THE DEVIL IN THE DETAILS

An Analysis of S-class Submarine Construction

1917-1925

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BACKGROUND

In the 1920's the U.S. Navy commissioned 51 submarines of the S-class (Fig. 1). These boats achieved an iconic stature because they made up the bulk of the post-WWI submarine force. Their ubiquitous nature found them in every waterway the Navy operated in, and they were frequently in the news, not always for good reasons.

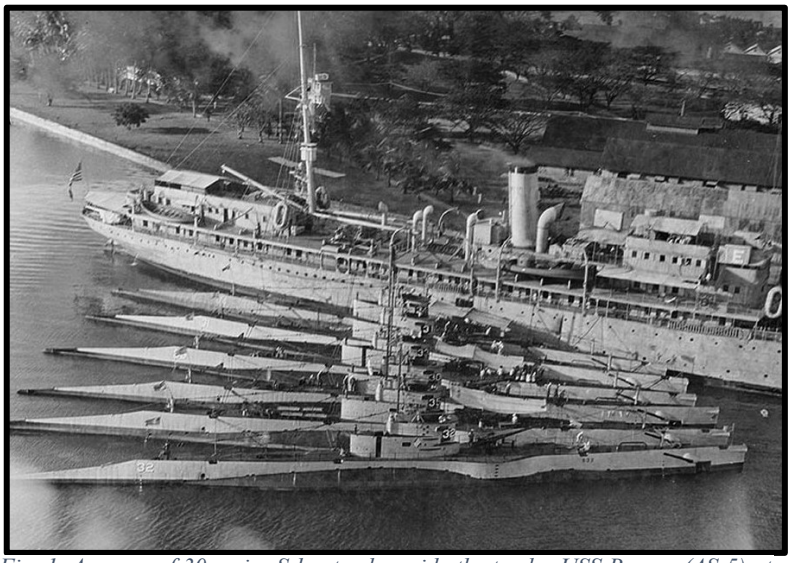

Fig. 1. A group of 30 series S-boats alongside the tender USS Beaver (AS-5) at Olongapo, P.I., March 1929. NHHC photo via Navsource.org

The S-class grew out of a general dissatisfaction with the open-ocean operating characteristics of the then current submarines of the H, K, L, and N-classes. Those boats were intended for operations in littoral waters, and were thought of as a mobile minefield that an enemy fleet could be impaled on.[1] With an at-sea endurance of just a few days, these boats were short-ranged, lightly armed, and very nearly uninhabitable after a week at sea. From 1914 to 1916 intelligence reports from Europe showed that the Germans in particular had greatly advanced the state-of-the art of submarine construction, and their boats could routinely spend three weeks in the war zone off Great Britain. Our boats fell far short in comparison, and this was perceived as a dangerous strategic weakness, particularly if Great Britain were to fall. Studies conducted by the Navy's Bureau of Construction & Repair (C&R) and Bureau of Engineering (BuEng) in the summer of 1916 showed that an 800-ton submarine capable of a 3,400 nautical mile range at 14 knots, 5,400 nm at 11 kts, and armed with four 21-inch torpedo tubes, would be able to cross the Atlantic to fight and stay there long enough to inflict serious damage on the enemy.[2] Convinced of the efficacy of an 800-tonner, appropriations for fiscal years 1917 and 1918 included funding for 43 coastal submarines of the improved O- and R-classes, and for three 800-tonners of the S-class.[3]

In the 16 years that the USN had been operating submarines, the service had employed a somewhat unusual method of submarine acquisition. The Navy would publish a set of general operational characteristics of what they wanted a submarine to meet, and then invite private companies to submit designs that would meet or exceed those characteristics. This encouraged competition, but it also cut the Navy out of the design process, and prevented the department from having any say in the arrangement of the boat or in the equipment that was installed in it, often resulting in less than optimal boats from the

Navy's point of view.[4] C&R did not have its own submarine design and construction capability, and thus, were forced to rely on private companies. During this period, only two corporations in the United States proved themselves capable of handling the complicated and specific process of designing and building submarines, the Electric Boat Company (EB) of New York, NY (later Groton, CT.), and the Lake Torpedo Boat Company (LTB) of Bridgeport, CT.

Any corporation that embarks on this endeavor has the understandable desire to build a submarine at a profit to its owners and investors, and this oftentimes puts them at odds with the Navy. The Navy naturally wants the most capable and lethal weapon possible, with only tangential regard for the profitability of the company that builds it. These diametrically opposed desires often put the Navy at loggerheads with its civilian contractors. Since it lacked an organic submarine design and construction capability, the Navy was forced to accept what EB and LTB offered them. In addition, when contracted to build submarines to the same characteristics, the two companies built two completely different designs with different equipment that caused further difficulties for the Navy in the areas of training and logistics support.

