30]

By the end of 1854, Morris, Dobbin, Lenthall, and Steers made the final decision on how to arm the new ships. In December, the Bureau of Ordnance and Hydrography placed the initial order of Dahlgren guns with four foundries. The Fort Pitt, West Point, Boston, and Richmond foundries would manufacture IX-, X-, and XI-inch guns for the *Niagara* and the frigates *Merrimack*, *Wabash*, *Roanoke*, *Colorado*, and *Minnesota*. The *Niagara* would carry XI-inch guns on her spar deck. The frigates would carry IX-inch guns on their gun decks and 8-inch guns and two X-inch pivot guns on their spar decks. Dahlgren was not satisfied with this arrangement. He preferred using his XI-inch guns in place of his X-inch guns but Morris' decision prevailed. He was unable to convince Steers to persuade the navy to place IX-inch guns on the *Niagara*'s gun deck. Dahlgren, unwilling to compromise, continued his efforts to arm at least one ship entirely by his plan.[31]

He centered these efforts on the *Niagara*, the only one of the six that would carry XI-inch guns. Dahlgren hoped that Steers and the navy department could be persuaded to incorporate a gun deck battery into the *Niagara*'s design. Steers and the navy, however, were more interested in the *Niagara*'s speed than her armament and would not change their minds. By the spring of 1855, Dahlgren realized his failure. In his diary, he lamented that if the Niagara's decks had only a few more feet of space between them, she could carry a battery of IX-inch guns on her gun deck. Unfortunately, her construction was too far advanced to raise the decks.[32] Steers kept Dahlgren apprised of the Niagara's progress and was willing to place the spar deck guns where Dahlgren wished. Dahlgren then tried to mount fourteen XI-inch guns on the Niagara's spar deck, but Steers would only allow twelve. Dahlgren considered it a "pity" that Steers should "go beyond his business."[33] On May 31, he wrote a letter to Dobbin in which he complained vigorously that his own plan of armament was not fully utilized on board the Niagara.[34] He believed that Steers would build only one vessel of this type rather than introducing several as a new class of ships. He thought that Steers emphasized speed at the expense of a powerful battery.[35]

Morris proceeded with his own plans to rearm ships in 1855, and these did not include Dahlgren guns. In June, he and Lenthall wrote Dobbin a letter suggesting that the San Jacinto's after pivot gun be removed. In its place, they proposed adding two 32-pounders of 57 cwt. and two 8-inch shell guns of 55 cwt. to the San Jacinto's battery.[36] In another letter to Dobbin, Morris stated that the armament regulations of 1845 had resulted in heavy guns being placed on board ships not designed to carry them. He suggested that commanders of certain vessels be allowed to remove guns that they felt were interfering with their ships' sailing qualities.[37] In excluding Dahlgren's guns from his plans and removing heavy guns and pivot guns from ships, Morris indirectly attacked Dahlgren's plan of armament. In his section of the secretary of the navy's annual report for 1855, Morris made no mention of Dahlgren's progress.[38]

However, Dahlgren was not lacking in general support for his guns in 1855. William Wade, one of the Fort Pitt foundry's owners, applauded the XI-inch gun's safety. Percival Drayton, who at the time was an ordnance officer and would later have a distinguished career in the United States Navy during the Civil War, considered Dahlgren's ordnance superior to French and British ordnance. In a letter to Dahlgren concerning the opposition, Drayton wrote that "from the time of Galileo, . . . stupidity with power has proved itself too much for genius without it."[39] Henry Wise, the ordnance officer stationed at Alger's foundry, noted that a British ordnance officer who had seen the Dahlgren guns at Boston was "much pleased with [the] Iron Leviathans and thought they might distinguish themselves at Sevastopol."[40] Even Morris, avid critic of Dahlgren that he was, ordered that rejected XI-inch guns be broken up and that the plans of the XI-inch gun were not to be sold to foreign powers. In his annual report of 1855, Dobbin once again praised Dahlgren's work and promised to assign him a ship for gunnery practice.[41]

In many ways, 1856 was a banner year for Dahlgren. By the year's end, all six of the new propeller ships were launched. The _Merrimack_, commissioned in December 1855, would be the first vessel to fire Dahlgren guns at sea. Problems with the new guns bursting prematurely would be solved by the cylinder-casting method. Several guns cast by the Rodman method, of which Dahlgren disapproved, performed poorly. Dahlgren's _Shells and Shell Guns_ and the second edition of his _Boat Howitzers_ were published. By the end of the year, he would finally receive a vessel to test his XI-inch gun at sea and thereby put an end to most of the criticism of the XI-inch gun. His old adversary Morris died in January, and the bureau chief's successors were more open to Dahlgren's views.

Joseph Smith was the interim chief of the Bureau of Ordnance and Hydrography. In Smith's opinion, if the XI-inch gun proved to be manageable at sea, it would be superior to both the X-inch shell gun and the 64-pounder. In February 1856, Smith reported to Dobbin that after the six new ships received their ordnance, there would be only eight guns "of the latest [Dahlgren's] and most approved models remaining." Smith then asked for the necessary appropriations to cast twenty XI-inch, twenty X-inch, and sixty IX-inch Dahlgrens.[42]

That month, the Merrimack put to sea for a trial voyage during which each class of her guns was fired. Catesby Jones, who assisted Dahlgren in his experiments at the Washington Navy Yard and later served in the Confederate navy, was the Merrimack's ordnance officer. After the voyage, Jones made a report to the Merrimack's captain about the performance of her battery. He was satisfied with the IX-inch guns, finding that they were not too heavy to handle. He did not like the roller handspike, a device for maneuvering the IX-inch gun's Marsilly carriage. He suggested increasing the number of IX-inch guns carried on board from twenty-four to twenty-eight. He preferred the IX-inch guns over the 8-inch guns because they delivered more metal per broadside. He proposed replacing her spar deck battery of fourteen 8-inch guns and two X-inch pivot guns with ten XI-inch pivot guns.[43]

Dahlgren used this report as the basis for further arguments on rearming ships. In April, he wrote a letter to Dobbin in which he compared the batteries of the *Merrimack* and the *Congress*. A broadside from the *Congress*' gun deck threw 582 pounds of projectiles from 44¼-tons of guns manned by 204 crewmen. A broadside from the *Merrimack*'s gun deck threw 864 pounds of projectiles from forty-nine tons of guns manned by 204 crewmen. Dahlgren argued that his ordnance was more efficient than the old ordnance. He suggested replacing the *Merrimack*'s spar deck battery with two XI-inch pivot guns fore and aft and ten IX-inch guns mounted to fire broadsides. He viewed this as a compromise between the *Merrimack*'s unacceptable spar deck battery and the ideal spar deck battery of twelve XI-inch guns. Dobbin did not change the *Merrimack*'s armament.[44]

In October, Dahlgren proposed a similar change in the *Wabash*'s battery. He reiterated his old arguments that his proposed spar deck battery was more powerful, economical, and accurate than the X- and 8-inch guns that the *Wabash* carried on her spar deck. He admitted that the roller handspike used to maneuver the IX-inch gun's Marsilly carriage was "far from perfect" and offered to consider any suggestions for modifying it. His proposal was rejected again.[45]

Critics gave the Dahlgren guns mixed reviews in 1856. R. L. Stevens, who was trying to get congressional approval for his ironclad ship, asked Dahlgren what his largest gun could do. Dahlgren offered to fire his XI-inch gun at Stevens' vessel. If it withstood the punishment, he would certify it as "proof against any known ordnance." Stevens declined.

