

CHANGES TO UNITED STATES NAVY SUBMARINE DESIGN
AND CONSTRUCTION DURING WORLD WAR I, AS
DETERMINED BY THE GENERAL BOARD

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degree

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Military History

by

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ABSTRACT

CHANGES TO UNITED STATES NAVY SUBMARINE DESIGN AND CONSTRUCTION DURING WORLD WAR I, AS DETERMINED BY THE GENERAL BOARD, by LCDR David R. Yocum, 83 pages.

Prior to World War I, the United States envisioned employing submarines in a defensive role for coastal and harbor defense. Submarines' defensive role was based on the current state of U.S. submarine technology making long range open ocean operations difficult. Germany's introduction of unrestricted submarine warfare forced the U.S. Navy to reevaluate the design of its submarines to develop an offensive deep ocean (blue water) capability. The work for redesigning submarines, while carried out by contractors, was initiated by the actions of the General Board of the Navy, the primary military advisory committee to the Secretary of the Navy for all matters concerning naval operations, war plans, and responsibility for determining requirements for naval ships. As the primary driver for change, the Board evaluated current designs against evolving requirements to determine the best course for future design development. The Boards' official transcripts provide detailed information regarding the considerations affecting changes to designs made during the war to understand the changes implemented.

Much academic work has been devoted to the development of submarines during the interwar period, however, very little is available regarding changes initiated during the war. This study addresses the question of what changes came about during the war and the final state of submarine construction and design at the end of the war with the goal of providing historical context regarding development of naval technology and influence of operational doctrine that led to significant innovation during the interwar period.

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ACRONYMS

ASW	Anti-Submarine Warfare
CARL	Combined Arms Research Library
CNO	Chief of Naval Operations
SONAR	Sound Navigation and Ranging

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CHAPTER 1

INTRODUCTION

Background

Prior to World War I, the U.S. Navy did not view the submarine as an offensive weapon. The Secretary of the Navy, Josephus Daniels, as late as June of 1915, still believed that submarines were best utilized for harbor defense.¹ The usage of the submarine as an offensive weapon by the German Navy during the war caused the U.S. Navy to reevaluate its future use of the submarine. The subsequent reevaluation of the potential uses for submarines and their designs was driven by this new way of looking at the capabilities and advantages of a submarine platform. This re-evaluation led to significant changes in submarine design, construction, and use during the interwar period. The primary agent for determining changes to ship construction and design was the influential General Board of the Navy. Under the direction of Admiral of the Navy George Dewey and his successors, the Board oversaw the effort to understand the novel ways Germany employed the submarine and the best ways to counter this new usage, to say nothing of its use as part of a sea going battle fleet. It also oversaw the efforts to change the U.S. Navy submarine design and construction.

Prevailing beliefs about submarine usage in war leading up to World War I led the United States to adopt a much less offensive design and employment concept for submarines. The concept of naval power at the time was inextricably linked to battleships and the ideas of Captain A. T. Mahan. Many leaders within the Navy failed to recognize

¹ Josephus Daniels, *The Cabinet Diaries of Josephus Daniels, 1913-1921*, ed. David Cronon (Lincoln: University of Nebraska Press, 1963), 101.

that a naval war could occur entirely without full fleet engagement and thus require the novel use of lesser known and used vessels within a naval arsenal.

Serving as a submarine officer for the last ten years and as an enlisted submariner the previous six, I have been onboard three U.S. submarines during major construction and modernization periods. While an enlisted Engineering Laboratory Technician onboard the USS *Ohio* (SSGN-726), I experienced the beginning of the SSGN conversion process. After commissioning and follow on training I served onboard USS *Texas* (SSN-775) for the completion of her Post Shakedown Availability as well as the subsequent modernization of her sonar, fire control and navigation systems. I served most recently as the Combat Systems Officer onboard USS *Seawolf* (SSN-21) where I completed two Northern Atlantic deployments and oversaw the commencement of her Engineering Department Selected Restricted Availability and modernization of her sonar, fire control, and navigation systems. My interest in this topic stems from my great grandfather, Job Melvin Yocum, having served on the submarine *L-3* during World War I and my desire to learn more about the influence that war had on subsequent submarine design and construction.

Research Questions

This study will examine the changes to U.S. Navy submarine design and construction in response to the German use of submarines during World War I. The primary research question asks: what changes to submarine design and construction were implemented or considered by the Board during World War I? It also explores and searches for the specific driving factors of change for the U.S. Navy in submarine design and construction from 1914 to 1918. The primary research question drove the

development of several secondary research questions: (1) what specifically was determined to be the factors of change to the U.S. Navy submarine design and construction; (2) what changes to submarine design and construction were mandated by the Board during World War I; (3) who were the primary proponents for changes to submarine design and construction within the Board; (4) what inputs for conceptual design changes were considered by the Board; and (5) what does the existing literature say about the primary question?

Limitations and Delimitations

This thesis is limited to primary source material from the Combined Arms Research Library (CARL) and the National Archives as available online, via email contacts, or Dr. Kuehn's collection of archival material will be used for this study. The study assumes that little to no travel money or time will be available to conduct the research. The serials of the Board were inaccessible; therefore the research was limited to the hearings of the Board. This study will be delimited to U.S. submarine construction and design changes brought about by World War I. The study will look at documents from 1914 to 1918 as well as published studies tangent and pertinent to the topic.

Significance

With the increased challenges posed to today's naval forces by Chinese and Russian government Anti Access and Area Denial programs, it can be seen how submarine design and construction remains as important today as when Germany began its unrestricted submarine warfare campaign in World War I. Significant challenges drive changes in tactics and technology resulting in shifts in how submarines will be used in

the future and likewise, changes in how a submarine is used will result in further changes to design and technology.

Literature Review

Much literature exists that discusses the tactical use of submarines and the official Navy position regarding submarines prior to and during World War I. Secondary sources regarding changes to design during World War I have very little information but provided context and background information about the changes to usage during the war that led to changes in design and construction. Primary source and archival information is more detailed regarding submarine design and changes considered during the war.

The archived records of the Board were the largest information source for this study. Transcripts of the Board hearings provide detailed information about submarine design considerations evaluated during World War I and describe actions taken by the Board.

The research also included several other published primary sources. The autobiography of Rear Admiral Bradley A. Fisk, *From Midshipman to Rear-Admiral*, and biography of Rear Admiral Stephen B. Luce by Rear Admiral Albert Gleaves, *Life and Letters of Rear Admiral Stephen B. Luce*, provided the thoughts of senior U.S. Navy officers on the eve of World War I regarding U.S. submarine usage and Germany's use of unrestricted submarine warfare. *The Cabinet Diaries of Josephus Daniels 1913-1921*, Secretary of the Navy during the Wilson administration, provided the viewpoints of the cabinet and the Wilson administration regarding the submarine threat as well as interactions between the Secretary of the Navy and the Board. All of these sources

provided valuable insight into the political influences on the Board and submarine design in general.

Several secondary literature sources were also extremely informative. The book by Norman Friedman, *Submarine Design and Development* (1984), provided an overview of submarine development leading up to World War I as well as a brief analysis of submarine usage by the German, British, and U.S. navies during the war. Friedman's book, however, focuses primarily on the interwar period and is largely silent on any changes considered during World War I itself. George Baer's book, *One Hundred Years of Sea Power* (1994), provided a good analysis of the political situation in the U.S. leading up to and during World War I. His analysis provided much needed context to understand the influences on the Navy in preparation for and execution of the war. Eberhard Rossler's book, *The U-boat: The Evolution and Technical History of German Submarines*, translated by Harold Erenberg (1975), provided a detailed look at U-Boat development both prior to and during the war. Rossler's book allowed for a comparison of U.S. and British intelligence estimates discussed in the Board's records and provided relevant background to the tactics employed by Germany during the war.

Brian Bond's *Britain's Two World Wars Against Germany, Myth, Memory and the Distortions of Hindsight*, (2014) provided details of the effect of the German U-Boat campaigns on Great Britain. Tim Benbow's review of Gautama Makunda's, *We Cannot Go On: Disruptive Innovation and the First World War Royal Navy* (2010), provided background about the failure of the Royal Navy to counter the U-Boat threat to merchant shipping. The most useful secondary source used for this study was Gary E. Weir's book *Building American Submarines, 1914-1940* (1991). Weir's analysis of the processes in

place for submarine construction and design in the period just prior to World War I and discussion of the factors influencing design during the war were extremely useful. Specifically, his work identified the contractor led research and development process used during this time that resulted in submarines that were technologically inferior to the German U-Boats employed during the war. The article “Josephus Daniels and the U.S. Navy’s Shipbuilding Program During World War I” (1996), by William Williams provided additional background on the driving factors behind the Navy’s overall construction program.

Research Design

There was sufficient literature on submarines during World War I, however, much of it was limited to the tactical adaptation required by the allied navies to overcome Germany’s use of unrestricted submarine warfare. This study focuses on those sources that provided background information regarding German and U.S. submarine design and construction and the tactical considerations that drove change. Additionally, the shift in U.S. interests leading to more control of the design and constructions of submarines by the Board will be evaluated to include the factors that led to this shift. Finally, the tactical and design changes that resulted during World War I will be researched.

The transcripts of the Board starting in 1917 were available at the CARL. Dr. Kuehn also provided scanned copies of various correspondence of the Board. These documents were all used to determine what changes the Board directed for submarine design and construction from 1914 to 1918.

The specific characteristics of submarine design that were addressed by the Board directly and those that were evaluated by industry will be researched. The considerations

leading to the Board assuming more power in the design and construction of submarines will also be researched to determine what factors led to increased Navy involvement in control of submarine design.

Primary sources, primarily the microfilm *Proceedings and Hearings of the General Board* at CARL will be used to determine what changes were made to submarine construction and design as a result of World War I. Contemporary journals such as the U.S. Naval Institute *Proceedings* may also be used to assess the attitudes of naval officers of the periods. Dr. Kuehn has made some Board studies material available as well. Several additional primary sources, specifically the Cabinet Diaries of Josephus Daniels will be used to determine inputs to the Board regarding submarine construction and design change requirements.

This thesis consists of five chapters. Chapter 1 reviewed the thesis purpose, scope, research questions, and literature review. Chapter 2 is an evaluation of German submarine development, both technological advances and tactical usage, prior to and during the war. Chapter 3 evaluates the tactical use of the submarine by Great Britain and the United States and the approach taken by both nations to counter the U-Boat. Additionally, chapter 3 will assess the influence the technological advances and changing tactics had on the Board during the war. Chapter 4 will be a review of the hearings of the Board, regarding submarine design and construction changes considered or implemented during World War I. Chapter 5 will be a summary and conclusion of influences on and changes to U.S. submarine design and construction and a discussion of areas requiring further study.

CHAPTER 2

GERMAN SUBMARINE DEVELOPMENT AND EMPLOYMENT

The German employment of the U-Boat during World War I developed as a means to counter the British blockade of Germany and the inability of the German Navy's High Seas Fleet to counter the Royal Navy's Grand Fleet at sea. Germany conducted two separate unrestricted submarine warfare periods during the war. The first campaign began on 4 February 1915 with the German declaration of the submarine campaign and the warning that neutral shipping was at risk due to the "difficulties of clear identification."² This first campaign was ultimately abandoned due to fears that it would draw the United States into the war. Following the Battle of Jutland on 31 May 1916, the German fleet did not sail again as a consolidated fleet for the remainder of the war. Therefore, to counter the British threat, Germany turned to the submarine as the best way to continue to fight the blockade of their ports and the second campaign began on 9 January 1917 after the Kaiser issued a new declaration of unrestricted submarine warfare. The interception of a letter sent by Germany to Mexico asking them to declare war against the United States, the infamous Zimmerman note, and the resumption of unrestricted warfare drove the United States to finally join the war on 6 April 1917.³

German submarine experimentation prior to the war, starting in 1904, resulted in the older paraffin burning engines being replaced by the more powerful and reliable

² Daniels, 29 June 1915, 97 (notes).