EB was a well-funded and competently managed company with a great deal of political support. Their products, however, had gained a reputation amongst submarine personnel as lacking in build quality and of being behind their foreign contemporaries in tactical capability.[5]

LTB, with its idealist owner/engineer Simon Lake, oftentimes found itself struggling. The company was beset by poor process and personnel management. Costs were high and efficiency low, resulting in boats that were overpriced and usually quite late upon delivery.[6] Over the years Lake had made several believable but legally unproveable accusations that EB was using bribery and its political influence to pre-determine the outcome of the Navy's submarine acquisition process in their favor; in essence, accusing them of trying to establish a monopoly. Lawsuits were filed back and forth. EB's strong political support deflected many of the accusations, and in the end the acrimony between EB, Lake, and the government did nothing for Lake except to gain him numerous vocal critics.[7] Ironically, the department continued to give Lake a limited number of construction contracts, using him and his company as a foil because in actuality they *did* fear an EB monopoly. The visionary Lake also had several pet technical concepts such as watertight superstructures, midships diving planes, and wheels for rolling along the bottom that he kept trying to push on the Navy, despite their questionable effectiveness. All of these factors had made Lake something of a pariah within the Navy Department.

By 1915 the Navy's dissatisfaction with this process led the department to take a different tack. The Navy wanted to be able to dictate the design and construction process to a much greater degree, but it lacked the facilities and the expertise to do so. In order to develop this ability, the Navy obtained a license from the perpetually cash-strapped LTB to build the USS *L-8* (SS-48) to a Lake design at the government owned Portsmouth Navy Yard (PNY) in Kittery, ME.[8] Surprisingly, they also were able to get a license from EB in 1917 to build two boats of that company's O-class design. One was built at Portsmouth and one at the Puget Sound Navy Yard, and thus by the time the S-class was approved, C&R had enough experience in the process to develop their own version to a completely unique design. Portsmouth was designated as the Navy's submarine design and construction center. It was felt that by building boats at Portsmouth, pressure could be placed on the civilian yards to do a better job.[9]

THREE DESIGNS

EB's model became the USS *S-1* (SS-105). It was a single hull design (Fig. 2), with all of its ballast tanks internal to the pressure hull. The hull was a rounded spindle shape with a free-flooding superstructure that ran three quarters of the way to the stern, before the skeg tapered sharply down to the rudder. The rudder itself was axial-mounted, in line with the end of the hull and aft of the twin propeller shafts. A squared-off conning tower and bridge fairwater sat dead center on the superstructure and supported the periscopes and radio aerials. In essence, she was a scaled-up version of all of EB's previous designs, tracing its lineage directly back to the USS *Holland*. The battery well was split in two, with half forward of the control room and half aft, separating the control room from the engine room. This had the visual effect of centering the conning tower fairwater. The bow planes retracted into the superstructure in an upward angled slit, a first in an EB design. There was a prominent slab-sided fairing at the forward edge of each bow plane pivot point.

Fig.2. USS S-1 (SS-105) entering a New England port, late summer 1920. Photo courtesy PigBoats.COM.

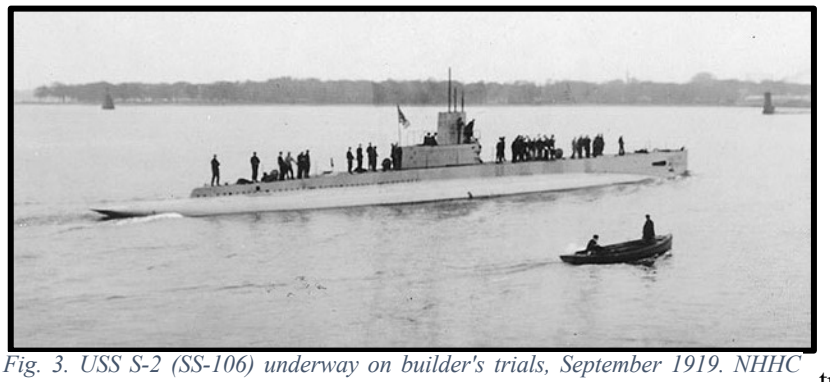

Fig. 3. USS S-2 (SS-106) underway on builder's trials, September 1919. NHHC photo via Navsource.org

LTB submitted a design that became the USS *S-2* (SS-106). Built to a modified double-hull design (Fig. 3) it was generally cylindrical in shape, but it tapered sharply upward forward and aft, giving the amidships portion a somewhat squat, almost pregnant look. The stern was a flat, horizontal "shovel" shape, a Lake trademark that provided needed aft buoyancy. Her rudder was mounted ventrally and the rudder pivot structure also supported the stern planes. To match the position of the planes, the propeller shafts also exited beneath the hull. The superstructure ended short of the stern. She also had a starboard side anchor and fully retractable bow planes. Her battery was situated in one compartment forward of the control room, and that had the visual effect of pushing the conning tower fairwater aft.

The design built by Portsmouth was a unique configuration that incorporated features of the Lake and EB designs, and from their own ideas that were borne from C&R's experience with *L-8, O-1,* and *O-2*.[10] The boat was