While cruising on board the Merrimack, Catesby Jones kept Dahlgren informed of any comments he heard about her battery. An American officer named Powell believed that 32-pounders were better than X-inch shell guns. He called the Merrimack's new ordnance a "sham" and asserted that her guns were not properly proven. Most comments Jones heard about the IX-inch guns, however, were favorable. Many officers desired them for their own vessels. British and French officers touring the Merrimack in Lisbon admired the Dahlgrens and admitted that they were "constructed upon proper principles." Many of the officers that fought in the Crimean War favored heavy guns but doubted the value of shells. Duncan N. Ingraham, who replaced Joseph Smith as chief of the Bureau of Ordnance and Hydrography in March 1856, believed that the Niagara would be "an entire failure in point of appliances and armament." He considered the Wabash to be better armed and a better ship. In his annual report of 1856, Dobbin again praised Dahlgren's work. He believed that "the recent adoption on the new frigates of the 9, 10, and 11-inch shell guns to the exclusion of shot, was by no means inconsiderately or hastily made."[46] Comparing shot to shell, Dobbin noted that the holes made by shot in ships were easy to repair, but if a vessel was struck by one of Dahlgren's "monster shells . . . one can hardly conceive of the crashing of timbers and the havoc and destruction. . . ."[47] He announced that Dahlgren would soon be given command of the Plymouth, which was being fitted out as a gunnery practice ship. Her armament would be a mixed battery of guns, including Dahlgren's XI-inch model. Her mission was to train gunners in the operation of Dahlgren's ordnance and to determine if the XI-inch gun would be manageable at sea.[48]

On July 7, 1857, the Plymouth put to sea armed with four IX-inch shell guns, one XI-inch pivot gun and one 12-pounder and two 24-pounder boat guns. She was ordered to cruise by way of the Azores to Lisbon, along the coast of France to Amsterdam, visit England, then return to the United States via Bermuda. During the cruise, Dahlgren fired 121 shells from the XI-inch gun and 230 shells from the IX-inch guns. He reported that the rates of fire of these guns were satisfactory in all kinds of weather. He found no difficulty in securing the guns in the roughest weather. He stated that the XI-inch gun performed well despite its weight.[49] Isaac Toucey, Dobbin's successor as secretary of the navy, was impressed by Dahlgren's guns and the Plymouth's cruise. In his annual report of 1857, Toucey wrote:

> The result of the operations of the Plymouth seem to dispel all remaining doubt whether the heavy cannon which she carried would be manageable, and not only to justify the previous adoption of such ordnance in the steam frigates recently built, but also to render it expedient to extend this plan of armament.[50]

The IX-inch gun received favorable comments from other officers in 1857. George Sinclair, the Wabash's ordnance officer, reported the results of practice with the IX-inch guns in rough weather to his captain. In this report, Sinclair noted that one of his subordinates was afraid that the guns would kill some of the men because of the heavy roll of the ship. Sinclair was sure that no target could be hit at any distance except by chance. He found that the men handled the guns well and without accidents despite the rough weather, but did not like the roller handspike. On the Minnesota's maiden voyage, Samuel F. DuPont, her captain, reported that target practice with the IX-inch guns was satisfactory.[51]

In 1858, opinion of the Dahlgren guns was still mixed. R. B. Hitchcock, who was then the Merrimack's commanding officer, found that the roller handspike damaged the deck so much that the crew refused to use it. Ingraham did not favor replacing the X-inch pivot guns of the Merrimack class with XI-inch guns. However, he chose XI-inch guns for some of the screw sloops that Congress approved that year.[52] By the year's end, Toucey was completely convinced of the Dahlgren guns' value. He believed that they combined strength, range, accuracy, and power. He commented that "in the Dahlgren gun we have found what we want, and it is believed that there is no gun in any service that surpasses it in these qualities."[53]

In 1859, nearly all the opinion of the Dahlgren guns was favorable. DuPont wrote of the Minnesota:

> The size of the Minnesota, the great beauty of her lines, the novel theory of her combinations; that is a colossal clipper sailing Frigate, with auxiliary Steam Screw power, and an armament (Dahlgren's) which has yet defied criticism . . . made her an object of universal attraction in the Eastern Seas.[54]

The Russian navy was impressed with the IX-inch gun and copied Dahlgren's soda bottle shape for their own ordnance. In fact, one Russian frigate carried two guns bearing such a close resemblance to the IX-inch gun that Dahlgren launched an investigation. F. A. Hunt, an American officer, was sent on board the Russian frigate to inspect and measure these guns. He found that they actually were Dahlgrens that had been cast in Boston that the navy had rejected. Alger's company claimed that it could sell rejected IX-inch guns abroad because under the current contract, only rejected XI-inch guns were to be broken up. Near Vera Cruz that year, the *Brooklyn*, armed with Dahlgren guns and the *Saratoga*, armed with 32-pounders and 8-inch shell guns, fired their batteries for practice. The *Saratoga*'s battery proved to be as accurate as the *Brooklyn*'s. Dahlgren attributed this to the poor handling of his guns by the *Brooklyn*'s crew, asserting that his guns actually were more accurate. No fresh criticisms of Dahlgren's guns surfaced as a result of this. The XI-inch gun was chosen for some of the screw sloops approved by Congress the previous year, and half of the vessels of the *Merrimack* class were ordered to carry XI-inch guns in place of the X-inch guns pivoted on their spar decks.[55]

By the end of the decade, most contemporary ordnance experts no longer rejected Dahlgren's ideas or his ordnance. The principle that a battery of a few heavy guns was superior to a battery of more numerous, lighter guns was taught at Annapolis. Dahlgren's cruise on board the *Plymouth* in 1857 and another the next year enabled him to prepare a manual of instructions on his guns for distribution to the navy. Some officers favored increasing the number of Dahlgren guns in their ships' batteries. Toucey, in his annual report of 1860, declared the XI-inch guns mounted on the screw sloops approved two years earlier by Congress to be a success.[56]

On the eve of the Civil War, the Dahlgren guns had a good reputation in the United States and had made a favorable impression on foreign naval officers. Their performance during the Civil War has been praised, although a thorough study of their combat record has not been made. The classic example of the Dahlgrens' reputation was the battle between the *Alabama* and the *Kearsarge*. Union contemporaries of the period proudly attribute the *Kearsarge*'s victory to the superiority of her Dahlgren guns over the *Alabama*'s English-built ordnance. When officers found the XI-inch gun only had a limited effect on Confederate ironclads, Dahlgren and Rodman developed a XV-inch gun that was more successful. Dahlgren guns remained in service nearly until the end of the century.