³ Eberhard Rossler, *The U-boat: The Evolution and Technical History of German Submarines*, trans. Harold Erenbert (Annapolis, MD: Naval Institute Press, 1975), 75.

diesel engines in U-Boat designs by the end of 1910.⁴ This change resulted in several significant improvements. First it allowed for a significantly increased range over the paraffin engines and second it burned much cleaner in that it did not produce the thick white smoke associated with burning paraffin. It was through the introduction of the diesel engine that the true capability of the U-Boats as a commerce raider was finally recognized. A noted German historian, Eberhard Rossler wrote, “It was the diesel engine that changed the role of the German U-Boat from a defensive to an offensive one and made possible its successful application in a war of blockade.”⁵ The extended range afforded by the new diesel engine allowed U-Boats to attack British shipping not only in the English Channel but to expand into the western approaches to the British Isles. The recognition of the possibilities provided by this increased range, combined with the inability of the German fleet to directly challenge the British at sea, led to the primary influence of the U-Boat during the remainder of the war as a *Guerre de Course* weapon. According to Rossler, “Tirpitz had placed little trust in U-boats, but as the war progressed he had become strongly convinced of their indispensable role.”⁶

With the ability to send a U-Boat not just into the channel but to be able to send them to the west of Ireland allowed the Germans to hazard British shipping commencing a *Guerre de Course* that eventually challenged the British control of the sea despite the lack of further decisive surface battles. The British estimated that there were up to five submarines going through the English Channel each day and this presented a serious

⁴ Rossler, 25-28.

⁵ Ibid., 31.

⁶ Ibid., 53.

challenge to the Royal Navy.⁷ As was stated by the Board, the U-Boats were destroying shipping at a rate of 500,000 tons each month. With such a high rate of loss, the Board thought it would take until October 1918 to generate the ship building capacity required to exceed the loss rate. In effect as the Board noted “The German nation is basing its hope of victory on the success of the submarine.”⁸ The British had been attempting to control the U-Boat problem by using a patrol system to locate and destroy the German submarines. Commander Taussig discussed the failure of the patrol system to limit U-Boat sinking of British shipping, and how in the two weeks prior to his ship’s arrival, the British had lost 95 ships.⁹ This is discussed further in chapter 3. This type of success by the U-Boats against allied shipping was routine until the convoy system was adopted.

Several tactical features of German U-Boat employment were identified by British and subsequently American naval intelligence. It was noted that German commanders were very navigation conscious and routinely fixed their position. The U-Boats were also known to submerge when they sighted a destroyer. It was also identified that the Allied mining operations were having an effect since the U-Boats were now having to go “around the tip of Jutland” to get around the channel and that the German Navy was increasing the use of mine sweepers to clear a path for their U-Boats to get to

⁷ *Proceedings and Hearings of the General Board of the US Navy, 1900-1950*, vol. 1-2, 14 August-31 December 1918, Archival Information Record Group 80, Combined Arms Research Library, Fort Leavenworth, KS, (microfilm), 137. Hereafter referred to as PHGB.

⁸ PHGB, 1917, 420.

⁹ *Ibid.*, 686.

sea.¹⁰ In order to press an attack, it was assumed the U-Boat had to surface to be able to fire a torpedo. While executing an attack the U-Boat was vulnerable to counter-attack and therefore submerged once it had been fired upon.¹¹ The need for rapid diving procedures developed during the war as the British began to target the U-Boats with aircraft. It was noted by Lieutenant Commander Davis of the Royal Naval Air Service that “Some of the submarines take 2-1/2 minutes to submerge” and that “In that time we could cover about four miles.”¹² This suggests the importance of stealth for a submarine and highlighting the necessity to be submerged during daylight to prevent being spotted by an aircraft. The British Navy was able to take advantage of this information and were successful in using the destroyers they did have to control the U-Boat threat against the Grand Fleet but the Royal Navy’s efforts had little impact on the losses to shipping. The stark contrast between the response to one and the lack thereof with the other has been explained by Tim Benbow’s review of Gautam Makunda’s theory of disruptive innovation. They explain the effects of disruptive innovation on an organization in relation to its primary mission and secondary missions. “Those impacting the company’s primary mission, or ‘sustaining innovations,’ tend to be coped with highly effectively but those affecting secondary missions can be overlooked.”¹³ Makunda uses this disruptive innovation concept to explain why the Royal Navy was able to successfully counter the U-Boat

¹⁰ PHGB, 1917, 457.

¹¹ Ibid., 690.

¹² Ibid., 678.

¹³ Tim Benbow, “We Cannot Go On: Disruptive Innovation and the First World War Royal Navy,” *Security Studies* 19, no. 1 (January 2010): 124-159

threat to the Grand Fleet but failed to adapt to the German use of the U-Boat against merchant shipping.

One additional consideration that significantly aided the German Navy in employing the new diesel U-Boats was the establishment of naval bases in Belgium. By moving the submarines forward, they were able to take advantage of the new technology and mass-produce many smaller U-Boats to use from the forward bases. German construction of the UB-classes began in late 1914 with the intentions of building a U-Boat that was rail portable to facilitate a rapid deployment to forward ports for assembly and use. Based on the constraints of a rail portable U-Boat, the final UB design was roughly 125 tons with a 60-horsepower diesel and a 120-horsepower motor with a battery that provided ten hours at four knots and allow for a maximum speed of 5.5 knots submerged and a 1,600-mile surface range. Similarly, the UC was built to be a rail portable U-Boat based on a UB-class design modified to carry 12 mines.¹⁴ British intelligence assessed that UB and UC-class boats were being employed from Ostend and Zeebrugge on the Belgian coast. The use of Ostend and Zeebrugge required a long surface transit of between fifteen and twenty miles during which time the U-Boats were more vulnerable.¹⁵

Following the initial success of the UB and UC-class U-Boats, Germany developed slightly larger designs of both classes during 1915. Both new classes were no longer rail portable but had significantly improved endurance ranges based on a larger displacement allowing more storage space for fuel. Several incidents including the

¹⁴ Rossler, 40-41.

¹⁵ PHGB, 1917, 457.

sinking of the *Lusitania* in 1915 resulted in Germany shifting its strategy from unrestricted submarine warfare to keep the United States from entering the war. The shift in policy, along with the realization that the war would last much longer than anticipated, led Germany to focus on the UCII-class minelaying submarine.¹⁶

The introduction of smaller German submarines had significant impacts on the Board during its deliberations regarding the future U.S. submarine design. The utility of the smaller German submarines was that Germany could produce a significant number of submarines to replace wartime losses that larger submarines did not allow. The Board's assessment of the U-boat endurance as of 19 October 1917 was stated by the former Commander-in-Chief of the Atlantic Fleet, Admiral Albert Winterhalter: "I find that the UC boats starting from UC-16 have 6,000 miles radius. The UB starting with 18 to UB-65 have 4500 miles. The U-boat radius starting with U-19 is 4250 miles and runs to 10,000 miles. There don't seem to be any diminution of the submarine menace as far as going through the North Sea [sic] is concerned."¹⁷ Despite not having the full range of the fleet submarines, these smaller U-Boats based forward allowed the Germans to continue to hold Great Britain's maritime shipping at risk and hinder Britain's war efforts on the continent.

¹⁶ Rossler, 52-53.

¹⁷ PHGB, 1917, 497.



Figure 1. U-117 with U.S. Sailor following Turnover to Allied Forces after the War

Source: From author's personal collection.

Another significant use for the German U-Boats was found in laying minefields in vicinity of the entrances to British harbors. Starting early in 1915, Germany began planning for their UE-class that was to be between 600 and 700 tons and provide dry

storage for 34 mines.¹⁸ According to Mr. C. E. Eveleth, who was working on the listening technology and had just come back from Europe, “The fact is that they are placing mines at the mouths of practically every important harbor on the British Coast.”¹⁹ The successful employment of these mine-laying submarines forced the British to significantly increase the number of mine sweepers and patrol vessels.²⁰ This effort was extended to include mining operations off the coast of the United States later in the war with the introduction of a larger minelaying U-Boat. U-117 was the first of the larger mine laying U-Boats and with a displacement of 1,164 tons she was more than twice as large as the UCIII-class and with a range of 12,500 nautical miles could reach the United States.²¹ The U-117 had a devastating impact off the New England coastline in August of 1918. During her attacks along the coast from Cape Hatteras to Long Island, she sank five vessels directly, four by mines and damaged one additional ship with a mine. During her return transit, she sank an additional five vessels.²²

Lieutenant M. R. Pierce testified about the estimated status of German U-Boat construction during his hearing with the Board on 9 October 1917. Pierce described how the Germans had three different types of submarines and that as of the end of March they had built 130 U-Boats. The U-Boats were believed to be a double hull boat of

¹⁸ Rossler, 45.

¹⁹ PHGB, 1918, 137.

²⁰ Ibid., 1917, 418.

²¹ Rossler, 332.

²² Gary E. Weir, *Building American Submarines, 1914-1940* (Washington, DC: Naval Historical Center, Department of the Navy, 1991), 10.

approximately 700 tons.²³ This type was the current Ms-class that the Germans had estimated in 1915 that they needed at least 48 of to execute the blockade of Great Britain. Germany had slightly reduced the tonnage to be 600-650 tons thereby making production faster to make up for wartime losses. Germany ordered 11 additional Ms-class on 16 June 1915 to expand its offensive capability. The new modified Ms-class was designed with four bow torpedo tubes and two stern tubes and had a sharper bow to cut through the submarine nets. The senior member of the Board, Admiral Charles Badger, mentioned during the 4 December 1917 hearing on anti-submarine warfare that it had been assessed the Germans were using a 5.9-inch gun on their newer U-Boats.²⁴ This intelligence turned out to be accurate since a 15-centimeter gun was mounted on the Large Ms U-Boat, the Large Minelaying U-Boat and two 15-centimeter guns were mounted on the U-cruisers.²⁵ The cessation of unrestricted submarine warfare by the autumn of 1915 shifted the focus from this type to the smaller UBII and UCII type.²⁶ The innovations implemented on these new U-Boats proved extremely effective in an offensive campaign but they had to wait until the resumption of unrestricted submarine warfare in 1917 to be fully realized.

German innovations during this time were by no means limited to offensive capability. Mr. E. S. Land, the naval constructor, a future vice admiral and Chief of the Bureau of Construction and repair, described to the Board how German atmospheric

²³ PHGB, 1917, 353.

²⁴ Ibid., 691.

²⁵ Rossler, 331-332.

²⁶ Ibid., 48-50.

control equipment was very similar to the American design but that their “Draeger apparatus” used potassium hydroxide vice the soda lime the U.S. device used. It was not assessed to be superior to the U.S. soda lime and there was thought that the Germans might even be shifting to the soda lime due to shortage of potash caused by explosives production.²⁷

Land laid out for the Board on 14 April 1918 the current estimate of the relative size of the UB-Boats. Table 1 is taken from his hearing before the Board.

Table 1. UB-class Size Estimates

Class I	No. 1 to 17	125 tons
Class II	No. 18 to 47	250 tons
Class III	No. 48 to 72	700 tons
Class III	No. 72 to 100 and upwards	At least 700 tons and probably 800, as their length is[sic] 213 feet and they more nearly approach the double hull sea-going U-Boat.

Source: Created by author using data from *Proceedings and Hearings of the General Board of the US Navy, 1900-1950*, vol. 1-2, 14 August-31 December 1918, Archival Information Record Group 80, Combined Arms Research Library, Fort Leavenworth, KS, (microfilm), 539.

As can be seen by comparing the above table with the actual displacements of the UB-classes the intelligence estimates were remarkably accurate with regard to Class I and Class II however they began to diverge beginning with Class III. The actual displacements are in table 2.