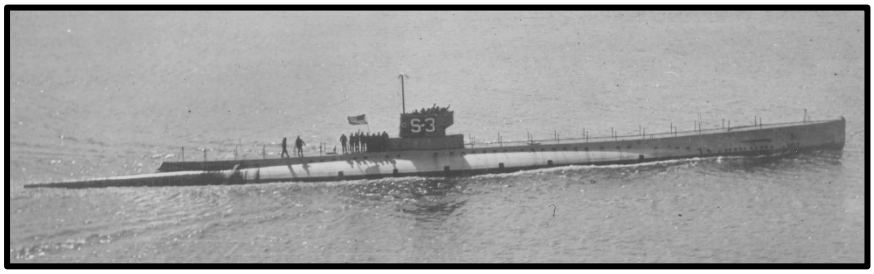

Fig. 4. USS S-3 (SS-107) underway in 1919 after commissioning. USN photo via NARA, courtesy Daniel Dunham and Navsource.org

commissioned as the USS *S-3* (SS-107). A full double hull boat, all of her main ballast tanks were mounted external to the pressure hull. She was considerably longer (231 ft. vs. 207 ft. for *S-2* and 219 ft. for *S-1*) and a little wider than the other two boats, giving her a long, sleek appearance (Fig. 4). Similar to *S-2*, her battery was contained in one large compartment forward of the control room, which had the visual effect of pushing her conning tower fairwater well astern. The long hull had far less upward curve to it than the *S-1* or *S-2,* and the stern ended in a sharp vertical "chisel". The rudder was ventrally mounted, and the stern planes were suspended on their own support post above the rudder.[11]

It was never intended for the three 800-tonners of the FY-18 appropriations to be prototypes in the traditional sense. In other words, there was no intention of the three boats being compared during trials to determine which design was the best. Each design was intended for series production from the start. Historian John D. Alden did mention that "since all three designs were produced to the same set of specifications, it was planned to take the best features of each prototype and combine them into improved versions for mass production."[12] Even though there was some design-tweaking done to later boats by EB and Portsmouth, this consolidation process mentioned by Alden actually never fully took place because S-class production was stopped in 1925. The last boat in name sequence was the *S-51* (SS-162), but some contemporary correspondence indicates that boats were planned through *S-71.* These later boats would have incorporated some of the improvements Alden mentioned, but they were never built.[13]

INITIAL PRODUCTION ISSUES

As soon as the appropriations were signed into law, all three builders promptly began laying keels. LTB actually led the way by laying the keel for *S-2* on 30 July 1917, followed by Portsmouth with *S-3* on 29 August, and finally EB with *S-1* on 11 December.

Electric Boat was at the apex of the company's 22-year relationship with the Navy. Despite being the leading submarine construction entity in the country, EB, unlike most other shipbuilding firms, had been a design and marketing firm only. They did not have a company owned shipyard or production facility. A subsidiary company, the New England Ship and Engine Company (NELSECO), had been established in 1910 on the banks of the Thames River in Groton to build diesel engines under license to the German MAN company designs. The facility was for engine production only and did not have building slips. EB sub-contracted all submarine construction to either the Fore River Shipbuilding Company of Quincy, MA, or the Union Iron Works of San Francisco, CA. Both companies had been sold to Bethlehem Steel, and by the time of the start of S-boat construction, the yards were known as Bethlehem Quincy (BQ) and Bethlehem San Francisco (BSF).[14] This somewhat unusual business arrangement prompted C&R to award EB the lion-share of the S-boat construction contracts; not necessarily because their design was superior, but because of their greater construction capacity when BQ and BSF were taken into account. Electric Boat would not actually have its own shipyard in Groton until 1924.[15] There had been a massive national expansion of shipbuilding since the start of the war in 1914, and both BQ and BSF were extremely busy building merchant ships, destroyers, and submarines. Both yards initiated construction of near-duplicates of *S-1* as soon as their building schedules allowed. This very high building tempo had a deleterious effect on the building pace for the S-boats at these yards, as will be seen below.

The Lake Torpedo Boat Company struggled with numerous in-house production and management issues. The company had been contracted to build 20 submarines of the *L, N, O,* and *R*-classes starting in 1914. Their boats of the *O*- and *R*-classes took an average of 40 percent longer to build than their contemporaries from EB.[16] Lake had contracted with California Shipbuilding in Los Angeles to build three of his O-boats on the west coast. CALSHIP performed so poorly that all three boats had to be towed north to Mare Island Navy Yard for completion. LTB was given the contract for *S-2* in a hope that perhaps they

could contribute something to the process and to provide a foil to EB. But again, the company fell behind. Even though it was the first boat laid down, *S-2* was the fifth boat commissioned. Because of ongoing production delays, and because Lake was unable to demonstrate the efficacy of his pet features, C&R refused to buy any more of Lake's unique designs. Putting aside his injured pride, Lake accepted an offer to build eight boats to the C&R *S-3* design because he badly needed the cash.[17] At least this way the Navy could have the confidence that they would get boats with known and trusted features. In a surprisingly nimble move, Lake started construction on *S-14* to *S-17* before *S-2* was even launched, and while his yard still littered with incomplete R-boats.

The team at Portsmouth was anxious to demonstrate what they could do, and they promptly got the construction of their S-boats underway. *S-3, S-4,* and *S-5* were all under construction before BQ started on *S-1.* They laid down the initial boats two at a time on the yard's long, covered building slips (Fig. 5). This allowed continuous work on the boats, even during the harsh Maine winter, and this was undoubtedly a factor in their relatively speedy completion times. Just as they started work, both anecdotal and verified intelligence reports from overseas filtered back, indicating that German U-boats were having great success with stern-mounted torpedo tubes. Accordingly, C&R modified the plans for *S-10* to *S-13* to incorporate a single stern tube. This redesign work delayed these boats quite a bit.