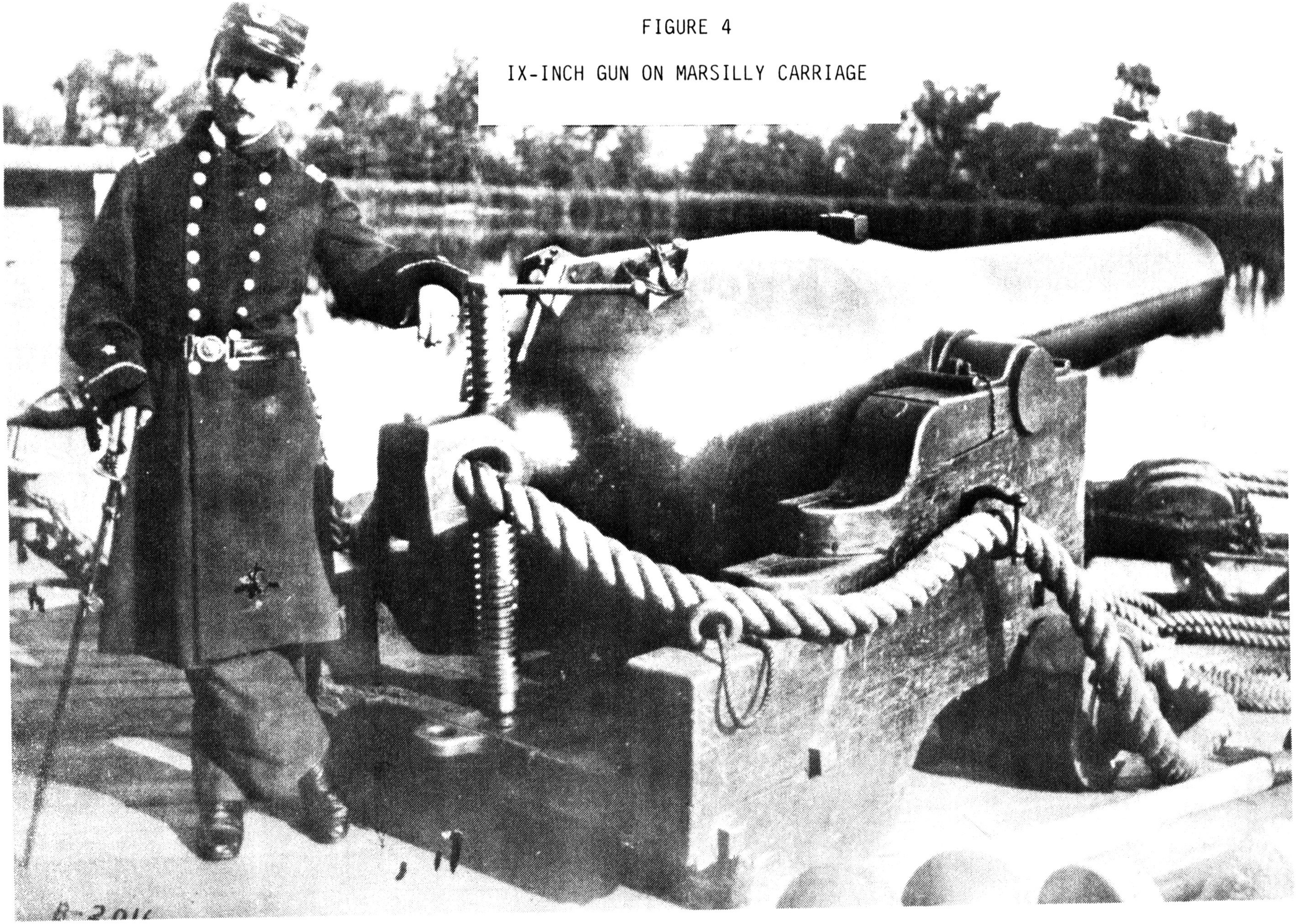
By the end of the Civil War, however, critics had renewed their assault on the Dahlgren guns. Ordnance expert Alexander Holley noted that because of their weight, XI-inch guns impaired the seaworthiness of some of the lighter vessels.[57] One British critic wrote in 1864:

> The Americans appear to have a natural prediliction for what is big, and they have applied themselves to the production of huge guns, made on every variety of pattern, with very little scientific uniformity and direction. If we are accurately informed, none of these guns have [sic] shown that durability which is essential to permanent service, nor have their effects corresponded to the cost and labor bestowed on them.[58]

Several modern critics doubt the value of Dahlgren's guns. Andrew Lambert, a British historian, believes that heavy guns did not advance the effective fighting power of ships armed with them. He states that the *Niagara*'s twelve XI-inch guns constituted an armament that would have proved disasterous in a battle on the high seas. He argues that because the naval engagements of the Civil War were fought in calm coastal waters, the difficulty in handling heavy ordnance on small vessels was not exposed. In Lambert's opinion, Confederate ironclad vessels exposed the "folly" of the American prediliction for heavy guns.[59]