²⁷ PHGB, 1917, 650.

Table 2. UB-class Size Actual

Class I	No. 1 to 17	127 tons
Class II	No. 18 to 47	263 tons
Class III	No. 48 to 72	516 tons
Class III	No. 72 to 100 and upwards	516 tons

Source: Created by author using data from Eberhard Rossler, *The U-boat: The Evolution and Technical History of German Submarines*, trans. Harold Erenbert (Annapolis, MD: Naval Institute Press, 1975), 332.

The shift away from unrestricted submarine warfare brought with it a shift to the slightly larger UBII-class starting in mid-1915. It was recognized that the UBI was inadequate with regard to range, battery, armament, periscopes, and communication masts. This brought about the UBII which incorporated all the desired improvements including the addition of another periscope and communication mast, and a 5-centimeter gun. Similarly, the UCII was upgraded to improve its capabilities. These upgrades resulted in the loss of rail portability but did produce much more capable U-Boats.²⁸ As early as January 1916, the German Naval Staff recognized the need for more U-Boats to carry out a continued blockade, *Guerre de Course*, of Great Britain. The staff sent a memorandum to the Kaiser laying out the overall naval plan including the reduction of Great Britain's economy as a means to end the war. Specifically, the memo called for a significant increase in the number of available U-Boats, calling for a U-Boat fleet of 209 "ocean-going U-boats" and 60 "small U-boats" just to carry out western operations in vicinity of Great Britain and the North Sea. The numbers increased significantly when

²⁸ Rossler, 50.

adding in desired U-Boat operations in the Baltic and Mediterranean to 270 “ocean-going U-boats,” 96 “small U-boats,” 74 “ocean going mine-laying U-boats” and 43 “small mine-laying U-boats.” The shift in thinking clearly indicates a focus on larger U-Boats at a time when Great Britain and the United States were looking towards smaller submarines based on the emergence of the smaller UB, UBII, UC and UCII-classes. The memorandum also discusses the possibility of using the larger extended range U-Boats to carry out attacks off the coast of the United States.²⁹

The German Navy began work on the new larger U-Boats in 1917 with the introduction of large mine-laying submarines and the U-cruisers and continued with plans to replace the Ms U-Boats with large Ms U-Boats. However, this did not signal the end of the smaller U-Boats with an order for 24 of the new UBIII-class to be produced in 1917 as well.³⁰

Despite the technological advantage held by German submarines over their British and American counterparts the U-Boat campaign was doomed to failure. With the advent of the convoy system the U-Boats were subject to attack and destruction by convoy escorts. The result was that despite the ability to roughly keep up initially with material losses, the reduction in trained submariners proved to be devastating to the U-Boat efforts in the long term. Commander Rowcliff attributed this lack of experience and training for the significant increase in U-Boats losses. 23 U-Boats were validated sunk from the beginning of 1918 through 15 April and with 9 already sunk in the first two

²⁹ Rossler, 63-65.

³⁰ Ibid., 66.

weeks of April the loss rate was rapidly increasing.³¹ Germany simply could not keep up the high level of training for the remaining crews and many crews were taken from the surface fleet that was sitting stagnant in port. The overall reduction in experience led to rising losses of both U-Boats and crews and the ultimate failure of the *Guerre de Course* effort.

³¹ PHGB, 1918, 691.

CHAPTER 3

U.S. SUBMARINE EMPLOYMENT

The way submarines were employed by both sides during World War I could not have been anticipated prior to the commencement of hostilities. This chapter will explore the way submarines had been thought of prior to the war and the evolution of U.S. and British tactical employment during the war for the employment of submarines and the means to counter the German U-Boat threat.

Prior to World War I, the United States had employed submarines exclusively as a defensive weapon. Officers considered submarines best for coastal and harbor defense and they were kept close to their homeport.³² One noted naval historians wrote, “Faced with the prospect of some Japanese attempt to seize the Philippines, the United States very early deployed its own submarines to the Far East, on just this theory.”³³ Secretary of the Navy, Josephus Daniels, even made an entry in his diary after meeting with Admiral Benson, the newly created Chief of Naval Operations (CNO), about “How to fortify Guam?” and that “Submarines may be better.”³⁴ The tendency to keep the submarines close to port was due to several considerations. First, the technological development of submarine propulsion at the time precluded operations at significant distances from homeports and “submarines were just too slow to catch fast ships, even

³² Weir, 5.

³³ Norman Friedman, *Submarine Design and Development* (London, UK: Conway Maritime Press, 1984), 28.

³⁴ Daniels, 29 June 1915, 101.

when they were surfaced.”³⁵ The historical usage had been for attacking enemy craft only when they threatened U.S. ports. These considerations combined to relegate the submarine to a defensive role early in the war. Despite being employed in a defensive role, the utility of submarines was beginning to be understood. The Aid for Operations, Admiral Bradley A. Fiske, wrote a report to Secretary of the Navy, Josephus Daniels dated 13 May 1913. Fiske described that if the fleet were required to blockade Japan he thought the submarine in conjunction with mines and torpedoes constituted the greatest threat to the Navy.³⁶ Fisk continued to recognize the threat posed by the submarine and attributed the sinking of the *Bulwark*, a British battleship, on 14 November 1914 to the work of a submarine.³⁷ Fiske’s diary entries in early February 1915 indicate that he was beginning to be aware of the increasing threat of the U-Boat, not just to the Royal Navy but also to merchant shipping.³⁸ Despite Fiske’s notable insight, few shared his assessment of the threat.

On the eve of war in 1913, it was inconceivable to U.S. naval officers that they would confront an enemy of such a vastly different nature than what had been prepared for. The thought of using a submarine to establish control of the sea was unthinkable. Using the U.S. Navy to transport troops and protect convoys instead of fighting the

³⁵ Friedman, 36.

³⁶ Bradley A. Fiske, Letter dated 13 May 1913, in Joseph Daniels, *The Cabinet Diaries of Josephus Daniels, 1913-1921*, ed. David Cronon (Lincoln: University of Nebraska Press, 1963), 57.

³⁷ Bradley A. Fiske, *From Midshipman to Rear-Admiral* (New York: The Century Co., 1919), 562.

³⁸ *Ibid.*, 573.

German fleet had not even been considered as the primary employment of the Navy.³⁹ In a letter to Admiral Luce from Captain Beehler, Beehler noted that the German Navy and the Emperor in particular, had been impressed with the work of Mahan and believed that “Our (Germany’s) future is on the Sea.”⁴⁰ With all indications that Germany was building her Navy along similar lines to the United States, any future war with Germany was expected be a decisive fleet action. The war at sea that was to come took many by surprise.

In 1915, the U.S. Navy still “discounted, by doctrine and experience, the importance of building, or even emphasizing, submarines.”⁴¹ To be fair, the Navy at the time did not believe it would be involved in the current war, rather it was concerned with a future war with Germany if they came out the victor. Wilson’s neutrality policy had made the Navy focus on defending the mainland and the full offensive capability of the submarine had not been realized. There was a push by the administration to increase the number of submarines in the U.S. fleet yet the focus remained on defensive use. In 1916 as the United States began to look towards preparedness, the Naval Act of 1916 resulted in “67 submarines (9 for the fleet and 58 for the coast).”⁴² The remainder of the Naval Act focused on capital ships following traditional Mahanian ideas of sea control. Jutland appeared to reinforce the belief that battleships and decisive naval action remained the

³⁹ George W. Baer, *One Hundred Years of Sea Power The U.S. Navy, 1890-1990* (Stanford, CA: Stanford University Press, 1994), 53.

⁴⁰ Albert Gleaves, *Life and Letters of Rear Admiral Stephen B. Luce, Founder of the Naval War College* (New York: The Knickerbocker Press, 1925), 302.

⁴¹ Baer, 61.

⁴² *Ibid.*, 60.

focus of naval warfare.⁴³ There was still a preponderant view that the submarine was best used as a coastal defense tool. The United States at the time still did not have an appreciation for the effects of the unrestricted warfare on Great Britain. Great Britain had not been forthcoming with the United States about the U-Boat threat and just how effective they were being in attacking British shipping. Therefore, as 1917 approached, the United States was still firmly attached to its reliance on capital ships and “the doctrine of offensive sea control by capital ships reigned.”⁴⁴

With America entering the war, the submarine situation off the British coast began to be understood by the United States. The Admiralty had been less than honest with the United States about the severity of the problem and the Navy was taken by surprise on receiving word from Admiral Sims in London regarding the severity of the threat facing Britain. As of October 1917, the Germans were inflicting a loss of 500,000 tons each month making the submarine the gravest threat to the Allies.⁴⁵ The supply ships the Germans had been destroying were taking an enormous toll on the war effort.⁴⁶ “Britain herself had become dangerously vulnerable to economic warfare. Whereas during the Napoleonic Wars she had been largely self-sufficient in food, by 1924 she imported four-fifths of her wheat, two-thirds of her bacon and all of her sugar from

⁴³ Baer, 60.

⁴⁴ Ibid., 54.

⁴⁵ PHGB, 1917, 420.

⁴⁶ Baer, 67.

abroad.”⁴⁷ The reliance on the import of food combined with Germany’s resumption of unrestricted attacks on shipping led Great Britain to the brink of starvation by 1917. It was estimated by October 1917 that Great Britain only had five months of flour and France only had one and a half months.⁴⁸ The *Guerre de Course*, being indiscriminate also impacted fuel. Secretary of the Navy, Josephus Daniels noted in his diary that “Lord Northcliffe called & had a special telegram from Lloyd George: ‘Must have 200,000 tons of oil Situation most serious and lack of tonnage required to bring oil fuel here from US threatens to lead to the immobilization of the Fleet’.”⁴⁹ German submarines posed a grave threat to Great Britain’s ability to remain in the war. A means to counter the German submarine threat had to be found to keep Britain in the war. Commander W. S. Pye described for the Board in October how the convoy system was employed to minimize the chances of German submarines finding an unprotected isolated merchant and reduce the sinking of commercial shipping.⁵⁰ By concentrating the merchants together with anti-submarine warfare (ASW) escorts, the United States and Britain significantly reduced the amount of shipping lost. Convoy operations were understood to be necessary with the knowledge that they would not be decisive for victory but could keep the war effort alive.⁵¹ The early implementation of the convoy system involved the protection of loaded

⁴⁷ Brian Bond, *Britain’s Two World Wars Against Germany: Myth, Memory and the Distortions of Hindsight* (Cambridge, UK: Cambridge University Press, 2014), 90.

⁴⁸ Daniels, 11 October 1917, 219.

⁴⁹ *Ibid.*, 2 July 1917, 171.

⁵⁰ PHGB, 1917, 418.

⁵¹ *Ibid.*, 421.

ships inbound to Great Britain. Commander A. W. Taussig mentioned that he had been told by Captain Long that the majority, 75 percent of vessels sunk, were sunk while loaded but that shortly after implementing the convoy of inbound vessels the U-Boats shifted to attacking the empty vessels outbound from Great Britain. Taussig told the Board, “It then became necessary to adopt the convoy system for out bound vessels also.”⁵²



Figure 2. Electricians Mate Job Melvin Yocum on the Bridge of the L-3

Source: From author's personal collection.

⁵² PHGB, 1917, 687.

During the war, the United States began to utilize submarines at more remote locations, stationing several classes out of Ireland, and in a more offensive manner. Boats of the K, L, O, and E-class were used for these early attempts at offensive ASW operations off the coast of Ireland and in the Azores.⁵³ Specifications for these classes are included in table 3.