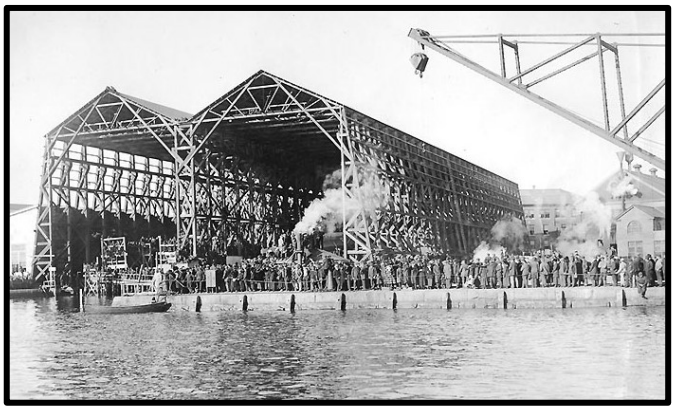

Fig. 5. Covered building ways at Portsmouth Navy Yard, 10 November 1919 at the launch of S-5. NHHC photo via Navsource.org

THE DETAILS

Much of the data in the chart below was pulled from Norman Friedman's seminal work, *U.S. Submarines Through 1945: An Illustrated Design History.* Wanting to get a feel for how the various shipyards performed during S-boat construction, I decided to take a look at the numbers by computing the cumulative time that each builder took during the two distinct periods of construction (Table 1). I found that the numbers confirmed earlier beliefs, but they also provided some surprising revelations. Keep in mind that this table shows only the S-boats. All four yards were still building *O*- and *R*-class submarines as the new class were being laid down. In fact, *O-1* and *S-3* were built side-by-side in the old Franklin Shiphouse at PNY.

TABLE 1: S-BOAT DATES AND CONSTRUCTION TIMES

BOAT	BUILDER	LAID DOWN (LD)	LAUNCH (L)	LD-L CUMULATIVE TIME (DAYS)	COMMISSION DATE (C)	L-C CUMULATIVE TIME (DAYS)	LD-C TOTAL CONSTRUCTION TIME (DAYS)
S-1	EB/BQ	11-Dec-17	26-Oct-18	319	5-Jun-20	588	907
S-2	LTB	30-Jul-17	15-Feb-19	565	25-May-20	465	1030
S-3	PNY	29-Aug-17	21-Dec-18	479	30-Jan-19	40	519
S-4	PNY	4-Dec-17	27-Aug-19	631	19-Nov-19	84	715
S-5	PNY	5-Dec-17	10-Nov-19	705	6-Mar-20	117	822
S-6	PNY	29-Jan-18	23-Dec-19	693	17-May-20	146	839

BOAT	BUILDER	LAID DOWN (LD)	LAUNCH (L)	LD-L CUMULATIVE TIME (DAYS)	COMMISSION DATE (C)	L-C CUMULATIVE TIME (DAYS)	LD-C TOTAL CONSTRUCTION TIME (DAYS)
S-7	PNY	29-Jan-18	5-Feb-20	737	1-Jul-20	147	884
S-8	PNY	9-Nov-18	21-May-20	559	1-Oct-20	133	692
S-9	PNY	20-Jan-19	17-Jun-20	514	21-Feb-21	249	763
S-10	PNY	11-Sep-19	9-Dec-20	455	21-Sep-22	651	1106
S-11	PNY	2-Dec-19	7-Feb-21	433	11-Jan-23	703	1136
S-12	PNY	8-Jan-20	4-Aug-21	574	30-Apr-23	634	1208
S-13	PNY	14-Feb-20	20-Oct-21	614	14-Jul-23	632	1246
S-14	LTB	7-Dec-17	22-Oct-19	684	11-Feb-21	478	1162
S-15	LTB	13-Dec-17	8-Mar-20	816	15-Jan-21	313	1129
S-16	LTB	19-Mar-18	23-Dec-19	644	17-Dec-20	360	1004
S-17	LTB	19-Mar-18	22-May-20	795	1-Mar-21	283	1078
S-18	EB/BQ	15-Aug-18	29-Apr-20	623	3-Apr-24	1435	2058
S-19	EB/BQ	15-Aug-18	21-Jun-20	676	24-Aug-21	429	1105
S-20	EB/BQ	15-Aug-18	9-Jun-20	664	22-Nov-22	896	1560
S-21	EB/BQ	19-Dec-18	18-Aug-20	608	24-Aug-21	371	979
S-22	EB/BQ	6-Jan-19	15-Jul-20	556	23-Jun-24	1439	1995
S-23	EB/BQ	18-Jan-19	27-Oct-20	648	30-Oct-23	1098	1746
S-24	EB/BQ	1-Nov-18	27-Jun-22	1334	24-Aug-23	423	1757
S-25	EB/BQ	26-Oct-18	29-May-22	1311	9-Jul-23	406	1717
S-26	EB/BQ	7-Nov-18	22-Aug-22	1384	15-Oct-23	419	1803
S-27	EB/BQ	11-Apr-19	18-Oct-22	1286	22-Jan-24	461	1747
S-28	EB/BQ	16-Apr-19	20-Sep-22	1253	13-Dec-23	449	1702
S-29	EB/BQ	17-Apr-19	9-Nov-22	1302	22-May-24	560	1862
S-30	EB/BSF	1-Apr-18	21-Nov-18	234	29-Oct-20	708	942
S-31	EB/BSF	13-Apr-18	28-Dec-18	259	11-May-22	1230	1489
S-32	EB/BSF	12-Apr-18	11-Jan-19	274	15-Jun-22	1251	1525
S-33	EB/BSF	14-Jun-18	5-Dec-18	174	18-Apr-22	1230	1404
S-34	EB/BSF	28-May-18	13-Feb-19	261	15-Jun-22	1218	1479
S-35	EB/BSF	14-Jun-18	27-Feb-19	258	17-Aug-22	1267	1525
S-36	EB/BSF	10-Dec-18	3-Jun-19	175	4-Apr-23	1401	1576
S-37	EB/BSF	12-Dec-18	20-Jun-19	190	16-Jul-23	1487	1677
S-38	EB/BSF	15-Jan-19	17-Jul-19	183	11-May-23	1394	1577
S-39	EB/BSF	14-Jan-19	2-Jul-19	169	14-Sep-23	1535	1704
S-40	EB/BSF	5-Mar-19	5-Jan-21	672	20-Nov-23	1049	1721
S-41	EB/BSF	17-Apr-19	21-Feb-21	676	15-Jan-24	1058	1734
S-42	EB/BQ	16-Dec-20	30-Apr-23	865	20-Nov-24	570	1435
S-43	EB/BQ	13-Dec-20	31-May-23	899	31-Dec-24	580	1479
S-44	EB/BQ	19-Feb-21	27-Oct-23	980	16-Feb-25	478	1458
S-45	EB/BQ	29-Dec-20	26-Jun-23	909	31-Mar-25	644	1553
S-46	EB/BQ	23-Feb-21	11-Sep-23	930	5-Jun-25	633	1563