FIGURE 4

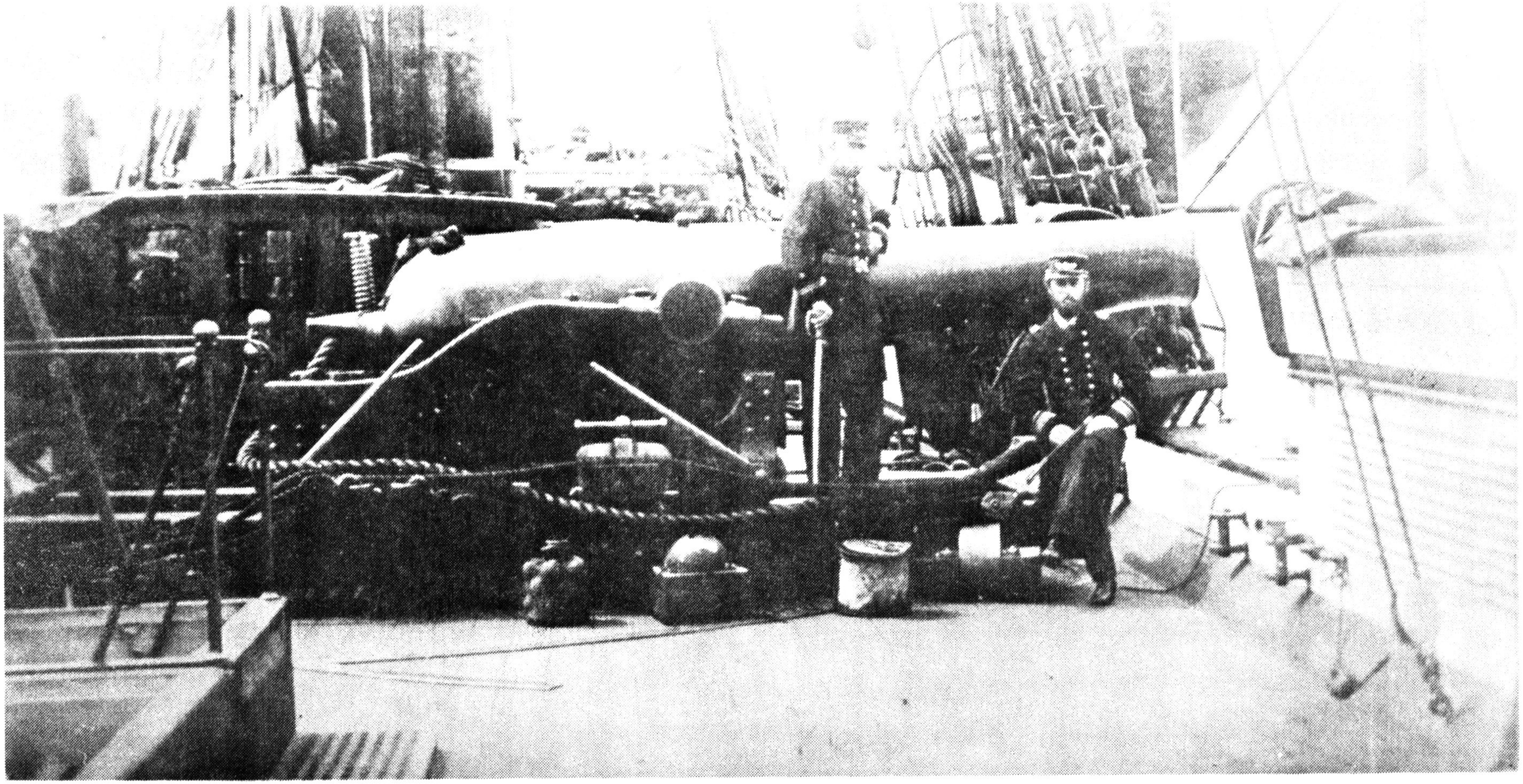
IX-INCH GUN ON MARSILLY CARRIAGE



SOURCE: Photo 111-B-2016, National Archives, Washington, D. C.

FIGURE 5

AFTER XI-INCH PIVOT GUN ON BOARD U.S.S KEARSARGE



SOURCE: National Historical Center Photo NH61671, Navy Yard, Washington, D. C.

FIGURE 6

DAHLGREN GUNS ACCEPTED BY THE NAVY
CAST BETWEEN 1855 AND 1860

Year	IX-inch	X-inch	XI-inch
1855	48	2	0
1856	55	13	10
1857	44	0	7
1858	81	2	0
1859	51	2	14
1860	18	0	3

SOURCE: "Register of Naval Guns," Vols. 2, 3, Entry 112, RG 74, NA.

FIGURE 7

DAHLGREN GUN DATA

Class	Length of bore (inches)	Maximum diameter (inches)	Weight (pounds)	Service charge (pounds)	Weight of shot (pounds)	Weight of shell (pounds)
XI-inch	132	72.2	16,000	15	170	130
X-inch	119.3	32	12,000	12.5	125	100
IX-inch	107	29.1	9,200	10	93	70

SOURCE: Alexander L. Holley, _A Treatise on Ordnance and Armor_ (New York: D. Van Nostrand, 1865), p. 120.

FIGURE 8

ORDNANCE OF SHIPS BUILT IN THE 1850s
(initial issue)

Vessel	Year authorized	Year ordnance issued	XI-inch	X-inch	IX-inch	32-pdr. of 57 cwt.	32-pdr. of 42 cwt.	8-in. of 63 cwt.
Merrimack	1854	1856		2	24			14
Wabash	1854	1856		2	24			14
Minnesota	1854	1857		1	26			14
Roanoke	1854	1857		2	24			14
Colorado	1854	1858		2	24			14
Niagara	1854	1860	12					
Pensacola	1857	*		1	22			
Lancaster	1857	1859	2		20			
Hartford	1857	1859			16			
Richmond	1857	1860			16			
Brooklyn	1857	1859		2	16			
Saginaw	1858	1859					1	
Mohican	1858	1859	2				4	
Iroquois	1858	1859	2				4	
Wyoming	1858	1859	2			4		
Dacotah	1858	1859	2				4	
Narragansett	1858	1859	1				4	
Seminole	1858	1860	1				4	
Pawnee	1858	*	4					

SOURCE: "Armament of Naval Vessels 1841-1863," Vols. 1, 2, Entry 111, RG 74, NA; Frank M. Bennett, *The Steam Navy of the United States* (Westport, CT: Greenwood Press, 1974), pp. 137-177.

*data missing.

ENDNOTES

[1] Dahlgren to DuPont, June 28, 1855, W9-7400, Henry Francis DuPont Collection of Winterthur Manuscripts, Eleutherian Mills Historical Library, Greenville, Delaware, hereinafter cited as DuPont Papers, Greenville, DE.

[2] George Sinclair to Dahlgren, January 23, 1856, Box 3, Dahl Gen Corres, LC.

[3] Dahlgren, *Shells and Shell Guns*, pp. 286-287.

[4] Dahlgren, "Penetration," 1851, Box 21, Dahl Nav Ord, LC.

[5] Draft of a letter from Dahlgren to T. Brooks, January 1851, Box 21, Dahl Nav Ord, LC.

[6] Dahlgren to Warrington, "Report to Bureau of Ordnance of Practice made with the Experimental Nine-Inch Shell Gun 1850," January 30, 1851, Box 21, Dahl Nav Ord, LC; Dahlgren, *Memoir*, pp. 150-151.

[7] *Annual Report of the Secretary of the Navy 1851*, S. Ex. Doc. 1, 32nd Cong., 1st Sess., serial 612, vol. 2, p. 9.

[8] Paolo E. Coletta, *American Secretaries of the Navy* (Annapolis: Naval Institute Press, 1980), p. 263; Dahlgren, *Memoir*, p. 152.

[9] Dahlgren, *Memoir*, pp. 157-158.

[10] Stanton to the Secretary of the Navy, August 7, 1852, Box 22, Dahl Nav Ord, LC; John Dahlgren, "Reorganization of the US Naval Ordnance No. 1," August 10, 1852, Box 22, Dahl Nav Ord, LC; Dahlgren, *Memoir*, pp. 157-159.

[11] John Dahlgren, "Reorganization of the US Naval Ordnance No. 1," August 10, 1852, Box 22, Dahl Nav Ord, LC.

[12] "Speech of Hon. F. P. Stanton of Tennessee, on Improvements in the Navy," August 17, 1852, Box 2, Dahl Gen Corres, LC; *Annual Report of the Secretary of the Navy 1852*, S. Ex. Doc. 1, 32nd Cong., 2nd Sess., serial 659, vol. 2; Dahlgren, *Memoir*, pp. 160-161; Simpson, *Ordnance*, p. 25.

[13] John Dahlgren, "Reorganization of the US Naval Ordnance (XI-in gun)," May 31, 1853, pp. 9-87, Entry 201, RG 74, NA.

[14] Dahlgren, *Shells and Shell Guns*, p. 24; Morris to John P. Kennedy, February 17, 1853, p. 275, Vol. 1, Entry 1, RG 74, NA; Morris to William Shubrick, February 24, 1853, pp. 276-277, Vol. 1, Entry 1,

RG 74, NA.

[15] Morris, "Remarks upon Lieut. Dahlgren's propositions for substituting heavier guns for the present armaments of our ships of war," May 30, 1853, pp. 309-315, Vol. 1, Entry 1, RG 74, NA; Dahlgren, *Memoir*, pp. 161-162.

[16] Morris, "Remarks upon Lieut. Dahlgren's propositions for substituting heavier guns for the present armaments of our ships of war," May 30, 1853, pp. 309-315, Vol. 1, Entry 1, RG 74, NA; Dahlgren, *Memoir*, pp. 161-162.

[17] Morris to Dobbin, August 31, 1853, p. 299, Vol. 1, Entry 1, RG 74, NA.

[18] Dahlgren to Dobbin, "Reorganization of the US Naval Ordnance, No. 3," December 9, 1853, Box 22, Dahl Nav Ord, LC, hereinafter cited as Dahlgren, "No. 3;" Peterson, *Father*, p. 36.