Table 3. Specifications for E, K, L, and O-class Submarines

	E-Class	K-Class	L-Class	O-Class
Displacement	287	392 surf 521 subm	450 surf 548 subm	520.6 surf 629 subm
Length	135'3"	153'7"	167'5"	172'4"
Beam	14'7"	16'8"	17'5"	18'
Draft	11'7"	13'1"	13'7"	14'5"
Speed	14kts	14kts surf 10.5kts subm	14kts surf 10.5kts subm	14kts surf 10.5kts subm
Complement	20	28	28	29
Armament	4-18" TT	4-18" TT	1-3" 4-18" TT	1-3" 4-18" TT
	TT: Torpedo Tube 3": 3 in Deck Gun			

Source: Created by author using data from Naval History and Heritage Command, "Dictionary of American Naval Fighting Ships—Index," US Navy, accessed 10 April 2017, <https://www.history.navy.mil/research/histories/ship-histories/danfs.html>.

⁵³ Carroll S. Alden, "American Submarine Operations in the War," *Proceedings* 46, no. 6 (June 1920): 811-850 and *Proceedings* 46, no. 7 (July 1920): 1013-1048, in Gary E. Weir, *Building American Submarines 1914-1940* (Washington, DC: Naval Historical Center Department of the Navy, 1991), 11.

Submarines were predominately used to protect the western approaches to the British Isles. This approach began to show the limitations of U.S. design since current U.S. submarines were not capable of maintaining open ocean operations for sufficient time to employ offensive tactics.⁵⁴ Despite submarines' inability to routinely operate at extended distances from their support bases they eventually became the greatest weapon against the U-Boat.⁵⁵ Pierce, having just returned from England where he had gone on a patrol with the British E-34 patrolling Heligoland Bight and the North Sea, commented to the Board on 9 October 1917 that, "During the last few months the British have come to the decision that submarines are one of the most important method for fighting German submarines."⁵⁶ Pierce went on to describe how the submarines operated in designated sectors and if they located a German submarine they submerged and then approached to within torpedo range to carry out an attack. Pierce gave the Board the cases of British submarines sinking German U-Boats which, as of 1 August 1917, had amounted to eleven all executed with a torpedo attack. Winterhalter felt that the submarine contributions to the ASW effort was not very significant. Pierce explained how the number of U-Boats sunk by submarines was rapidly increasing as there had been three each in 1915 and 1916 and already five in the first half of 1917 and that they were now averaging one sinking a month since the start of the submarine patrols. The sinking of

⁵⁴ Weir, 11.

⁵⁵ Baer, 77.

⁵⁶ PHGB, 1917, 343-344.

two in the month prior to Pierce returning home amounted to half of the total for the month.⁵⁷

At home a more conventional approach was used. “Submarines of the N and O-classes, as well as some of the E boats, patrolled American coasts and harbors following a defensive strategy.”⁵⁸ The specifications for the E, N and O-classes is included in table 4. It was found during the war that there were other uses for which submarines were better suited than surface ships. A submarine could provide covert scouting. In areas where a surface ship was unable to operate without being attacked a submarine could avoid detection and gather valuable information.⁵⁹

Table 4. Specifications for E, N, and O-class Submarines

	E-Class	N-Class	O-Class
Displacement	287	348 surf 414 subm	520.6 surf 629 subm
Length	135’3”	147’3”	172’4”
Beam	14’7”	15’9”	18’
Draft	11’7”	12’6”	14’5”
Speed	14kts	13kts surf 11kts subm	14kts surf 10.5kts subm
Complement	20	25	29
Armament	4-18” TT	4-18” TT	1-3” 4-18” TT
TT: Torpedo Tube 3”: 3 in Deck Gun			

Source: Created by author using data from Naval History and Heritage Command, “Dictionary of American Naval Fighting Ships—Index,” US Navy, accessed 10 April 2017, <https://www.history.navy.mil/research/histories/ship-histories/danfs.html>.

⁵⁷ PHGB, 1917, 363-364.

⁵⁸ Weir, 9.

⁵⁹ Friedman, 36.

Several tactical considerations came to the fore during the war that changed the way submariners operated their ships. First was a recognition that stealth was the only true means of defense available to the submarine and that extended diving times unacceptably risked forfeiting this advantage. “During World War I it became common practice to operate with the Kingstons open, so that the main tanks were partly full, and flooded completely as soon as the vents above were opened.”⁶⁰ Kingstons were the valves on the bottom of the submarine that kept water from entering the main ballast tanks. In order to flood the main ballast tanks both the kingstons and the upper vents had to be open. By operating on the surface with the vents shut and the kingstons open the main ballast tanks became partly filled with water thereby reducing the time to complete flooding and speeding the diving process. Second was the need to be able to maneuver for a prolonged period of time submerged in order to evade enemy ASW forces. In order to facilitate the ability to evade submerged for an extended amount of time it became a necessary to maintain the batteries at a high state of charge. “Wartime memoirs show almost an obsession with preserving the charge in the batteries, which was the only guarantee of a submarine’s underwater mobility.”⁶¹ Another consideration that Badger asked Pierce about was the employment of a “fan arrangement” to fire multiple torpedoes at intervals to increase the likelihood of achieving a hit. Pierce explained that he felt it would help and with multiple bow tubes it was possible but that it required a lot of effort to “set each tube differently.”⁶²

⁶⁰ Friedman, 119.

⁶¹ Ibid.

⁶² PHGB, 1917, 366.

The largest advances in tactics and naval warfare technology were centered around countering the German submarine force. It was recognized that the Germans had a relative superiority in their submarine design, in particular it was noted that their optics were significantly ahead of both the British and U.S. designs. This relative advantage was articulated by Pye when he said that the Germans “undoubtedly sink more British boats than are lost by themselves.”⁶³ The result was that multiple means had to be incorporated to counter the U-Boat threat. The convoy system, while arguably the most effective means of countering the threat, was only one piece of the overall strategy the Board developed. Most of the means to counter the threat were centered around the desire to commence an offensive campaign against the U-Boats. The president had expressed to Secretary Daniels his desire to start an offensive against the submarines and his frustration that the British had not also adopted the convoy system.⁶⁴ Based on the president’s desires, the Board was extremely interested in getting some sort of an offensive started using any available means. The use of sea-planes, destroyers, submarine chasers, and even submarines were all discussed. The Board experienced a significant amount of frustration at the U.S. Navy’s inability to rapidly commence offensive operations against the U-Boat threat. The Board felt the British were being extremely hesitant to commence any sort of offensive operations and as the Americans began to take a more active part in the war at sea it became clear that much of the current anti-submarine technology required either additional infrastructure to support operations or changes to ships’ systems and tactics to be effective.

⁶³ PHGB, 1917, 419.

⁶⁴ Daniels, 3 July 1917, 172.

There was a growing desire to use aircraft for locating and cueing in surface vessels to execute an attack or to carry out a limited attack of their own. CDR E. J. King, future fleet admiral and CNO during World War II, currently serving on the staff of the Commander-in-Chief Atlantic Fleet, explained how the air platforms had been used to form what he referred to as “hunting-groups” which were being used to locate U-Boats. Several of the new air platforms could make better use of the new listening technology than surface ships by employing it from kite balloons to remove the background noise associated with employment from a surface ship.⁶⁵ Lieutenant Commander F.R.E. Davis of the Royal Naval Air Service described combined air and destroyer operations to counter the submarine. After an aircraft or blimp had sighted a submarine it called in a destroyer and continued to follow the submarine until the destroyer arrived to carry out an attack.⁶⁶ Davis also described how British aircraft had been working with submarine patrols to locate submarines and that the aircraft themselves were carrying out attacks against the U-Boats with 100-pound bombs.⁶⁷ However, in the case of the sea-planes, the lack of facilities and the shortage of planes and pilots precluded the rapid commencement of an aerial offensive.

Similarly, destroyer’s maneuvering characteristics were found wanting, precluding them from being truly effective against submarines in close combat. Due to the shortcomings of destroyers, the Board spent many hearings discussing the expansion of the submarine chaser program and the rapid development of the listening technology

⁶⁵ PHGB, 1917, 457.

⁶⁶ Ibid., 678, 684-685.

⁶⁷ Ibid., 684.

as a means to carry out the desired offensive campaign against the submarine.

Commander Submarine Force, Captain S. S. Robison, described his recommendation to start a new chaser program to build 250 new chasers and how the submarine force felt that with 250 they could make a good impact on the problem.⁶⁸ Timing of the offensive was another concern and Pye explained to the Board during his testimony on 16 October 1917 that the timing was not right for an offensive in the fall or winter and that the spring to summer of 1918 would be more conducive to commencing offensive operations. It was his recommendation that the efforts be focused on the “defense of commerce” and “the preparation for offensive operations” the following year.⁶⁹ King described what he had observed while overseas was primarily defensive in nature. King detailed how there were “in the vicinity of two thousand vessels engaged in patrol and escort work. All on account of submarines.”⁷⁰

In addition to the desired offensive campaign to counter the U-Boats, the British had been looking at mines as another possible way to address the problem. Pierce, having just returned from England discussed how the Admiralty felt that mining could “stop the submarines” if they were able to procure enough mines.⁷¹ Additionally, King explained how the Admiralty had “filled up the Heligoland Bight with mines” in the past few months. Despite the mining in Heligoland Bight, the only effect the British believed they

⁶⁸ PHGB, 1917, 599.

⁶⁹ *Ibid.*, 420.

⁷⁰ *Ibid.*, 456.

⁷¹ *Ibid.*, 356.

had was to force the Germans to exit by going through “neutral territorial waters.”⁷²

During further discussion with the Board on 19 October 1917, Pye explained that during the winter months even the mine barrage was ineffective against the U-Boats because of the inability to patrol it sufficiently due to the weather.⁷³ This made even a mine offensive during the winter difficult at best. Captain F. H. Schofield, later to become a member of the Board and ultimately Commander-in-Chief Battle Force, told the Board that in his opinion the mining efforts were best used to close the Straits of Dover.

Schofield felt that closing the Straights of Dover would result in a significant reduction in the sinking of merchant shipping. Schofield further explained a means of using mines to attack a submarine after being found in an offensive manner. He felt that a limited minefield had a better chance of destroying a submarine than a depth charge since the depth charge had to explode in close proximity to the submarine.⁷⁴

King explained how the British records showed that submarines were responsible for destroying more U-Boats than any other type of ASW. This was most likely due to the fact that the British were diverting most of their destroyers for convoy work and only those not engaged in convoy were assisting the submarines in countering the U-Boats.⁷⁵ Based on the success of British submarines in the anti-submarine effort against the U-

⁷² PHGB 1917, 456.

⁷³ *Ibid.*, 485.

⁷⁴ *Ibid.*, 510.

⁷⁵ *Ibid.*, 456.

Boats, Land submitted an estimate of the situation detailing the reasons “To place all effective American submarines in the war zone at the earliest possible date.”⁷⁶

As the war progressed, the United States became proficient in submarine operations, given the limitations of submarines at the time. Initial forays into offensive operations, while initially limited, paved the way for interwar submarine design and tactical development resulting in extremely successful submarine operations during World War II. As the technology continued to progress, the tactics evolved to take advantage of the new technology to improve submarine operations as well as the methods used to counter them. One of the most significant discoveries of the war was the use of a convoy system to protect shipping against submarine operations.

Many changes occurred during the war regarding the way a submarine should fit into a nation’s naval strategy. The rising influence of the submarine could no longer be ignored and the future development and importance of the submarine to naval campaigns was just beginning to be understood. Ultimately, it was the changes in tactics facilitated by technological development that led to a continuing refinement of submarine employment and tactics. Chapter 4 will discuss the specifics of technological development and the resulting changes to submarine design and construction in the United States during the War.

In the end, the submarine played a part in the anti-submarine campaign; however the technology employed by the Allies during the war prevented them from having as dramatic an impact as they did during World War II. The German use of the submarine did solidify the importance and the utility of the submarine in the psyche of the U.S.

⁷⁶ PHGB, 1917, 654.