BOAT	BUILDER	LAID DOWN (LD)	LAUNCH (L)	LD-L CUMULATIVE TIME (DAYS)	COMMISSION DATE (C)	L-C CUMULATIVE TIME (DAYS)	LD-C TOTAL CONSTRUCTION TIME (DAYS)
S-47	EB/BQ	26-Feb-21	5-Jan-24	1043	16-Sep-25	620	1663
S-48	LTB	22-Oct-20	26-Feb-21	127	14-Oct-22	595	722
S-49	LTB	22-Oct-20	23-Apr-21	183	5-Jun-22	408	591
S-50	LTB	15-Mar-20	18-Jun-21	460	20-May-22	336	796
S-51	LTB	22-Dec-19	20-Aug-21	607	24-Jun-22	308	915
		AVERAGES:	EB/BQ	926		658	1584
			EB/BSF	294		1236	1529
			PNY	581		321	903
			LTB	542		394	936

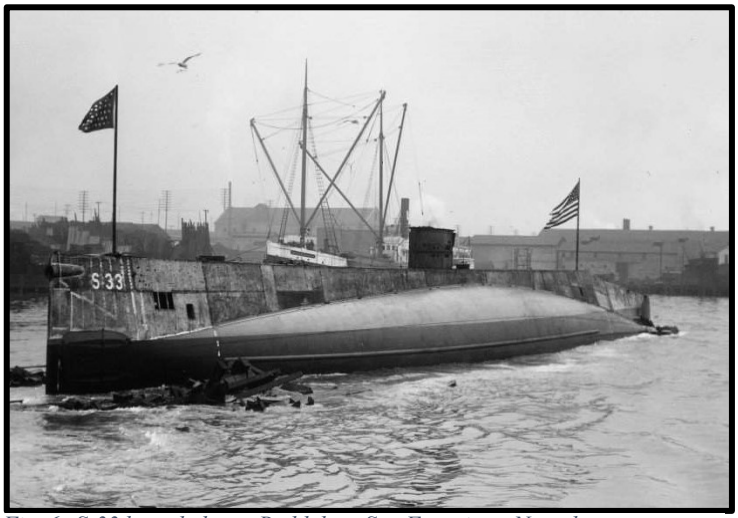

Fig. 6. S-33 launch day at Bethlehem San Francisco. Note the spartan state of completion of these boats at launch. BQ did far more work on the ways. NHHC photo courtesy Darryl Baker and Navsource.org

In general, the numbers will illustrate the differences in operating philosophies between the yards. PNY, BQ, and LTB did the majority of the work while the boat was still on the building slip, with an average of 59 percent of the work completed before the boat was launched. BSF operated very differently, choosing to complete only 19 percent of the work on the ways, launching the boats with just the basic shell complete, clearing the ways for the next hull (Fig. 6). PNY and LTB in particular operated with a much smaller waterfront and thus adopted this method to compensate. BSF had a comparatively roomy waterfront and thus could afford to get the boats off the ways and into the water quicker, finishing the work during the alongside fitting out period. With BQ and BSF owned by the same company, it was surprising to note the extreme difference in LD-L, which highlighted the operational differences from the two former competitors. In the end, neither yard's method proved to be substantially more efficient than the other, as the LD-C difference was only an average of 55 days.

In general, there was a slowdown in construction times after the Armistice was signed,[18] and the numbers bear this out. This is not unexpected, with the changing priorities as the country shifted back to a peacetime economy. However, the numbers also show that PNY actually got more efficient in LD-L as they learned more about the process. It looks as if BQ was struggling with supplier or labor issues, as their LD-L was very inconsistent.