[19] Dahlgren, "No. 3;" Peterson, *Father*, p. 36.

[20] Dahlgren, "No. 3;" Peterson, *Father*, p. 36.

[21] Morris to the Secretary of the Navy, "Remarks upon Lieut. Dahlgren's propositions for substituting heavier guns for the present armament of our ships of war, transmitted by him December 9, 1853," December 19, 1853, pp. 315-319, Vol. 1, Entry 1, RG 74, NA.

[22] *Annual Report of the Secretary of the Navy 1853*, S. Ex. Doc. 1, 33rd Cong., 1st Sess., Serial 692, Vol. 3, p. 302.

[23] Frank M. Bennett, *The Steam Navy of the United States*, (Westport, CT: Greenwood Press, 1972), p. 138, hereinafter cited as Bennett, *Steam*.

[24] Peterson, *Father*, p. 38.

[25] Morris to Dobbin, January 30, 1854, p. 321, Vol. 1, Entry 1, RG 74, NA.

[26] John Dahlgren Diaries, May 12, 1854, Dahlgren Papers, Syracuse.

[27] *DAB* 6: 173; John Niven, *Gideon Welles, Lincoln's Secretary of the Navy* (New York: Oxford University Press, 1973), pp. 349-350; Bennett, *Steam*, pp. 145-151.

[28] Dahlgren to Morris, May 24, 1854, Box 22, Dahl Nav Ord, LC.

[29] Dahlgren to Morris, May 24, 1854, Box 22, Dahl Nav Ord, LC.

[30] John Dahlgren Diaries, July 8, 1854, July 11, 1854, July 29, 1854,

August 23, 1854, Box 1, Dahlgren Papers, Syracuse.

[31] Dahlgren, *Memoir*, p. 169.

[32] John Dahlgren Diaries, March 29, 1855, Box 2, Dahlgren Papers, Syracuse.

[33] John Dahlgren Diaries, April 9, 1855, Box 2, Dahlgren Papers, Syracuse.

[34] Peterson, *Father*, p. 40.

[35] Steers to Dahlgren, April 4, 1855, Box 1, Dahlgren Papers, Syracuse; John Dahlgren Diaries, April 9, 1855, Box 2, Dahlgren Papers, Syracuse.

[36] Morris and Lenthall to Dobbin, June 27, 1855, p. 383, Vol. 1, Entry 1, RG 74, NA.

[37] Morris to Dobbin, November 7, 1855, p. 385, Vol. 1, Entry 1, RG 74, NA.

[38] *Annual Report of the Secretary of the Navy 1855*, S. Ex. Doc. 1, 34th Cong., 1st Sess., serial 812, vol. 3.

[39] Drayton to Dahlgren, August 9, 1855, Box 1, Dahlgren Papers, Syracuse.

[40] Wise to Dahlgren, May 17, 1855, Box 1, Dahlgren Papers, Syracuse.

[41] Wade to Dahlgren, July 28, 1855, Box 1, Dahlgren Papers, Syracuse; *DAB* 3: 445-446; Drayton to Dahlgren, June 28, 1855, Box 1, Dahlgren Papers, Syracuse; Dahlgren to Morris, November 24, 1855, Box 3, Dahl Gen Corres, LC; *Annual Report of the Secretary of the Navy 1855*, S. Ex. Doc. 1, 34th Cong., 1st Sess., serial 812, vol. 3, p. 19.

[42] Smith to Dobbin, February 25, 1856, pp. 400-401, Vol. 1, Entry 1, RG 74, NA.

[43] John Dahlgren Diaries, February 26, 1856, Box 2, Dahlgren Papers, Syracuse; *DAB* 5: 164; Smith to Dobbin, January 26, 1856, p. 400, Vol. 1, Entry 1, RG 74, NA; Catesby Jones, "Report on the trial of the *Merrimack*'s Battery at Sea," March 24, 1856, Box 24, Dahl Nav Ord, LC. NOTE: The Marsilly carriage was a modified truck carriage usually used to mount the IX-inch gun. It differed from standard truck carriages in that its rear trucks, or wheels, were removed. The rear of the carriage rested on wooden pads that produced more friction than wheels to absorb the increased force of recoil from heavier guns. The wooden pads were sometimes sanded to produce even more friction. See Hogg, *Naval Gun*, p. 73.

[44] Dahlgren to Dobbin, April 25, 1856, Box 3, Dahl Gen Corres, LC.

[45] *Annual Report of the Secretary of the Navy 1856*, S. Ex. Doc. 5, 34th Cong., 3rd Sess., serial 876, vol. 3.

[46] *Annual Report of the Secretary of the Navy 1856*, S. Ex. Doc. 5, 34th Cong., 3rd Sess., serial 876, vol. 3.

[47] John Dahlgren Diaries, March 12, 1856, Box 2, Dahlgren Papers, Syracuse; Jones to Dahlgren, June 21, 1856, Box 140, Old Subject File "BG" 1844-62, RG 45, NA; Jones to Dahlgren, November 29, 1856, Box 140, Old Subject File "BG" 1844-62, RG 45, NA; Ingraham to DuPont, October 2, 1856, W9-8043, DuPont Papers, Greenville, DE; *Annual Report of the Secretary of the Navy* 1856, S. Ex. Doc. 5, 34th Cong., 3rd Sess., serial 876, vol. 3.

[48] *Annual Report of the Secretary of the Navy 1857*, S. Ex. Doc. 1, 35th Cong., 1st Sess., serial 812, vol. 3; "Naval Gunnery," *Times* (London), 25 December 1857, p. 4.

[49] *Annual Report of the Secretary of the Navy 1857*, S. Ex. Doc. 1, 35th Cong., 1st Sess., serial 812, vol. 3.

[50] Sinclair to Frederick Engle, January 5, 1857, Box 3, Dahl Gen Corres, LC; DuPont to Ingraham, September 16, 1857, W9-3267, DuPont Papers, Greenville, DE.

[51] R. B. Hitchcock to Ingraham, April 1, 1858, Box 3, Dahl Gen Corres, LC; Ingraham to DuPont, June, 1858, W9-8955, DuPont Papers, Greenville, DE; Ingraham to DuPont, July 8, 1858, W9-8977, DuPont Papers, Greenville, DE.

[52] Quoted in Paolo E. Coletta, *American Secretaries of the Navy*, (Annapolis: Naval Institute Press, 1980), p. 307.

[53] DuPont, "Description of U. S. S. *Minnesota*," 1859, W9-2084, DuPont Papers, Greenville, DE.

[54] P. A. Hunt to Toucey, April 12, 1859, Box 3, Dahl Gen Corres, LC; Dahlgren to Toucey, April 20, 1859, Box 4, Dahl Gen Corres, LC; Dahlgren to Ingraham, November 2, 1859, Box 25, Dahl Nav Ord, LC; Dahlgren, untitled summary of his career, 1862, Box 27, Dahl Nav Ord, LC.

[55] Simpson, *Ordnance*, p. 25; Dahlgren to Toucey, December 29, 1859, p. 478, Entry 1, Vol. 1, RG 74, NA; Ingraham to Toucey, April 4, 1860, p. 484, Entry 1, Vol. 1, RG 74, NA; *Annual Report of the Secretary of the Navy 1860*, S. Ex. Doc. 1, 36th Cong., 2nd Sess., serial 1080, Part 3.