Navy. Significant efforts were subsequently implemented to improve the U.S. design and tactics to take advantage of the new technology based on lessons learned from the war and reverse engineering of captured U-Boats.⁷⁷ The next chapter will look at the specific design considerations that evolved during the war and their influence on the design of both the S-class and T-class submarines.

⁷⁷ Weir, 31-34.

CHAPTER 4

EVOLUTION OF SUBMARINE DESIGN, 1916-1918

During the early stages of World War I, the Board's discussions regarding submarine design centered on matching characteristics identified from German U-Boats. The Board hearings were conducted in a question and answer format where Board members asked questions of military and civilian experts to gather information about various topics. Hearings were held on topics from the use of technology and tactics the United States and Great Britain were employing at the time to changes being implemented by both Allied nations and Germany. The Board used these hearings to shape naval policy and develop design characteristics for future classes of ships. The Board of World War I was composed of the most senior officers in the Navy and as such had tremendous influence in the policy and fleet design of the Navy. The newly established CNO did not have the power to implement change in the way the Board could. The Board's discussions about submarines were largely concerned with the indications that Germany was working towards building much larger and more capable fleet submarines. The Board was also extremely interested in the development of British submarine designs since they had been engaged in ASW against Germany for more than two years.

To allow for ease of discussion, this chapter will look at submarine characteristics individually to identify what the Board was considering early in the war compared to final specifications enacted later in the war. By topic this chapter will evaluate the following characteristics: size, type of propulsion, endurance regarding size and type of motor and battery, speed, maximum submergence depth, hull characteristics regarding

survivability and serviceability, primary armament, secondary armament, sensor systems to include periscopes and detection systems, signal systems, navigation equipment, and habitability systems. From this analysis this chapter will also describe the final specifications established by the Board.

Size Considerations

Commander D. F. Boyd, having just returned from Europe, spoke with the Board on 8 September 1917 regarding his experiences with British and French submarine forces. Boyd had commanded a *Bushnell* submarine tender prior to the war and therefore was a highly trusted officer due to the high profile status required for selection as commanding officer of the newest submarine tender.⁷⁸ Boyd discussed the classes of submarines the British and French were currently using and his recommendations for the updated design of U.S. submarines. Much of his discussion was centered around the size of boats being employed by the British and what their plans were for submarines best suited to the antisubmarine effort. Boyd discussed how the British were moving away from larger fleet submarines towards smaller 400-ton submarines. His advice to the Board was “If the situation is such that a large number of submarines is needed and reliability was sought and that the Department was unwilling to try out any new device I should say a large number of small submarines of about the H-type of the British and our own would be advisable.”⁷⁹ During this hearing, Winterhalter made a statement indicating a general lack of understanding regarding the current state of U.S. submarine

⁷⁸ Don McGrogan, “USS *Bushnell*,” NavSource Naval History, accessed 15 February 2017, <http://www.navsource.org/archives/09/36/3602.htm>.

⁷⁹ PHGB, 1917, 178.

design when he said, “We should be able to duplicate here anything abroad in submarines.”⁸⁰ While at the time, the United States had a detailed understanding of British and French submarine design, little information was available to the Americans regarding German submarines.

Boyd’s recommendation for the smaller submarine came with another recommendation, that they should be used for coastal defense or submarine patrol. Where he began to depart from the common wisdom at the time was that he thought that they could also be employed for “distant service it having been proved by experience that they are able to keep the seas.”⁸¹ The British were building an H-Class boat similar to the US L-Class and the Germans were building a 350-ton mine-layer.⁸² Boyd also brought to the Board’s attention the ability of the submarine to conduct ASW. One naval officer, LT Varley, had recommended pursuing the smaller submarine design and continuing with the H-class but he was ultimately discredited due to the discovery that he had been influenced by Electric Boat to recommend the smaller boats.⁸³ The contractor viewed the smaller submarines as more cost effective and they would not have to spend additional capital on research and development.

One of the driving factors for the Board considering a larger submarine had to do with habitability. The shift to an 800-ton boat was being considered in order to improve

⁸⁰ PHGB, 1917, 178.

⁸¹ Ibid., 179.

⁸² Ibid., 188.

⁸³ Ibid., 1918, 541.

habitability.⁸⁴ A larger submarine allowed for more room for atmospheric control equipment to ensure the air quality was sufficient to allow the crew to keep the submarine at sea for longer periods of time. A compromise had to be reached that could afford the smallest size possible while meeting the desire for improved habitability.

In looking at size, the comparison was drawn to the existing L, O, and R-class submarines. The L-class with a submerged displacement of 527 tons, and the O and R-classes being 50 and 100 tons heavier respectively.⁸⁵ The general trend had been towards a larger boat that improved habitability and allowed for ease of access to make final adjustments on torpedoes prior to time of fire. The adjustment was necessary to improve accuracy and likelihood of a successful hit.

Propulsion Systems

At the onset of war, the U.S. Congress wanted the Navy to build a 25-knot submarine. The only way a submarine could reach 25 knots was by using a steam propulsion system since diesel engines were not capable of generating the required horsepower. The British had built a steam submarine, the K-class that was purported to achieve 25 knots however the design had some serious drawbacks. In using a steam propulsion system, the residual heat had to be accounted for and such a system required a means to dispose of the excess heat after submerging or a lengthy cool down time was required prior to submerging. After looking at the possibility of a U.S. steam submarine and identifying how the British were employing the K-class it was determined that a

⁸⁴ PHGB, 1917, 371.

⁸⁵ Ibid., 377.

steam model was incompatible with the design considerations for U.S. submarines. A true steam submarine did not come into existence until the age of nuclear power in the 1950s.

The M-1 employed a cross-head type two-cycle diesel engine that Pierce thought were the best available. Pierce had just returned from England where he had gone on patrol with the E-34 in Heligoland Bight and the North Sea. The engine being considered for the new design was a New London Ship and Engine Company (Nelesco) 4-cycle diesel. Nelesco was a subsidiary of Electric Boat, one of the two primary contractors for building U.S. submarines and had been building diesels for Electric Boat since the F-class.⁸⁶ Despite setbacks caused by storage battery problems, Pierce informed the Board on 9 October 1917 that the M-1 would be ready by “The 15th of next month.”⁸⁷

A link between the engines and detection ranges with the newly developed listening devices like the C tube and the Mason apparatus was identified during the hearing on 13 November 1917. Captain R. H. Leigh, discussed how the G-1 could effectively avoid detection by running its engines at a lower revolution than the other submarines. Even though the G-1 was only able to maintain this reduced engine speed for eight minutes it did allow her to avoid detection during the reduced speed run.⁸⁸ The difficulty with maintaining such a slow speed as Leigh described is that the lack of speed makes depth control more difficult. As Leigh put it when Badger asked about the speed

⁸⁶ Weir, 9, 119.

⁸⁷ PHGB, 1917, 359.

⁸⁸ Ibid., 532.

34 revolutions would get for the G-1 “So slow she would have to come to the top or go to the bottom after eight minutes.”⁸⁹

Endurance

During the hearing on 6 September 1917, Winterhalter mentioned, “According to the German accounts they are building what they call cruisers of 2,400 tons with two motors of 150 millimeters and these are building at the Krupp works and two were launched last February.”⁹⁰ These new U-cruisers were expected to have significant improvements in endurance over the previous U-Boats. The focus of this hearing was to establish the new submerged endurance requirement for U.S. submarines. Badger wanted to set the requirements at nine knots for two hours and five knots for 20 hours during the hearing on 6 September 1917.⁹¹ The desire was to achieve a submerged endurance of 100 nautical miles on a single charge resulting in the five knot for 20-hour requirement. The 100 nautical miles gave a submarine the ability to spend sufficient time submerged to avoid detection and if necessary open range from a counterattack. It had been identified by LCDR J. O. Fisher that the battery proposed was insufficient to support the combined requirements and that “Five knots for 20 hours would require four times as large a battery. That is, roughly. With nine knots maximum we can get about five knots for four hours.”⁹² Fisher identified for the Board how the combination of the battery and the

⁸⁹ PHGB, 1917, 587.

⁹⁰ Ibid., 134.

⁹¹ Ibid., 111.

⁹² Ibid., 135.

motor determined a submarine's endurance. The motor had to be sized according to the maximum speed desired which when put in combination with a given battery capacity at a given discharge rate determined the number of hours a submarine could travel at a given speed. An additional consideration regarding the size of the motor was its impact on charging time of the batteries when on the surface. "You have a motor for 9 knots and a battery for 5 knots for 20 hours. It will only deliver current at a certain rate. The current that motor will give as a generator will not be sufficient to charge that battery in the minimum time. You might have to take 10 or 12 hours. That is a decided disadvantage."⁹³ Having to spend 10 to 12 hours recharging the batteries meant that a submarine was forced to spend an inordinate amount of time in a vulnerable condition because a submarine charging its batteries on the surface is much more vulnerable to detection and subsequent prosecution. In the event a submarine was forced to submerge prior to having fully charged the battery the submerged endurance was reduced accordingly with the available charge on the battery. Winterhalter properly identified that "If we concede all you say and take the enormous increase of battery we will be building the submarine for the battery. We have got to sacrifice. We are forced to this conclusion that we could not provide a battery big enough without building a submarine for the battery."⁹⁴ In further discussions attempting to reduce the size of the battery it was considered to lower the minimum speed to 1.5 knots to achieve a higher endurance. Badger identified the problem with this when he said "From all I have heard three knots is the lowest speed which we can consider reasonably for controlling the boat. 1-1/2 is

⁹³ PHGB, 1917, 132.

⁹⁴ Ibid., 139.

not enough.”⁹⁵ This is a simple matter of speed being required to provide enough lifting force to allow a submarine to overcome negative buoyancy produced from an improper trim. If a boat is too heavy, then speed is required for the submarine moving through the water at an up angle in combination with the bow planes and stern planes to produce sufficient lift to compensate for the weight to keep the boat at a given depth. During hearings on 11 October 1917 with Land and 21 December 1917 with Mr. Goodall the endurance requirements were ultimately set to 20 hours at five knots and maximum speed for one hour.⁹⁶

It must also be recognized that diesel fuel storage and engine performance are only one component of endurance. The second component of endurance is human endurance. Sufficient stores must be brought onboard to feed and care for the crew. On 11 October 1917, the discussion question of provisions and stores arose. The original specification of 30 days came into question. It was not felt that 30 days was achievable on a smaller boat, Winterhalter and Land both felt that 30 days was too long for the type of assignments expected for the new class. Land told the Board “There is no use trying to bluff ourselves. They don’t get it.”⁹⁷ Robison met with the Board on 15 November 1917 and described how the K-boats were only able to stay at sea for 12 days due to food and water storage. The inability to carry sufficient supplies added credence for building the slightly larger 800-ton boats as a means to increase the human endurance.

⁹⁵ PHGB, 1917, 140.

⁹⁶ Ibid., 381, 751.

⁹⁷ Ibid., 384.

Speed and Depth Considerations

Winterhalter identified on 5 September 1917 during a hearing with Naval Constructor Stocker that U.S. Congress had set a speed requirement of 25 knots. Stocker informed the Board that 25 knots was unachievable with a diesel engine.⁹⁸ The only way to achieve speeds that high was to use steam turbine propulsion. The downside of a steam propulsion system being residual heat delaying submarine diving time to allow for cooling down the boiler. Additionally, a steam propulsion system could do nothing to improve submerged speed performance of a submarine which is only dependent on the size of the motor and the battery. During Boyd's meeting with the Board on 8 September 1917, the Board was interested in the speed specification of British submarines and what Boyd thought was best for the U.S. designs. Boyd, consistent with previous testimony by Chief of the Bureau of Construction and Repair, Admiral D. W. Taylor, on 6 September 1917, thought a maximum submerged speed of nine knots would suffice.⁹⁹ Discussion arose on 11 October 1917 regarding a higher submerged speed of 15 knots in order to allow a submarine to press an attack submerged. Land felt that 15 knots might be possible with only one propeller and modifications to the lines but that the idea should be referred to Steam Engineering to evaluate it further, however when further pressed by Badger he identified that in a larger boat he did not believe the speed was achievable.¹⁰⁰ Pierce described how British submariners were increasing their submerged depth at periscope depth to achieve higher speeds. The ability of a submarine to operate at higher speed at a

⁹⁸ PHGB, 1917, 102.