LTB's numbers were quite erratic, their inconsistency illustrating the management difficulties they experienced. Surprisingly, their LD-C numbers for *S-48* to *-51* (the second group of Government design boats they built) were actually better than their first group (*S-14* to *-17*). This may have reflected a maturity and familiarity with building the Government design as they moved along, but contradicts the fact that by 1922 the company was operating on the thinnest of economic shoe-strings. Given Lake's poor performance

in delivering his contracted *O-* and *R-* class boats, I found it very surprising that his average LD-C times compared favorably with PNY. It is indeed ironic to consider that poor delivery performance by Lake was the prime stated reason for C&R to not give him any further contracts for his unique *S-2* design. Given his performance in building copies of the Government's design, it is reasonable to speculate that he might have actually been able to deliver *S-2* copies within an acceptable period had he been given the chance.

Portsmouth did quite well when compared to the other yards. With the proviso that this was the first large scale construction effort at the yard, this is even more remarkable. *S-3* was completed and commissioned in an astounding 519 days. Indeed, *S-3, S-4,* and *S-5* were all in commission and operating before *S-1* even started builder's trials. Their LD-C times were considerably better than the other three yards. This is highlighted by the fact that for the first two and a half years of operation (30-Jan-19 to 24-Aug-21) the Navy's S-class was made up of 15 boats, 12 of which were of the Government C&R design. It should be noted, however, that PNY built only submarines and thus could afford to specialize and were not distracted by other shipbuilding projects in the way that BQ and BSF were.

THE DEVIL

Perhaps the most surprising aspect of the data from Table 1 was the fact that EB's contracted yards were so overdue in delivering their boats that they made LTB look like a bargain in comparison. Simply looking at the dates of keel laying, launch, and commissioning does not drive home the severe production delays that both yards experienced. Once the figures were computed, it proved to be revelatory. The reason for the massive delays has never been a secret, but neither has it been extensively covered and reported on. That reason proved to be the devil in the details.

The first two boats of the EB design laid down were the *S-1* at BQ and the *S-30* at BSF. Construction on both proceeded relatively smoothly until builder's trials began. During trials in April 1920, *S-1* experienced severe vibrations in both engines as they demonstrated a full speed run. The vibrations got so bad that both engines were completely wrecked.[19] *S-30* experienced a similar disaster just a few weeks later. The experience proved to be a severe shock to the EB/BQ/BSF personnel, and it threw the production process into chaos.

EB had both yards install the NELSECO 8-EB-15 engine, rated at 600 hp, built at their subsidiary in Groton. The engine was a scaled-up version of the successful 6-EB-14 that was in the previous O- and R-class boats. The new engine had performed well in bench tests, but when installed in the boats and connected to the long, direct drive propeller shafts severe torsional vibrations set in at high speeds.[20] The extra power of the engine caused the crankshaft to twist along its length as each cylinder fired, then quickly snap back during the non-power strokes. The problem was exacerbated by the long propeller shaft and the resistance provided by the propeller in the water. Since the vibrations dampened down at lower speeds, the immediate solution was to simply run the engines at lower than the critical speed. However, this meant that the boats could not make their designed-for and contracted-for maximum speed, thus placing EB in violation of the terms of their contract. Torsional vibration was a poorly understood phenomenon at this early point in internal combustion engine development, and the root cause was difficult to determine.

The immediate result of the engine debacle was that the construction pace of the remainder of the EB S-boats slowed considerably. This is shown rather dramatically by the numbers in the table, with the LD-L and the L-C numbers for both yards skyrocketing. EB representatives and the C&R managers immediately entered into a rancorous debate on how to manage the fiasco. EB attempted to argue that the problem was not one of design, but one of a flaw in the manufacturing of the crankshafts by a NELSECO sub-contractor.[21] C&R's research indicated that the problem lay in the diameter of the crankshaft, which

was too small for the increased power of the engine. They suggested increasing the diameter of the crankshaft to eight inches,[22] which would be better able to handle the increased engine power without twisting. EB understandably balked at this fix, arguing that the time and expense of completely rebuilding every engine would ruin the company. Both parties seriously considered simply re-rating the engines to a lower horsepower setting, but this was a bitter pill to swallow, as the Navy would have to accept boats that could not achieve their own published operational specifications, and EB would have to admit that they made a serious mistake.[23]

The numbers from the table indicate that at least two different philosophies were used to deal with the problem. Some boats were commissioned and then limped along at low speeds until a fix was implemented. Other boats lingered at the builder's yard waiting for the fix, with *S-39* spending an astounding 1535 days (4.20 years) at the fitting out pier, yet to be commissioned.

The Navy was in a terribly awkward position. Something had to be done or a majority of their submarine force was going to be virtually immobilized. Swallowing their pride, C&R settled the matter by offering EB an additional contract to rebuild the engines of all of their boats with a larger eight-inch crankshaft, the solution that all parties eventually agreed upon. This mollified the bottom-line concerned EB enough that they accepted. They expanded their NELSECO facility at Groton and immediately began work (Fig. 7). The boats that had already been commissioned limped under their own power to Groton, where they were decommissioned during the rebuild process. The others were towed down the coast from Quincy or sailed by EB personnel to Groton. The first into the Groton yard was the *S-20,* arriving in March 1922 without yet being commissioned. As more boats began arriving, EB added a third shift in early 1923 to accommodate the incoming boats.[24] Six of the BSF-built units (*S-36* to *S-41*) had the re-work done in San Francisco using parts shipped there from Groton and installed by NELSECO personnel sent cross-country for the purpose.[25]