[56] Holley, *Ordnance*, p. 333.

[57] Quoted in Holley, Ordnance, p. 188.

[58] Andrew Lambert, *Battleships in Transition* (Annapolis: Naval Institute Press, 1984), p. 92-93.

SUMMARY AND CONCLUSIONS

Dahlgren guns were the results of a synthesis of existing ideas rather than the products of innovation. Many of Dahlgren's ideas can be traced to Ben Robins, an Englishman who experimented with ordnance in the mid-eighteenth century. Robins proposed redistributing a gun's metal to areas where the strain from firing was greater. The resulting piece would throw a heavier projectile yet be safer to operate. He pointed out that a larger shot would have greater range and penetrating power. He knew that high muzzle velocities often reduced a gun's accuracy. To reduce muzzle velocity, he suggested using the smallest possible charge to fire a projectile. Dahlgren quoted Robins on this point. Robins' belief that accuracy could be increased by increasing projectile weight, not speed, was one of Dahlgren's major points.

Many ideas that Dahlgren incorporated into his ordnance system existed independantly in other ordnance systems. In the century following Robins' time, the breeches of British and American guns tended to be made thicker. The major powers had experimented with different types of ordnance since the first quarter of the nineteenth century. The British adopted and later phased out carronades that fired sixty-eight pound shot. The Americans phased out shot-firing 42-pounders, in favor of 32-pounders capable of firing both shot and shell. The latter guns were introduced to standardize the ammunition carried on board ships. Shell guns were in use in the English, French, and American navies before Dahlgren submitted his first design. Dahlgren was heavily influenced by Paixhans, the inventor of French shellguns.

The metallurgy of Dahlgren's guns was innovative. For most of the nineteenth century, United States naval officials and bureau chiefs chose cast iron to construct heavy ordnance because it was inexpensive. Unfortunately, it was not the best choice in terms of strength. The problem with cast iron was its inconsistancy. Ordnance experts did not know how to balance cast iron's properties to attain maximum strength in a gun nor did they know how to produce guns which performed predictably. They attempted to solve these problems using two different approaches: changing the casting technique and attempting to alter the metal's qualities before casting the gun. Changing the casting technique later proved to be the effective approach. Rodman's experiments with coring demonstrated that the casting technique employed had a profound effect on the properties that determined a metal's strength. Ordnance experts using the other approach tried to solve the problem of inconsistency in guns before casting them. They experimented with different types of cast iron to learn which properties of the metal had the most influence on a gun's strength. These experiments were unsuccessful because the experts involved lacked adequate chemical and metallurgical knowledge.

At first, Dahlgren pursued the latter approach. The densities of the first three Dahlgren guns were considered unusually high. Their long endurance, especially in the XI-inch gun's case, led Dahlgren to believe that higher density metals resulted in stronger guns. Both William Wade, one of the owners of the Fort Pitt foundry, and Robert P. Parrott, chief founder of the West Point foundry, argued that high density metal made poor guns. Wade pointed out that the first XI-inch gun rested sufficiently between its casting and extreme proof for the strain induced by the metal's contraction during cooling to diminish. His theory coincided with the results of the 1852 experiments that compared the performances of one year old and six year old guns, but Dahlgren appeared not to take the XI-inch gun's age into consideration. He favored casting guns out of high-density metal until such guns failed.

We know today that high-density cast iron in a thick-walled casting cools slowly. This causes the graphite flakes dispersed in the metal's silicon-iron matrix to lengthen. As flake length increases, the metal's modulus of elasticity, tensile strength, and hardness decrease. Gunmetal with a reduced modulus, tenacity, and hardness is better able to withstand the stress of firing. High-density cast-iron in a thin-walled casting cools quickly. This reduces flake length, thereby increasing the modulus, tensile strength, and hardness. The resulting metal is brittle and copes with the stress of firing poorly. The first three Dahlgren guns were cast nearly in their finished form, with their thick-walled breeches and thin-walled chases. These guns probably suffered from section effects, but endured because they were allowed sufficient time to rest before being fired. Section effects in a casting reduce its strength, but not significantly if the casting is not immediately subjected to strain.

The amount of contraction in a casting as it cools significantly affects its strength. High-density metal contracts more than low-density metal as it cools. The greater the contraction, the greater the strain on the casting. If sufficient time elapses before a casting is stressed, the strain produced by contraction diminishes. The Dahlgren guns first produced in Boston and Pittsburgh to fill the 1854 contract were probably not allowed sufficient time to rest before being fired. The metal used to cast these guns was extracted from the same mine. Its density was probably higher than the metal used in the Richmond and West Point guns. The strain induced by contraction during cooling coupled with section effects produced by casting the guns nearly in their finished shape, probably caused their failure.

Dahlgren's solution to the problem of exploding guns was changing the casting technique. Instead of casting guns nearly in their finished form, he tried casting them nearly in the form of a cylinder, then turning them to their proper dimensions. When the guns were cast in their soda-bottle shape, the differences in wall thickness between the breech and the chase were pronounced. When cast cylindrically, the differences between thick and thin wall sections were reduced. The resulting gun was more uniform with diminished section effects.

The cylindrical casting method also reduced the strain induced by contraction of the metal during cooling. When cooled from the exterior, the outer layers of metal in a gun naturally hardened first. The layers of metal in a Dahlgren gun's cross section cas be imagined as a set of concentric circles, much like a target with a bull's-eye. The outer layers of metal cooled more quickly than the inner layers and were therefore more brittle. When the first exterior layer of metal hardened, it contracted upon the next layer, forcing some of the liquid metal of the second layer in the direction of the sprue head. The second ring of metal then cooled with the majority of tis crystals aligned to compress on the third ring, but with some of the crystals aligned in the direction of the sprue head. Moving towards the center of the casting, as each successive ring of metal cooled a greater proportion of its crystals aligned in the direction of the sprue head. This is how strain was induced. The innermost rings of metal about the bull's-eye were strained the most. Additionally, the sprue head often hardened before the casting's center did. When the bull's-eye layer hardened and contracted, there was no liquid metal available in the sprue head to flow back into the casting. As a result, the density of the metal fell in the innermost rings and the whole casting therefore lacked uniform density. The denser outer rings induced the most strain because they cooled the fastest and shrank the most. When these rings were turned off to produce the soda-bottle shape, the greatest source of strain was thus removed. Since the outer rings were also more brittle, removing them resulted in a lower average modulus. As always, the weak bull's-eye core was removed. The resulting gun required less time for the strain induced by compression to diminish. Machining away the layers of metal with the highest and lowest densities produced a more uniform density in the whole piece. During the Civil War, coring was proven to be a more effective method than cylindrical casting and was adopted for the XI-inch model.

Ironically, Dahlgren's soda-bottle design probably caused more problems than it solved. The exaggerated breech was the design's salient feature. Bomford and Rodman demonstrated that the breech received the most strain when a gun was fired. The strain was less pronounced at other points along the barrel, diminishing as the projectile moved toward the muzzle. A Dahlgren gun's breech was made especially thick to cope with this extra strain. Unfortunately, the soda-bottle shape suffered from section effects and strain induced by unequal cooling of the metal due to significant differences between thick and thin cross sections. Adopting the cylinder casting method solved these problems.

