THE T-CLASS FLEET SUBMARINES 1916-1927:
AN ANALYSIS OF FAILURE

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The USN's first attempt at building a submarine capable of operating as a direct adjunct to the fleet battle line was the T-class of 1916 and 1917. It was not a good experience, and the failure of these boats was a blow to the ambitions of the still nascent Submarine Service.

The genesis of this class and the whole fleet submarine concept came from a November 1911 article in a British trade magazine that described a 950-ton, 17 knot boat that Electric Boat (EB) was building for Russia. The reported capabilities of this boat alarmed the submarine service in the USN and an insistent call for a "fleet-type submarine" immediately rose up within the community. The Navy's Bureau of Construction & Repair (C&R) immediately set to work developing the requirements for a design, trying to meet some rather unrealistic capabilities desired by the submarine community, which were inspired by war games at the Naval War College in 1912. Ranges of 5,000 nm at surface speeds up to an utterly unrealistic *30 knots,* submerged speeds of up to 5 knots, and armament that included deck mounted trainable torpedo tubes. These were extraordinary capabilities that far exceeded anything that the USN had built before, and as it turned out, would be very nearly impossible to achieve with the state of the art that existed in 1912-1915.

The design that was eventually decided on was proposed by (of course) EB and labeled internally by the company as design 63A. To achieve the long ranges desired the boat had to have an enormous fuel capacity and thus had to be a large boat. As built it was 268 feet 9 in. long, 22 feet 4 in. wide, and displaced 1,106 tons on the surface and 1486 tons submerged. It was to have four 18-inch torpedo tubes forward with two sets of twin trainable tubes inside the superstructure fore and aft of the conning tower. These trainable tubes could be swung out to either side giving the boat a theoretical "broadside" torpedo salvo capability. The designed specifications called for a maximum speed surfaced of 20 knots and 10.5 to 11 knots submerged. It was the intention to have the boats operate as a direct adjunct to the main fleet battle line of battleships and battle cruisers. They were to operate out ahead of the battle line, locate the enemy force, report on their location, speed, and course, and then conduct whittling down attacks to disrupt their formation and thus their concentration of firepower.

Lawrence Spear, EB's normally brilliant designer and John Holland's direct successor, developed the basic design and worked with the equally brilliant Hugo Grieshaber and R.C. Simpson on the detailed design. They were forced to make compromises in the attempt to get the needed performance. Although they can't be held responsible for the unrealistic expectations of the

Navy's tacticians and for what was unknown in the technical realm, their design choices ended up dooming the boats in the end.

There was a lot of pressure to get these boats off the drawing board and out to the fleet. The perceived threat of the Russian boats, combined with (as it turned out) largely exaggerated reports of high speed, long range submarines being developed by the Germans, the French, and the British pushed C&R and EB quite hard. Prior to this time EB had built mostly small and medium sized single hull submarines, with all of the tankage and machinery contained within the pressure hull. It was not feasible to simply expand a single hull design because once you did so it required that the hull plating and internal frames be enlarged and thickened to the point where they became unreasonably heavy. So, Spear turned to an enlarged version of the design that they had proposed for the Russians (EB 31A), which had a partial double hull. In this hull type, the inner pressure hull is wrapped by an outer hull, and the void spaces in between are used for fuel and ballast tanks. In EB 63A this double hull was faired into the inner pressure hull in the areas around the torpedo room forward and the auxiliary machinery room aft, thus the term "partial double hull". To avoid major departures to the existing hull construction practice for EB 31A, Spear decided to just expand out that existing full double hull and frame design without thickening the hull plating or beefing up the frame members. This resulted in the AA-class (eventually renamed the T-class) having a 150-foot test depth. When you consider that these boats were 268 feet long, this made for a very constricted operating envelope. With even a moderate down angle while diving, the stern would still be on the surface while the bow could be below its theoretical crush depth, vice-versa upon surfacing. A diving plane jam dive or operator inattention could become critical very fast.

Expanding out an existing design resulted in a very complicated tank arrangement. In some cases tanks were inside or on top of another, resulting in obvious complications in piping and venting. The boats were slow divers and even with training the crews were only able to achieve a fully surfaced to periscope depth time of approximately 2 minutes 30 seconds. They were somewhat unstable while in the transition from submerged to surfaced, sometimes resulting in large angles of heel until the tanks were fully dry. The ballast tank arrangement resulted in a lower than expected amount of reserve buoyancy, and when combined with a low and narrow bow the boats tended to trim down forward at high speeds on the surface, resulting in a very wet deck all the way back to the bridge.