Fig. 7. Newly commissioned S-18 sits with the still immobilized S-47 and S-44 alongside the EB owned engine repair barge Isaac L. Rice at the Groton company pier, 08 Apr 1924, four years after the S-18's launch. NARA photo courtesy Daniel Dunham via Navsource.org

As you study the numbers in Table 1, note that the times that the already commissioned boats spent sitting at the refit pier in Groton are not incorporated in the LD-C times. Those periods, which averaged six months, are *in addition to the already extended LD-C times*. Using *S-35* as an example, it took BSF 1525 days (4.17 years) for LD-C. The boat was in commission for two months, then spent another 6.5 months at Groton, decommissioned and immobilized. Adding 195 days to her LD-C time means that *S-35* was unusable by the Navy for 4.71 years. *S-18* stands out with a LD-C time of an incredible 2058 days (5.6 years). In this case the LD-C included the time spent at Groton undergoing engine rebuild.

All of the S-boats, including the PNY- and LTB-built units suffered from some sort of engine problems, although the issues faced by EB were by far the worst. LTB redeemed itself somewhat by using 4-cycle Busch-Sulzer diesels in the *S-14* to *S-17*, and these engines, although underpowered, operated quite successfully for the entire life of the boats. For the 2nd group (*S-48* to *-51*) the company went with a 900 hp 2-cycle Busch-Sulzer and these were quite well-liked, relative to the rest of the class.

THE IMMEDIATE AFTERMATH

All of this had a dramatic and unusual effect on the commissioning dates for these boats. Simply perusing the calendar dates in Friedman's book does not drive home the effect that the engine problems had on the commissioning dates. The layman's interpretation of how warships are built and commissioned is usually quite linear, i.e. the boats are commissioned in name order or hull number order. In the case of the S-class this couldn't be further from the truth. Table 2 illustrates how muddled the situation got with this class.

TABLE 2: S-CLASS BY COMMISSIONING DATE

BOAT	BUILDER	COMMISSION DATE		BOAT	BUILDER	COMMISSION DATE
S-3	PNY	30-Jan-19		S-48	LTB	14-Oct-22
S-4	PNY	19-Nov-19		S-20	EB/BQ	22-Nov-22
S-5	PNY	6-Mar-20		S-11	PNY	11-Jan-23
S-6	PNY	17-May-20		S-36	EB/BSF	4-Apr-23
S-2	LTB	25-May-20		S-12	PNY	30-Apr-23
S-1	EB/BQ	5-Jun-20		S-38	EB/BSF	11-May-23
S-7	PNY	1-Jul-20		S-25	EB/BQ	9-Jul-23
S-8	PNY	1-Oct-20		S-13	PNY	14-Jul-23
S-30	EB/BSF	29-Oct-20		S-37	EB/BSF	16-Jul-23
S-16	LTB	17-Dec-20		S-24	EB/BQ	24-Aug-23
S-15	LTB	15-Jan-21		S-39	EB/BSF	14-Sep-23
S-14	LTB	11-Feb-21		S-26	EB/BQ	15-Oct-23
S-9	PNY	21-Feb-21		S-23	EB/BQ	30-Oct-23
S-17	LTB	1-Mar-21		S-40	EB/BSF	20-Nov-23
S-19	EB/BQ	24-Aug-21		S-28	EB/BQ	13-Dec-23
S-21	EB/BQ	24-Aug-21		S-41	EB/BSF	15-Jan-24
S-33	EB/BSF	18-Apr-22		S-27	EB/BQ	22-Jan-24
S-31	EB/BSF	11-May-22		S-18	EB/BQ	3-Apr-24
S-50	LTB	20-May-22		S-29	EB/BQ	22-May-24
S-49	LTB	5-Jun-22		S-22	EB/BQ	23-Jun-24
S-32	EB/BSF	15-Jun-22		S-42	EB/BQ	20-Nov-24
S-34	EB/BSF	15-Jun-22		S-43	EB/BQ	31-Dec-24
S-51	LTB	24-Jun-22		S-44	EB/BQ	16-Feb-25
S-35	EB/BSF	17-Aug-22		S-45	EB/BQ	31-Mar-25
S-10	PNY	21-Sep-22		S-46	EB/BQ	5-Jun-25
				S-47	EB/BQ	16-Sep-25

Note that the last boat in name sequence, the *S-51,* was commissioned over three years before the last EB design boat to be completed, the *S-47.* Table 2 seemingly backs up the averages computed in Table 1, in that BQ was definitely the slowest of all four yards. In their defense, there were two mitigating factors. First, many of the BQ units were sent to Groton for the engine work *before* they had been commissioned, mostly because it was a relatively short trip from Quincy to Groton. Secondly, the boats of the *S-42* to *S-47* group were of a revised design, being six feet longer and 33 tons heavier. The redesign effort by EB resulted in these boats being the last to be laid down and the last to be completed. Their slower completion times were due to both the lessened urgency of the post-WWI environment and because of the engine rework.