⁹⁹ Ibid., 106, 187.

¹⁰⁰ Ibid., 379.

deeper submergence depth, especially at periscope depth, is because as a submarine proceeds deeper it is less affected by wave action and has an increased pressure on the propeller due to the deeper depth. For a given depth in water, the weight of the water above it increases the pressure felt on all exterior surfaces of a submarine. The combined effect being that as the submarine is then capable of a higher speed than at the shallower depth. Pierce explained how British submarines were shifting to a 30-foot periscope instead of a 25-foot periscope to take advantage of this concept. In conjunction with the longer periscope, British submarines were also shifting to a larger periscope shear in order to support the periscope.¹⁰¹ The shear was a means of supporting the barrel of the periscope to prevent the barrel from being damaged by higher submerged speeds. This is the precursor to the modern fairing used to support a periscope barrel. The final determination from all the discussions on 11 October 1917 came down to a submerged speed of nine knots for a fleet submarine and a motor able to take the current at a one-hour discharge rate.¹⁰²

During Robison's discussions with the Board on 15 November 1917, Winterhalter identified that the British were considering 15 knots submerged speed for an offensive submarine. Robison pointed out that while 15 knots submerged is achievable over a short period it is not sustainable for longer ones. This again points to the relationship between speed and battery capacity. The submergence depth was considered during a hearing with Taylor on 9 September 1917 and based on the welding and framing technology for submarines at the time was limited to 150-foot test depth with a factor of safety of 200

¹⁰¹ PHGB, 1917, 379.

¹⁰² Ibid., 384.

feet.¹⁰³ The depth specification was confirmed during the hearing with Land on 11 October 1917.¹⁰⁴ The only means available to test the watertight integrity of a submarine at the time prior to sea trials was to conduct a hydrostatic test pier-side. Winterhalter and Taylor discussed including a 60-pound hydrostatic test as sufficient for this purpose.¹⁰⁵

Hull Characteristics

Board discussions of the framing, welding, and lines were predominant concerns initially. The decision as to a single hull or a double hull and the evaluation of what the British and Germans were building, was discussed by the Board. The R-class was built using a single hull design and had been built for both the British and the U.S. Navy.¹⁰⁶ The final decision implemented in the U.S. Navy S-class was a double hull design while the EB built T-class was to use a single hull.¹⁰⁷ Other concerns that arose due to the German use of Zeppelins caused the Board to discuss possible means of painting the hulls in order to reduce the ability of Zeppelins and seaplanes from recognizing a submerged submarine.¹⁰⁸ During the 11 October hearing, Winterhalter also discussed the compartment specification. “Retain positive buoyancy in a light condition with any compartment flooded.”¹⁰⁹ This method of compartmentation meant heavier internal

¹⁰³ PHGB, 1917, 106,109.

¹⁰⁴ Ibid., 369.

¹⁰⁵ Ibid., 109.

¹⁰⁶ Ibid., 750.

¹⁰⁷ Ibid., 1918, 371.

¹⁰⁸ Ibid., 843.

¹⁰⁹ Ibid., 1917, 369.

bulkheads but assisted a submarine to avoid being lost due to a flooding casualty in any individual compartment.

Primary Armament

Regarding torpedo tubes and weapons storage, the Board considered the location and number of torpedo tubes to be built into the next design. CDR Kearny had noted that the British were using broadside tubes.¹¹⁰ A broadside tube was a tube that was mounted amidships either internal to the hull or external and mounted on the deck. Winterhalter identified that for the number of torpedoes to be carried the Board was currently planning on “An allowance of 12 torpedoes for the bow and four for the broadside.”¹¹¹ The discussion regarding the number of torpedoes to be carried identified that in the event broadside tubes were eliminated additional storage for weapons or for more frequent reloading from a tender would be required. CDR D. C. Bingham, just back from inspecting British naval development, identified that by 16 October 1917 the British had begun removing broadside tubes from their most recent designs.¹¹² The Board continued looking at broadside tubes and the submarine design for the AA-1, what was later reclassified as the T-1, was fitted with an experimental broadside tube.¹¹³ The number of torpedoes that should be available came up again periodically, the consensus being that for each tube there should be a spare inboard. The British were allowing for one reload of

¹¹⁰ PHGB, 1917, 203.

¹¹¹ Ibid., 203.

¹¹² Ibid., 452.

¹¹³ Ibid., 1918, 916.

each tube for a total of 12 14-inch torpedoes. Early U.S. designs had employed an 18-inch torpedo, however these were abandoned by the time of the R-class. For the S-class and the T-class the 21-inch torpedoes were ultimately selected.¹¹⁴

As it began to be recognized that the largest impact on German submarines was coming from Allied submarines, a renewed focus on torpedo construction and employment began to emerge. King described how regarding the torpedo, the British were looking at developing a smaller high speed torpedo and modifying torpedo employment to include a means of launching a salvo to increase the likelihood of achieving a hit.¹¹⁵

Whether to carry mines in future designs was also a major point of discussion. Germany had begun building numerous mine laying submarines and it made the Board question if the United States should consider building mine laying submarines of their own. Board member Captain Marvell identified that he did not believe they were required at the time as there was not a practical way to employ them against Germany.¹¹⁶ Marvell felt that there was no need to build a mine specific submarine and that they should not be employed from existing classes either. “There is not room enough and they can’t carry enough mines.”¹¹⁷ Board member Captain Belknap also did not think the United States needed a mine laying submarine.¹¹⁸ During the hearing on 11 October 1917 the Board

¹¹⁴ PHGB, 1917, 186-187.

¹¹⁵ *Ibid.*, 456.

¹¹⁶ *Ibid.*, 235.

¹¹⁷ *Ibid.*

¹¹⁸ *Ibid.*, 330.

tabled the discussion of mine laying submarines for the time being to focus on the fleet submarines. If a mine laying submarine became necessary both Pierce and Land felt that an existing submarine could be modified to carry mines in lieu of building a mine specific class of submarine.

Secondary Armament

The Board was interested in ensuring sufficient wet guns on future designs. The concern was that by providing additional deck guns the speed would be affected. Early discussion was based on towing basin testing and it was noted by Commander T. A. Kearney “the loss of speed was a little bigger than in actual service.”¹¹⁹ The Board was beginning to look at alternative mounting methods to increase the deck gun capacity and allow for two guns to include a 3-inch anti-aircraft gun.¹²⁰ However, there were some differing opinions on the number of guns. Land, along with Board members General Barnett and Captain Shoemaker, believed that there should only be one gun on a submarine but that the ammunition should be increased.¹²¹

Sensor Systems

Another important aspect that was just coming into being was the development of hydrophones, the predecessor of Sound Navigation and Ranging (SONAR). The Board referred to this technology as listening devices and Admiral Griffin had formed a committee, as part of the National Research Council, to focus on experimenting with the

¹¹⁹ PHGB, 1917, 202.

¹²⁰ Ibid., 202.

¹²¹ Ibid., 376.

new listening devices on submarines. Major R. A. Millikan, a noted U.S. Army physicist and future Nobel Prize for Physics winner in 1923, was selected as the new committees chairman.¹²² This predecessor to SONAR, while rudimentary at the time, gave the Allies for the first time the ability to identify that a submarine was present even when it was submerged. The detection range of this early sensor was extremely limited, however it did allow submarine chasers the ability to listen for a submarine and to identify its general direction. After initial demonstrations on submarine chasers there were experiments with installing them on submarines. The first installment went through the deck of the submarine in an arrangement that precluded use when the submarine was surfaced. Planning was begun for a means to install the sensor through the hull of the submarine allowing for use on the surface and when submerged. The concern with a through hull installation was that the detector component would be damaged in the event the submarine was required to bottom itself. Schofield described on 12 October 1917 how the initial submarine installation on the L-10 and the N-1 were installed through the keel to allow for operation to listen on the surface.¹²³ Leigh identified that it was able to be housed which prevented damage.¹²⁴ Schofield discussed how Professor Mason was working on improving the performance of the C tubes but they had not made much headway yet. Schofield also discussed how the Submarine Listening school was improving the operators' ability and that when trained operators were able to identify submarines at a distance of one to two miles. It is worthwhile to note that Lieutenant

¹²² PHGB, 1918, 83.

¹²³ PHGB, 1917, 393.

¹²⁴ Ibid., 307.

McCormack identified that Mr. Hewitt, a member of the Naval Consulting Board, felt that the U.S. C tube was a superior hydrophone to all British hydrophones in use.¹²⁵ As the work on listening devices progressed, the importance of placing them onboard submarines began to be identified. Taylor described how he believed that submarines were ideal to be fitted with the new listening devices.¹²⁶ When Millikan testified before the Board he explained how the Nahant group had been formed as a means to consolidate the expertise of the three major companies conducting work in the submarine detection field, the General Electric Company, the Western Electric Company, and the Submarine Signaling Company.¹²⁷ It was this Nahant group, based out of Western Electric Company in Nahant, Massachusetts, that made possible the relatively rapid advancement of the U.S. submarine detection technology compared to the British and the French.¹²⁸ Another development that Millikan brought to the Board's attention was a possible high frequency method of locating a submarine by transmitting a pulse and listening for a return. This type of active SONAR was recognized by Millikan as a short-range method due to the limited range of high frequency waves but the possibility for future development was recognized as well as other possible uses as a communication device.¹²⁹

The continuing development of the new listening technology, toward what became SONAR, resulted in the development of a towable hydrophone, called the fish

¹²⁵ PHGB, 1917, 465.

¹²⁶ *Ibid.*, 674.

¹²⁷ PHGB, 1918, 84.

¹²⁸ Weir, 73.

¹²⁹ PHGB, 1918, 99-103.

hydrophone, that allowed a ship to listen for submarines without having to shut down its own machinery. This new hydrophone allowed for a vessel to remain moving while still monitoring for an enemy submarine. “The Admiralty feel that this fish hydrophone will be a great help in eliminating the submarine menace”¹³⁰ At the time of Pierce’s testimony to the Board, the United States was not in possession of this new fish hydrophone. Schofield discussed the U.S. development of what they were calling a “drifter set.”¹³¹ This U.S. version of the fish hydrophone allowed for detection at up to 12 miles. The researchers at Boston were making significant progress by combining the C tube research and the new drifter set. It was felt that they could identify a submarine’s direction with the drifter set within 30 degrees for an inexperienced observer and 10 degrees with training.¹³² When King testified on 17 October 1917, he described the benefits of the new towable hydrophone as being able to operate “at speeds up to ten knots.”¹³³ This allowed a surface ship to move against a submarine as opposed to being much more vulnerable and stopping to listen. A stationary ship is much more vulnerable to attack than a ship making way. Experiments carried out from New London with the submarine chaser *Narada* and the new Mason apparatus were proving to increase the range of detection significantly. The Mason apparatus had been developed by Professor Mason from the University of Wisconsin working at New London over the summer of 1917 and consisted

¹³⁰ PHGB, 1917, 357.

¹³¹ *Ibid.*, 391.

¹³² *Ibid.*, 392.