Because the torpedo technology and the aiming and launching systems of the day were unable to angle the fire of torpedoes, a submarine had to aim itself to lead the target, in the way that a hunter has to lead a running animal in order to hit it. Because of this, dual trainable single shot deck tubes were installed in the superstructure in an attempt to give the boat some flexibility in how it approached its target. These tubes proved to be difficult to rig out underway and because of the limitations of the periscopes and slide-rule computers used to determine a fire control solution, they proved to be very inaccurate. It was also impossible to perform maintenance on the weapons in these tubes while at sea, furthering the accuracy problems. The forward set of tubes on *AA-1/T-1* were removed during her trials, and the after set removed a few months later. *T-2* and *T-3* were follow-on boats authorized in Fiscal Year 1917. The delay in their construction was

fortuitous as the deck tubes had been already shown to be a failure and they were never installed on either boat.

The single most vexing problem facing Spear and his team was the 20 knot surfaced speed requirement. The Germans had made impressive advances in diesel engine technology, but American industrial practices and metallurgy science lagged behind the Germans and the state-of-the-art of diesel engine development in the USA was underdeveloped. The T-class were diesel-direct drive submarines, meaning that the main propulsion diesels were connected directly to the propeller shafts. True diesel-electric drive boats were over a decade away technologically. No existing diesel plant in the USA could provide enough power in a small enough package to fit in the hull. Thus, Spear chose to mount two existing NELSECO (an EB subsidiary) 6-EB-19 four cycle 1000 hp engines to each shaft, with the aft end of the crankshaft on the forward engine connected via a clutch to the forward end of the crankshaft for the aft engines. The initial difficulty came from the inability to precisely match the speed of both engines. There were obviously no computerized control systems in those days and the manual systems were not up to the task. Even a minor speed mismatch resulted in each engine fighting the other. When combined with the high power of the engines this caused severe torsional vibrations that threatened to tear the engines and mounts apart.

Strangely, the tandem engine arrangement had been tried on the earlier Lake-designed *G-2* (Submarine No. 27) and the Laurenti-designed *G-4* (Submarine No. 26). Even though the engines used on these boats were gasoline powered, the tandem concept proved a failure on these boats for many of the same reasons stated here. Unfortunately, this failure lesson was not available to Spear, Grieshaber, and Simpson because these boats were still in the very early stages of their service and the depth of the tandem engine issue was not known when the men designed the AA/T-class

It proved un-workable to run both engines on each shaft while the boat was running at lower speeds. If run this way it resulted in a light load condition for all four engines. Running diesels at low power settings for long periods prevents them from developing the necessary heat to fully burn all the fuel injected into the cylinders. So, they smoke excessively and get carbon buildup in and around the pistons from the partially burnt fuel, causing ring wear and scored cylinders. This results in reduced or uneven compression. The ultimate outcome was poor fuel economy, excessive vibration, and shortened component life. The immediate fix to this problem was to simply declutch the forward engines and shut them down so that the aft engines could run at higher power settings with an optimum heat load. With the aft engines getting a lot more use they wore out faster than the forward engines. When high speed was needed the relatively unused forward engines were started and clutched in, causing an unbalanced situation with the heavily used aft engines, greatly aggravating the torsional vibration problems.

Because of this, engine reliability was quite poor. The boats struggled to make their designed speed (the whole rationale for their existence), and even then could only maintain it for short periods of time. The engines were maintenance nightmares and the boats spent a lot of time in overhaul. For example, *T-3* completed only four of 13 full power trials, and even one of the four very nearly failed. Judged to be failures, each spent less than three years in commission, with most

of that time spent tied to the pier. *T-3* was recommissioned in 1925 to test out a new M.A.N. engine design, but once those tests were completed it was promptly discarded.

The T-class was a clear case of high ambition outweighing the existing technology. A high-speed, long-range submarine was a good concept, but it could not be supported by the technology in existence in 1913/14 when the boats were designed. However, the T-class were valuable from the standpoint of showing the designers what didn't work. Their failure put Lawrence Spear and his contemporaries at Electric Boat and the USN on the path that led to the successful fleet boat designs of the mid to late 1930's.