The founding technique, not the design, was the key to the Dahlgren guns' strength. A gun can only bear an internal pressure per square inch equal to the tensile strength of a square inch of the metal, no matter how thick the wall is. Dahlgren was simply unaware that beyond a certain point, increasing the wall thickness does not increase the breech's strength. He hoped that if one of his guns did rupture, it would do so at the chase, not the breech. The whole idea behind thickening the breech was to provide an extra measure of safety for the crew, not to enhance the gun's performance. When the first XI-inch gun finally ruptured in 1855, it split into three pieces. The chase simply broke off and fell down while the left side of the breech overturned with the carriage. However, the right side of the breech flew ninety feet. Although it obviously was inconsistant with Dahlgren's expectations, neither he nor his critics ever brought up this point. Apparently, Dahlgren recorded the event in his diary but made no official report that the breech exploded in a manner that would potentially endanger a crew.

This instance is consistant with Dahlgren's pattern of rejecting experimental evidence that did not fit into his preconceived notions, about ordnance. Later in his life, he explained to his second wife that his designs were based on theories, not on experimental results. In his report on the test in which he compared the performance of the 64-pounder and the XI-inch shell gun, he admitted that he did not fire enough rounds to make firm conclusions. He made them anyway. Although both guns performed equally well, he believed that the 64-pounder's performance did not justify its weight. He admitted that a spar deck battery of 32-pounders and 8-inch shell guns had a higher rate of fire than a battery of XI-inch guns, but discounted this because he believed that future naval battles would take place at ranges where his guns were effective and others were not. Since XI-inch shells contained more powder than 32-pounder shells, he declared that their destructive power was greater. He performed no experiments to justify this assumption. In his "Reorganization of the US Naval Ordnance No. 2," he claimed that a battery of Dahlgren guns was more effective than a battery of 32-pounders and 8-inch shell guns. Again, this claim was not based on experimental results, but on mathematical calculations.

Part of Dahlgren's justification for his ordnance system was his belief that a battery of a small number of heavy guns was superior to a battery of a larger number of lighter guns. As a gun's projectile weight increased, he believed, its accuracy and power of penetration would increase. In an 1859 gunnery exercise, the Saratoga's battery of 32-pounders and 8-inch shell guns performed as well as the Brooklyn's battery of Dahlgren guns. Dahlgren simply explained that the Brooklyn's crew did not have adequate training. Morris had brought up the point that differences in crew training can negate the effects of heavy ordnance as a criticism of the Dahlgren guns.

Dahlgren often complained that he had to overcome an inordinate amount of opposition to convince the navy that his ideas were sound. Morris, one of Dahlgren's staunchest opponents, was at least willing to compromise on the issue of arming ships. Morris did not object to the IX-inch gun after Dahlgren demonstrated that its design was safe. He was never in favor of using the XI-inch gun, arguing that it was too heavy and its slide mount too bulky to be mounted on board ships. Additionally, he believed that the more guns a ship carried, the better its chances were of hitting its target. However, Morris agreed to introduce small numbers of X-inch pivot guns into the fleet as well as arming the Niagara with XI-inch guns to test their feasibility. Unsatisfied, Dahlgren continually claimed that this compromise was inadequate. On at least one occasion, he attempted to bypass Morris' objections by going over his head to the secretary of the navy. Morris often pointed out that Dahlgren guns suffered from slow rates of fire. Brushing this aside as unimportant, Dahlgren nevertheless countered with the results of an experiment in which he attained one round per minute with the XI-inch gun. This rate of fire was comparable with other classes of ordnance. However, Dahlgren only achieved this rate with two consecutive rounds during one test. In this and other cases, Morris simply wanted more experiments performed before he made any firm decisions about rearming ships.

Ironically, Morris' opposition was probably more beneficial than detrimental to Dahlgren's plans in some ways. The decision to arm the Merrimack, Wabash, Colorado, Niagara, Roanoke, and Minnesota with Dahlgren guns was based on the performance of three experimental pieces. When this decision was made, only the first IX-inch gun had been thoroughly tested and its design was more conventional than the others. Perhaps if Morris had supported Dahlgren, the first XI-inch gun may have been tested before sufficient time had elapsed for its high density metal to relieve itself of strain induced by compression during cooling. If Dahlgren were allowed to begin testing the XI-inch gun soon after its arrival at the Washington Navy Yard, it might have exploded within the first several firings. Such an event may have conceivably generated enough opposition to Dahlgren's ordnance that no further development would have occurred.

Many of Dahlgren's biographers attribute the longevity of his ordnance to its shape.[1] Although the first guns cast in Boston and Pittsburgh were rejected, most of those cast in Richmond and Cold Spring were accepted. The densities of the metal in the latter guns were probably lower. Additionally, many of these guns cast in 1855 were not distributed to the fleet until 1856 and 1857. This allowed at least as much time to elapse for the strain to diminish before ships' crews fired these guns as the first XI-inch gun had between casting and extreme proof.

Naval officers gave mixed reviews to the first Dahlgrens distributed to the fleet. Generally, officers whose ships were armed with them liked them while officers whose ships carried other ordnance were critical of them. The purpose of the Plymouth's 1857 cruise was to demonstrate to the critics that Dahlgren guns were indeed practical for shipboard use. With Dahlgren himself in command, they of course received a favorable report. As more officers became familiar with Dahlgren guns, negative criticism waned. Ships built in the late 1850s were for the most part armed with Dahlgrens, including the once controversial XI-inch gun.

Foreign naval officers praised the Dahlgren guns when they first appeared and later derided them. French and British officers visiting the Merrimack in Lisbon in 1856 expressed their approval. The Russians purchased two IX-inch guns that the United States Navy had rejected. By the end of the Civil War, foreign critics were downgrading the Dahlgren guns as newer rifled and breech-loading models appeared. European powers experimented with steel as a material for cannon in the decades following the Civil War, while, by comparison, American naval ordnance developement stood still.

Whether the Dahlgren guns were precursors of later naval guns or represented a dead end in the evolution of naval ordnance is debatable. They certainly reached the apex of firepower in the type of guns that navies had used for centuries: cast-iron, muzzle-loading smoothbores. The guns themselves were not revolutionary in design despite the advances in casting methodology which made them reliable. They were battle tested during the Civil War alongside many other types of ordnance built on different principles or designs to fill other needs. To effectively penetrate Confederate ironclads, the United States enlarged on Dahlgren's theme by adopting the XV-inch gun. European powers concentrated on developing guns of novel design and material: rifles, breech-loaders, and steel guns. Dahlgren's American contemporaries praised his guns' performances in battle, while several modern critics contend that they would have been inadequate against a European foe.

Dahlgren was certainly ahead of his time in his belief that warships armed with a few heavy guns were more powerful than those armed with many lighter guns, but the technology had not yet been developed to substantiate his opinion.

ENDNOTES

[1] Taylor Peck, Round-Shot to Rockets (Annapolis: United States Naval Institute, 1949), p. 106; DAB III: 30; Earle, "Dahlgren," p. 429.

BIBLIOGRAPHY

PRIMARY SOURCES

Manuscripts

Henry Francis DuPont Collection of Winterthur Manuscripts, Eleutherian Mills Historical Library, Greenville, Delaware.