¹³³ *Ibid.*, 457.

of multiple “Broca tubes on either side of the keel of the vessel.”¹³⁴ Detection ranges from the *Narada* trials were out to seven to eight miles with the *Narada* operating at a speed of up to 11 knots.¹³⁵ Leigh discussed the Mason apparatus during his meeting with the Board on 13 November 1917. Leigh described how that with the wind blowing at “5 or 6” and with the submarines periscope “just awash,” the Mason apparatus was able to provide a direction that the crew could use to relocate the submarine when her periscope was no longer held visually due to whitecaps.¹³⁶ Leigh felt that the test results proved that the Mason apparatus was superior to the conventional C tube for locating a submarine. Leigh went on to describe how the new K tube was being used to mount receivers 70 feet from each other and allow the listener to move the two receivers to determine a bearing within eight degrees. Millikan also described for the Board how the K tube and the Mason device allowed for further detection ranges as well as an improvement in bearing resolution over the earlier C tubes.¹³⁷ This new arrangement also let the user make an approximation of range.¹³⁸ Leigh finished his discussion by detailing how he thought a combination of C tubes, K tubes and a triangle formation of multiple submarine chasers could be used to locate and maintain contact with a submarine to allow the chasers to coordinate an attack.¹³⁹

¹³⁴ PHGB, 1917, 582.

¹³⁵ *Ibid.*

¹³⁶ *Ibid.*, 583.

¹³⁷ PHGB, 1918, 95-98.

¹³⁸ PHGB, 1917, 587.

¹³⁹ *Ibid.*, 590.

Navigation and Signals Equipment

The only significant navigational advancement from the earlier classes to the S-class was the inclusion of two gyrocompasses. The gyrocompass allowed for a submarine to overcome the inherent problems of using a magnetic compass in an enclosed metal hull where the hull itself made the use of a magnetic compass problematic at best. Land noted during a hearing that the Russian H boats were not equipped with a gyroscope to conserve space but that for U.S. designs, the gyrocompass was considered essential.¹⁴⁰

While at periscope depth, nothing provides as much situational awareness as the periscope. Bingham had been impressed with the British periscopes during his visit to Europe and felt them to be superior to the optics employed on surface ships.¹⁴¹

A significant problem existed with positively identifying a friendly submarine to friendly forces to prevent fratricide. Several British submarines had been lost to friendly fire for having been misidentified as a German submarine. During discussions on 11 October 1917, Pierce mentioned that as a possible means of mitigating this problem in the future, the British had been using lights as recognition signals. The light was projected using a periscope tube to make it visible even before the submarine surfaced and had been tried out on the G-1.¹⁴² Pierce and Winterhalter felt that some type of recognition signal should be included in the U.S. design. Millikan described one possible signaling device that had been found during research on the listening devices. A high frequency pulse could be sent through the water in the 50,000-100,000 hertz range that

¹⁴⁰ PHGB, 1918, 483.

¹⁴¹ PHGB, 1917, 454.

¹⁴² Ibid., 382.

allowed a submarine to signal through the water in a frequency range that could not be heard by current listening devices and therefore was able to provide a secure means of signaling both to and from a submarine.¹⁴³

Radio sets for submarines were discussed by McCormack on 17 October 1917 where he identified the current radio configuration on British submarines. McCormack mentioned that they were using a 3.5-kilowatt arc set that could achieve a range of 250-300 miles. The antennae were attached as follows: “They have two antennae, one rigged permanently from bow to stern and attached to the periscopes, and another on the side with either hinged or telescopic mast.”¹⁴⁴ For a submarine redundancy is extremely important as a failure of an individual component does not result in an inability to carry out a mission.

Habitability Systems

The Board was also interested in the habitability of submarines. Badger thought this curious because the United States felt “the 450-ton boat is too small for habitability and have practically stopped building them.”¹⁴⁵ Boyd discussed the need to refresh the air but that advances had been made, specifically he identified that “The ventilation troubles can be easily straightened out . . . If they stayed out three days before they thought they

¹⁴³ PHGB, 1918, 101-102.

¹⁴⁴ PHGB, 1917, 464.

¹⁴⁵ Ibid., 188.

were doing great things. Now they stay out a month.”¹⁴⁶ During the testimony of Pierce, Badger inquired about the habitability of the E-class. Pierce identified:

The air was quite bad, very bad, toward the end of the day and it was found necessary to start the air-purifiers going. The American boats are not equipped with those as they should be, and I suppose it is because the Americans have not considered it necessary to operate under water for so long a time as is now being done. The British have air-purifiers in all their boats. It consists of a motor which draws the air through chemicals.¹⁴⁷

During further questioning by the Board, Pierce talked about the adverse effects on personnel caused by environmental conditions on the E-class. The resulting impact of the environmental conditions required ten days in port for submariners to recover before going out again.¹⁴⁸ In comparison to the British, U.S. submarines were judged by Naval Constructor W. G. DuBose to be superior to the British designs “in most cases.”¹⁴⁹ Winterhalter identified that there was a correlation between the size of the boat and the success of the ventilation systems during discussions with Surgeon General of the Navy, W. C. Braisted, on 1 November 1917 and that the British H-class was “superior to the larger submarines except in the question of ventilation.”¹⁵⁰ Dr. Braisted identified that the Navy had obtained a “soda-lime” device from the British and were maintaining them at New London.¹⁵¹

¹⁴⁶ PHGB, 1917, 190.

¹⁴⁷ *Ibid.*, 351.

¹⁴⁸ *Ibid.*, 354.

¹⁴⁹ *Ibid.*, 472.

¹⁵⁰ *Ibid.*, 547.

¹⁵¹ *Ibid.*

Robison explained to the Board how the new air purifying equipment, “known as the ‘Gibbs’ machine” testing on the K and L-classes had maintained adequate breathing air during a 48-hour test. The “Gibbs” machine consisted of a 40-pound can of soda lime driven by a one-quarter-horsepower motor that combined weighed 65-70 pounds.¹⁵² Robison had gone onboard immediately after the test and informed the Board that the personnel were “perfectly comfortable.”¹⁵³ William E. Gibbs of the Bureau of Mines spoke with the Board on 20 November 1917 and described the development of the technology to remove carbon dioxide from the air. The idea had come from a Dr. J. S. Haldane who had developed a “new form of soda lime” that he suggested the Bureau of Mines use in their rescue device.¹⁵⁴ Gibbs had identified that the technology was well suited to the submarine environment based on its confined spaces. He had adapted several devices that were used in the 48-hour tests and described how the air was better following the test than at the beginning.¹⁵⁵ Gibbs initially wanted four units in each submarine, one for each compartment, however space considerations resulted in the number being reduced to two.¹⁵⁶ Gibbs informed the Board that the device required 10 cans for a 48-hour period.¹⁵⁷

¹⁵² PHGB, 1917, 620.

¹⁵³ *Ibid.*, 605.

¹⁵⁴ *Ibid.*, 617.

¹⁵⁵ *Ibid.*, 618.

¹⁵⁶ *Ibid.*, 619.

¹⁵⁷ *Ibid.*, 621.

Another habitability consideration was the supply of oxygen. To stay submerged for any extended period of time required a supply of oxygen to maintain sufficient levels for personnel safety. Gibbs identified 500 feet of oxygen was required for the same 48-hour period as the carbon dioxide test.¹⁵⁸ Therefore, to facilitate extended submerged operations the submarines were fitted with tanks to hold compressed oxygen that could be vented into the submarine to replenish the oxygen supply. Gibbs described the tanks used as “cylinders compressed to 120 atmospheres which weigh in the neighborhood of 100 pounds each. They are about 5 feet long and 8 inches in diameter.”¹⁵⁹ He went on to describe how for seven days a boat needed 1,400 pounds of soda lime and 1,750 feet of oxygen with a net result that a submarine could operate “free from the tender for a week and remain under 20 hours each day.”¹⁶⁰

Control of the hydrogen produced by battery charging and discharging, also needed addressing to allow for extended submerged operations. A hydrogen concentration of 10 percent presented an explosion hazard and even a concentration of 5 percent was a fire hazard. Gibbs discussed a possible means of disposing of the hydrogen with a small device that could filter out and burn the hydrogen in a controlled manner.¹⁶¹ Assistant Surgeon E. F. DuBois, U.S. Navy Reserve Force similarly discussed wanting to limit hydrogen to no more than 3 percent to prevent a fire or explosion hazard.¹⁶² Land

¹⁵⁸ PHGB, 1917, 621.

¹⁵⁹ *Ibid.*

¹⁶⁰ *Ibid.*

¹⁶¹ *Ibid.*, 619.

¹⁶² *Ibid.*, 637.

discussed with the Board on 22 November 1917 that a method for measuring hydrogen, called the Sperry apparatus, using a Wheatstone bridge was being developed for use onboard submarines. A Wheatstone bridge works using the nature of hydrogen, which produces a cooling effect which when run across a resistor changes the resistance producing a corresponding change in voltage that can be measured and a hydrogen concentration can be determined by the change in voltage. Land described this Sperry apparatus as being “complicated and expensive” but that a Burrill hydrogen detector had been issued to each boat that was easier to use and could still be performed onboard.¹⁶³ Land also felt that the Board should include a means for measuring and eliminating hydrogen in the future design.¹⁶⁴

While at the time of DuBois’s testimony, no method for handling carbon monoxide had been developed, he mentioned that Professor Frazer of Johns Hopkins was working on a means of dealing with it.¹⁶⁵ Other toxic gases, like chlorine gas, DuBois felt could be dealt with by simply donning the Navy mask, a similar mask to the Army mask developed to deal with chemical weapons introduced on the European battlefields.¹⁶⁶ Chlorine gas was the product of seawater interacting with an electric current, most notably occurring in the battery compartments. Other means to handle chlorine gas were implemented in the form of a change to the battery cell design which were designed to

¹⁶³ PHGB, 1917, 646.

¹⁶⁴ *Ibid.*, 648.

¹⁶⁵ *Ibid.*, 639.

¹⁶⁶ *Ibid.*, 640.

prevent seawater introduction into the cells thereby eliminating the source of chlorine gas production.¹⁶⁷

As a result of all the atmospheric considerations, monitoring for gasses was identified as a means to extend the life of the soda lime and the oxygen bottles. A means of measuring the carbon dioxide by use of the “Orsatt apparatus” allowed the crew to wait until carbon dioxide rose to a level that required filtering.¹⁶⁸ Gibbs was more concerned with oxygen as the effects of low oxygen were not as identifiable as the presence of carbon dioxide and had been developing a device to measure the oxygen concentration. The recommendation Gibbs made was to never let oxygen fall below 17 percent and to use a continuous bleed type delivery to avoid a mistake resulting in excessively low concentrations that could render the crew incapacitated.¹⁶⁹ Gibbs identified that a bleed rate of “20 cubic feet an hour is sufficient for a crew of 23 men.”¹⁷⁰ While DuBois also agreed with the 17 percent limit for oxygen, he identified that as the point when oxygen would be supplied from the tanks. With the inclusion of monitoring for gas concentrations and devices to do so, the early signs of modern day submarine atmospheric control appear. The Board also questioned DuBois on 21 November 1917 about atmospheric controls. Like Gibbs, DuBois identified the need to control carbon dioxide below 3 percent as well as to devise a measuring device to determine when the

¹⁶⁷ PHGB, 1917, 649.

¹⁶⁸ *Ibid.*, 623.

¹⁶⁹ *Ibid.*, 624.

¹⁷⁰ *Ibid.*, 628.

soda lime device had to be started.¹⁷¹ DuBois also believed that a method for determining oxygen concentration should be developed for practical use onboard a submarine.¹⁷² The recommendation of Gibbs and DuBois reflected the Bureau of Construction and Repair *Instructions for Use of Air Purifying Apparatus and Compressed Air in Submarines* dated 10 November 1917 which called for a 3 percent and 17 percent limit for carbon dioxide and oxygen respectively.¹⁷³

Consolidated Specification Summary

During the Board's discussion with Boyd on 8 September 1917, Winterhalter laid out the current design considerations for what eventually become the T-Class. "In this boat here, 2400 tons or more, 5 officers and 50 men, with a battery of two 5-inch guns, one 3-inch anti-aircraft gun, 21-inch torpedoes, four bow tubes and one 21-inch tube on each broadside, with the radius prescribed and stores for 45 days"¹⁷⁴ Despite numerous hearings on design characteristics throughout the war, the basis for the final specifications enacted as the war came to a close had been identified as early as September of 1917.