PNY's last boat commissioned was the *S-13,* part of their four boat 2nd series that had been redesigned with a stern torpedo tube. These four boats were also equipped with improved Kingston valves in the main ballast tanks, a turbo blower for the final emptying of the MBTs, and better pumps and air

compressors. With a more reliable 1,000 hp BuENG MAN diesel they were considered vast improvements over the first series, *S-3* to *S-9*.[26]

As both tables indicate, LTB worked through their contracts and came out in a respectable position when compared to the other yards. They mostly dodged engine problems by the fortunate adoption of Busch-Sulzer engines. In fact, their first group of Government design boats, *S-14* to *S-17,* were among the best liked boats of the whole class.[27] Their 2nd group consisted of *S-48* to *S-51,* and these boats turned out to be the largest of the entire class. Lengthened by nine feet, they incorporated a separate maneuvering room in addition to the stern torpedo tube. *S-48,* the last of the LTB boats commissioned, still preceded into service three of the PNY boats and 22 of the EB design boats.

AND FINALLY… REDEMPTION

The S-boats were the largest class of submarines built for the USN prior to WWII, making up the bulk of the submarine force during the 1920s and 30s. Their ubiquitous nature made them iconic, but they also gained a measure of infamy as well. *S-4* and *S-51* were sunk in collisions with heavy loss of life,[28] and their wrecks were salvaged in dramatic fashion. *S-5* was lost to a diving accident, but her crew was saved in an equally drama-filled episode. *S-48* sank on trials while still under the ownership of LTB. She was salvaged and repaired but ran aground several years later and was heavily damaged. She was repaired and heavily modified in a one-off scheme to turn some of the S-boats into near-Fleet Submarines. *S-19* ran aground and was repaired, and *S-50* suffered a severe fire. Tarnished image notwithstanding, the service moved on with the boats, the engine issues now in the past.

Despite the success of C&R's design process, most of the boats of the Government design, saddled with slow diving times and sluggish underwater performance, proved to be less than optimal and disliked by the force. They were among the first boats to be discarded once the terms of the London Naval Treaty were enacted. However, with their stern torpedo tubes and upgraded equipment, *S-11* to *S-13* and *S-48* were retained, along with *S-14* to *S-17* with their Busch-Sulzer engines. They served all the way to the end of WWII.

The EB-design boats finally found their sea legs once the engine issue had been rectified. They turned in excellent service after that and could be found in every theater of operation, from the East Coast down to the Caribbean, the Panama Canal area, the Pacific coast, Alaska, Hawaii, and the Far East. They received upgraded safety modifications in the wake of the *S-4* disaster and were considered for a modification scheme similar to what was done to *S-48.* However, their single hull design proved to be non-optimal for the upgrade, and studies showed that building a whole new class to meet a Fleet Submarine standard was a more efficient route. The scheme was dropped after *S-48.*[29]

The S-boats soldiered on through the 30s, turning in yeoman service to the fleet. They were on the front line in the Philippines when hostilities commenced, with several racking up impressive war records despite their antique status. In particular, *S-44* gained some level of revenge in the aftermath of the Savo Island defeat by sinking the heavy cruiser *Kako* with a four torpedo spread. Some of the 20 S-series boats were transferred to the Royal Navy and to the Free Polish Navy, but the rest served in at least a training capacity (minus the tragic war losses) with the USN to the end of 1945.

S-class construction proved to be the swan song of the Lake Torpedo Boat Company. With the dearth of submarine construction brought on by the post war armament drawdowns, the already fragile company shuttered its doors for good in 1924. Simon Lake went on to engineer several commercial salvage projects during the remainder of his life and even took one of his company-built O-boats, the

decommissioned *O-12* (SS-73) in hand for modifications for Sir Hubert Wilkins' 1931 Arctic expedition. He died at his home in Milford, CT, just as the war was closing in 1945.

The design and construction of the S-class proved to be a watershed event in the history of the USN submarine service. The performance of the naval architects, engineers, and workmen at Portsmouth Navy Yard had proved the value of C&R's involvement in submarine design and construction. Never again would the service just stand by and accept whatever was offered them. The Navy had finally taken the reigns of the submarine acquisition process, and its entirely successful outcome set the stage for the tremendous progress that lay ahead.

Lastly, Electric Boat was left with a mixed legacy in the wake of the engine fiasco. Once they finished the rebuild work on the *S-47* in the fall of 1925, not a single submarine was built by the company for the USN for the next six years. The navy yards at Portsmouth and Mare Island were given steady work on the V-class fleet submarines, but EB was left with nothing until the end. This six-year banishment was directly related to the fallout of the engine fiasco. Several of the early V-class could have been given to EB but they weren't. This was a pointed message to the company management that the Navy was no longer going to bow down. To their credit, the company managers refused to go the way of LTB. They developed an aggressive and broad-based diversification strategy that had the company building everything from printing presses to fish skinning machines. They even repaired electric hair curlers for local beauty salons. To keep their shipbuilding skills sharp, they expanded the facilities in Groton to a full shipyard and did overhaul work on Coast Guard vessels, yachts, and merchant ships. A contract was awarded to them in 1925 by Peru to build four R-class submarines for their Navy, and these were the first submarines built at the Groton yard.[30] The company emerged from this period stronger than ever, and in 1931 was awarded a contract for the last V-boat *Cuttlefish* (SS-171). Their work on that boat was highly regarded, and it was the beginning of a new and symbiotic relationship with the Navy that continues to this day.

The tarnish of the devil in the details had been polished off, and the S-boats have left a strong and enduring legacy that the USN Submarine Service can be proud of.

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