J. A. B. Dahlgren Papers, Manuscript Division, Library of Congress, Washington, D. C.

J. A. B. Dahlgren Papers, Syracuse University Library, Syracuse, New York.

Letters Received by the Secretary of the Navy from Chiefs of Navy Bureaus 1842-1885, (Microcopy M518), Naval Records Collection of the Office of Naval Records and Library, Record Group 45, National Archives, Washington, D. C.

Letters Received from Chiefs of Naval Bureaus 1842-1859, Records of the Bureau of Ordnance, Record Group 74, Entry 17, National Archives, Washington, D. C.

Letters Received from Navy Yards and Stations, Records of the Bureau of Ordnance, Record Group 74, Entry 19, National Archives, Washington, D. C.

Letters Sent to the Secretary of the Navy and the Chiefs of Naval Bureaus, Records of the Bureau of Ordnance, Record Group 74, Entry 1, National Archives, Washington, D. C.

Record of Armament of Naval Vessels 1841-1903, Records of the Bureau of Ordnance, Record Group 74, Entry 111, National Archives, Washington, D. C.

Registers of Naval Guns 1842-1900, Records of the Bureau of Ordnance. Record Group 74, Entry 112, National Archives, Washington, D. C.

Reports of the Proof and Inspection of Cannon, Records of the Bureau of Ordnance, Record Group 74, Entry 35, National Archives, Washington, D. C.

Subject File "BG" — Ordnance, Guns, and Gunnery, Naval Records Collection of the Office of Naval Records and Library, Record Group 45, National Archives, Washington, D. C.

Printed Government Documents

Annual Report of the Secretary of the Navy, 1851, 32nd Congress, 1st Session, Senate Executive Document No. 1.

________________________, 1852, 32nd Congress, 2nd Session, Senate Executive Document No. 1.

________________________, 1853, 33rd Congress, 1st Session, Senate Executive Document No. 1.

________________________, 1854, 33rd Congress, 2nd Session, Senate Executive Document No. 1.

________________________, 1855, 34th Congress, 1st Session, Senate Executive Document No. 1.

________________________, 1856, 34th Congress, 3rd Session, Senate Executive Document No. 5.

________________________, 1857, 35th Congress, 1st Session, Senate Executive Document No. 1.

________________________, 1858, 35th Congress, 2nd Session, Senate Executive Document No. 1.

________________________, 1859, 36th Congress, 1st Session, Senate Executive Document No. 1.

________________________, 1860, 36th Congress, 2nd Session, Senate Executive Document No. 1.

United States Navy Department, *Ordnance Instructions for the United States Navy*. Washington: Government Printing Office, 1866.

Contemporary Books

Dahlgren, John A. *Shells and Shell Guns*. Philadelphia: King and Baird, 1856.

Dahlgren, Madeleine V. *Memoir of John A. Dahlgren*. Boston: James R. Osgood and Company, 1882.

Holley, Alexander Lyman. *A Treatise on Ordnance and Armor*. New York: D. Van Nostrand, 1865.

Johnson, Robert V. and Clarence G. Buel (eds). *Battles and Leaders of the Civil War*. 4 vols. New York: The Century Company, 1887-1888.

Simpson, Edward. *A Treatise on Ordnance and Naval Gunnery, Compiled and Arranged as a Textbook for the U. S. Naval Academy*. Second ed., New York: D. Van Nostrand, 1862.

Periodical Literature

"Casting Heavy Guns," Scientific American, 30 October 1858, p. 60.

"Strength of Guns and How to Cast Them," Scientific American, 15 November 1862, p. 307.

Newspapers

Times (London) 1857.

SECONDARY SOURCES

Books

Baxter, James Phinney, III. The Introduction of the Ironclad Warship. Cambridge: Harvard University Press, 1933.

Bennett, Frank M. The Steam Navy of the United States. Pittsburgh: Warren and Company, 1896.

Brodie, Bernard. Sea Power in the Machine Age. Princeton: Princeton University Press, 1941.

Brodie, Bernard and Fawn M. From Crossbow to H-Bomb. Bloomington: Indiana University Press, 1962.

Bruce, Robert V. Lincoln and the Tools of War. New York: The Bobbs-Merril Company, Inc., 1956.

Canfield, Eugene B. Civil War Naval Ordnance. Washington, D. C.: Government Printing Office, 1969.

Coletta, Paolo Enrico, ed. American Secretaries of the Navy. Annapolis: Naval Institute Press, 1980.

Cowburn, Philip. The Warship in History. New York: The Macmillan Company, 1965.

Dew, Charles B. Ironmaker to the Confederacy. New Haven: Yale University Press, 1966.

Ekey, D. C. and W. P. Winter. Introduction to Foundry Technology. New York: McGraw-Hill, 1958.

Gould, Dudley C., ed. Metalcasting Dictionary. Des Plaines, Illinois: American Foundrymen's Association, 1968.

Headley, J. T. Farragut and Our Naval Commanders. New York: E. B. Treat and Co., 1867.

Hogg, Ian and John Batchelor. Naval Gun. Poole, England: Blanford Press, 1978.

Johnson, Allen, ed. Dictionary of American Biography (10 vols). New York: Charles Scribner's Sons, 1959.

Lambert, Andrew. Battleships in Transition. Annapolis: Naval Institute Press, 1984.

Manchester, William. The Arms of Krupp 1587-1968. New York: Bantam Books, 1970.

Manucy, Albert. Artillery Through the Ages. Washington, D. C.: Government Printing Office, 1969.

Niven, John. Gideon Welles, Lincoln's Secretary of the Navy. New York: Oxford University Press, 1973.

Paullin, Charles Oscar. Paullin's History of Naval Administration, 1775-1911. Annapolis: United States Naval Institute, 1968.

Peterson, C. Stewart. Admiral John A. Dahlgren, Father of U. S. Naval Ordnance. Cynthiana, Kentucky: Hobson Book Press, 1945.

Peck, Taylor. Round-Shot to Rockets. Annapolis: United States Naval Institute, 1949.

Ripley, Warren. Artillery and Ammunition of the Civil War. New York: Van Nostrand Reinhold Co., 1970.

Robertson, Frederick Leslie. The Evolution of Naval Armament. London: Harold Storey and Sons, 1968.

Simpson, Bruce L. History of the Metal-casting Industry. Chicago: Edward Keogh Printing Co., 1969.

Walton, Charles F. and Timothy J. Opar, eds. Iron Castings Handbook. Iron Castings Society, Inc., 1981.

Articles

Bolander, Louis H. "The Introduction of Shells and Shell Guns in the United States Navy," Mariner's Mirror, XVII (April 1931), 105-112.

"The Bureau of Ordnance," United States Naval Institute Proceedings, LXXV (1949), 213-224.

Earle, Ralph. "John Adolphus Dahlgren," United States Naval Institute Proceedings, LI (1925), 424-436.

Unpublished Manuscripts

Glasow, Richard Dwight, "Prelude to a Naval Renaissance: Ordnance Innovation in the United States Navy During the 1870s." Unpublished Ph.D. Dissertation, University of Delaware, 1978.

Gutierrez, Joseph A. Jr., "Confederate Naval Ordnance, 1861-1865." Unpublished M.A. Thesis, East Carolina University, 1977.