Early in the war during a hearing on 11 October 2017, the Board discussed with Land how many of each class were being built. Land identified that there were currently

¹⁷¹ Ibid., 636.

¹⁷² PHGB, 1917, 639.

¹⁷³ Ibid., 646a.

¹⁷⁴ Ibid., 187.

25 that would be commissioned by June “Fourteen O-boats, 7 N-Boats and 4 L-boats.”¹⁷⁵

Winterhalter wanted to know if there was room to start work on one of the classes the Board was currently working on. Land brought to the Board’s attention that the current boats were being immediately followed by R-class and S-class boats that had already been contracted for. Land also presented the Board with a comparison of the S-class to the H-class “Showing improvements and added equipment in the S-class.”¹⁷⁶ The detailed report is included in table 5.

¹⁷⁵ PHGB, 1917, 386.

¹⁷⁶ PHGB, 1918, 544-545.

Table 5. S-class Improvements over H-class

1. 50 to 75% more torpedoes.
2. Can carry a gun.
3. Can carry proper ammunition allowance (50% more than 600 ton boats).
4. Greater reliable surface speed and radius of action.
5. Greater submerged speed and radius of action.
6. Proper ventilation for main motors.
7. Proper ventilation for motor room.
8. Proper ventilation for torpedo room.
9. Housing periscopes – Proper housing lengths.
10. Alti-periscope – anti-aeroplane instruments.
11. Submarine Signal Set.
12. Wireless apparatus – mast, 2 K.W. set, etc.
13. 3 man conning tower.
14. Two Gyro Compasses.
15. Chariot Bridge.
16. Four machine tools – lathe, drill, grinder, etc.
17. Evaporator.
18. Distiller.
19. Fresh water tanks for battery water.
20. Bunk for each member of crew.
21. Lockers for each member of crew.
22. Provisions for thirty days.
23. Refrigerating Outfit.
24. Independently driven auxiliaries – air compressors – bilge pumps, oil pumps, circulating water pumps.
25. More efficient batteries – much heavier than formerly.
26. Air purifying apparatus.
27. Hydrogen detectors.
28. Hydrogen eliminators.
29. Target Bearing Indicators.
30. Sound Detecting Devices – various types.
31. Cork sheathing.
32. Marker Buoy.
33. Fireless Cooker.
34. Fire extinguishers.
35. Running lights in conning tower.
36. Torpedo work bench, tool locker and equipment.
37. Enlarged Torpedo Room.
38. Adequate torpedo loading equipment.
39. Two W. C's.
40. Proper mess gear equipment.
41. Pneumereator System.
42. Confidential Locker.
43. Anchor (deck) housed in hawse pipe.
44. Towing gear operable inside of boat.
45. Chart Board.
46. Clearing Lines and Jumping Wires – Sounding Machine.

Source: Created by author using data from *Proceedings and Hearings of the General Board of the US Navy, 1900-1950*, vol. 1-2, 14 August-31 December 1918, Archival Information Record Group 80, Combined Arms Research Library, Fort Leavenworth, KS, (microfilm), 544-545.

Early in the war, the growing consensus was that the U.S. H-Boats were better suited as general-purpose submarines than the British K-Boats. DuBose described on 17 October 1917 how “considering only operating features the ‘H’ boats are much handier all around than their ‘K’ boats.”¹⁷⁷ There was a time when the Board sought to secure a smaller design. It was through the consistent work of submariners, in particular the efforts of Land that the Board began looking at alternatives to the smaller submarines towards a slightly larger more capable platform. Robison’s largest concern was the inability of the contractors to deliver completed boats. “They show 99% completion, but remain in the hands of the contractors for months waiting while they are endeavoring to meet some specification on which they have failed.”¹⁷⁸ Lake had shown through a series of labor problems that they needed a change in management.¹⁷⁹ Similarly, Land described how the progress was insufficient and by peace time standard production was only at 2/10 vice 10/10. Winterhalter agreed that progress must be improved to meet 99 boats for 1918.¹⁸⁰ Land described how the 99 boats being currently built for completion in 1918 met the need. Specifically, Land wrote to the Board “No new designs are necessary. No new construction need be authorized. The problem is in hand. The one thing required is governmental pressure behind two private concerns and one navy yard.”¹⁸¹ With the

¹⁷⁷ PHGB, 1917, 472.

¹⁷⁸ *Ibid.*, 607.

¹⁷⁹ *Ibid.*, 608.

¹⁸⁰ *Ibid.*, 652.

¹⁸¹ *Ibid.*, 656.

approval of the S-class, the debate over building smaller submarines was finally ended and no longer would the Navy consider the smaller 300 to 400-ton submarines.

The overall design hearing effort during World War I resulted in the finalization of the S and T-class designs. The efforts undertaken by the Board during the war led to the shift in control of submarine design away from the manufacturers and transferred it to the Navy. The Navy now having control over design prior to production allowed the Navy to dictate what technological development would be pursued as opposed to the manufacturers building a submarine without sufficient input from the submariners. Ultimately the S-class and the experimental T-class became the model for interwar development of the fleet submarines that would dominate in the Pacific during World War II. The next chapter will analyze the overall impacts of the Board's involvement in submarine design during the war on submarine development and the shift in naval thinking produced by the new possibilities for submarines.

CHAPTER 5

CONCLUSIONS

Germany's introduction of unrestricted submarine warfare during World War I led to a rapid change in the thinking of Navy leaders in the United States and Great Britain, about the tactical employment of submarines, their design and construction, and the best means to counter the new submarine threat. The evolution in thinking was reflected in the Board hearings throughout the war and had dramatic impacts on the submarine force and the Navy. No longer could the United States continue its Mahanian influenced buildup of battleships as the answer for achieving naval supremacy at sea.¹⁸² Smaller, more capable anti-submarine platforms came to dominate conventional U.S. naval construction during the war with the rise of the destroyer and the submarine chasers. These changes were vital to countering the German U-Boat threat and allowed Great Britain to remain in the war and allowed the United States to bring troops and supplies to Europe to sustain the allied war effort.

The adoption of the convoy system forced the German U-Boats to attack the Allies at their points of strength, and therefore this was where the Allied naval forces had the most success. This reminds one of the strategies proposed by the noted British theorist Sir Julian Corbett. Corbett's strategy was to focus a nation's naval efforts on an

¹⁸² Alfred T. Mahan, *The Influence of Sea Power Upon History 1660-1783* (Boston: Little, Brown and Company, 1890), 25-89. This early work (1890) of Mahan significantly influenced the U.S. Navy in its decision to pursue a large battleship fleet, however, by 1906 he was opposed to the mass construction of dreadnought battleship preferring instead a balanced fleet approach; see Alfred T. Mahan, "Reflections, Historic and Other, Suggested by the Battle of the Japan Sea," *Naval Institute Press Proceedings* 32, no. 118 (June 1906): 447-471.

enemy's sea lines of communication and held the belief that by doing so it forced the adversary to seek out that nation's forces to achieve a decisive battle.¹⁸³ The shift in thinking resulted in a conclusion that decisive battle was no longer a fleet on fleet battle as had been envisioned by Mahan—and especially his readers—but rather a U-Boat against a convoy escort force. The result being that continued effort over time protecting the lines of communication resulted in a cumulative victory that produced the same results as a decisive battle.¹⁸⁴

The shift in usage of the submarine initiated by Germany resulted in American naval officers evincing a desire to rapidly develop U.S. offensive submarine capability. As was noted during the beginning of the American war effort, the submarines designed for defensive coastal patrols were less than ideal for the new concept of open ocean submarine operations required by the new German approach. Despite their shortcomings, the U.S. Navy remained focused on smaller submarines based on the introduction of the smaller German UB-class and the UC-class, intended for mining, produced for operations from local bases along the English Channel. This thinking was rapidly embraced by the Board and the U.S. submarine manufacturers but for different reasons. The Board adopted this thinking as a way to rapidly produce a larger number of submarines to conduct coastal operations, thinking that because the Germans had taken this tact and it was proving successful, the United States should also pursue the smaller submarines. The

¹⁸³ Julian S. Corbett, *Some Principles of Maritime Strategy* (Annapolis, MD: Naval Institute Press, 1911), 183-208; see also William R. Hawkins, "The Man Who Invented Limited War," *Military History Quarterly* 4, no. 1 (Autumn 1991): 432.

¹⁸⁴ Joseph Caldwell Wylie, *Military Strategy: A General Theory of Power Control* (Annapolis, MD: Naval Institute Press, 1967).

Board, while entertaining this concept, was unaware that Germany had already begun to shift away from the smaller U-Boats in favor of the larger Ms U-Boats, the new U-Cruisers, and the large mine laying U-Boats.

The U.S. submarine manufacturers had latched on to the concept of the smaller submarine because for them it meant a higher profit margin since they could continue building the type of submarine they were most familiar with and therefore expend less time and effort on new development designs. The submarine manufacturing establishment went so far as to influence several Navy officers to take their side and to testify before the Board that the smaller type submarine was indeed the course to pursue. This became apparent later as the Navy had to take administrative action against several of these individuals based on their conduct. The submarine force saw the necessity for the larger submarines as had its German counterparts. Key in this story was the influence of Emory S. Land and his consistent drive to pursue the larger submarines, which ultimately won out. The Navy abandoned thoughts of the smaller submarines because Land had demonstrated that the larger submarine was more capable in coastal and open ocean operations.

As the war progressed, the technological development was astounding. The caliber of the personnel brought in to consult and develop technology was second to none. With world class scientists working on the advancement of submarine technology the progress made was noteworthy. The work done by these men laid the foundation of the interwar advances in SONAR, radio, atmospheric control equipment, navigation equipment, and more.

Where the United States ultimately found itself lacking in submarine technology was in the inferiority of its propulsion systems and the unreliability of mechanical equipment. German engineering had produced far superior submarines that were more reliable, longer lasting, and better performing than their American counterparts. It took reverse engineering of the captured and surrendered U-Boats during the early interwar period to allow the United States to finally close this gap.

Finally, the research conducted has raised a few areas that require further research regarding U.S. submarine development, tactics, and doctrine during World War I, to say nothing of similar questions about anti-submarine war developments unique to the U.S. Navy. In particular the development of the SONAR system and the integration of key scientists in the advancement of the technology would require a study all its own. The development of the early atmospheric control equipment discussed in this study could also use some additional research. The mechanism by which U.S. and British ASW development during World War I made the United States so successful against Japanese submarines during World War II would also be worth significant additional research and study. Finally, this study included a more comprehensive examination of the contemporary body of opinion resident in the U.S. Naval Institute *Proceedings* and the discussions therein regarding submarine design and this would also be an area that could use additional study.

As can be seen by this analysis, the impact of the Board on the submarine construction and development during World War I was tremendous. Having a workable design for the submarines as early as 1917, prior to major submarine operations against Germany that came to fruition during the interwar period indicates that the Board was

focused on the correct concepts for submarine design despite the U.S. lack of practical experience. The largest shortcomings in U.S. submarines would come from technological inferiority to their German counterparts. With the reverse engineering of German U-Boats, the United States was able to close this gap during the interwar period to make the designs envisioned by the Board a reality. The increased influence of the Navy via the Board on the submarine manufacturing establishment ensured that the U.S. Navy was able to control and direct future development of U.S. submarines ensuring that they met the actual needs of the Navy rather than having to fit the corporate designed submarines for a role they were insufficient to meet. The combined efforts of the Board and key submariners such as Emery S. Land led to a hugely successful interwar advancement of U.S. submarines.

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