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How to Sink a Submarine

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Introduction

The Canadian Navy did not set out to be an anti-submarine warfare (ASW) force but events conspired to make it one. Consequently, the Canadian War Museum's collection of naval artifacts includes a fair assembly of weapons used throughout its history by the Navy in its prosecution of submarines. In theory, it should not be hard to sink a submarine – submariners do it all the time (with the objective of reversing the process of course). This has two consequences: the submarine has limited buoyancy when submerged (and often on the surface as well) which means that often very little damage to the hull will be fatal. However, because it is designed to take great pressure, a submarine's pressure hull is quite thick for a small vessel making that limited damage difficult to inflict.

World War I

Up to 1914 the Royal Navy (RN) had written off the submarine as a major threat to its fleet and merchant marine and consequently had not pursued means to destroy it or detect it underwater. The rapid loss of six cruisers in the opening months of World War One quickly disabused it of this attitude and lead to a scramble to find a response. Some initial attempts were almost comical: arming blacksmiths with hammers to hit periscopes; encouraging seagulls to foul the optics; or training explosive laden seals to associate submarines with free food (turns out seals could not tell submarines from surface ships). The difficulty in killing a submarine of course lies in finding it in the first place and some of the more serious early weapons attempted to combine the two operations. Indicator nets, explosive-armed grappling hooks, long wire sweeps rigged with explosives and a depth keeping kite, and explosive equipped paravanes were all experimented with before the war with limited success. The only practical way of finding a submarine was visually – either by surprising it on the surface or by sighting a periscope. If the submarine dived quickly (which they were designed to do) a method of attacking its estimated submerged position at relatively high speed was needed.

The solution involved modifying a mine by equipping it with a float and a lanyard of a set length connected to the mine's detonator. When the falling mine started to pull the float down the lanyard would activate the detonator. These devices proved cumbersome to handle and the lanyards often got tangled, setting the weapon off early. However in 1915 a practical depth charge using a hydrostatic fuse set to operate at 40 and 80 feet was developed. This "Type D" version, with 300 pounds of TNT or Amatol explosive, had a danger radius of about 140 feet against the boats of the day and became the principal depth charge used by the allies in the first war. Further refinements to the arming system involved a hydrostatic chamber with various sized holes exposed to flooding by turning a depth setting key, which operated a bellows that cocked the charge's firing pin. . Ships were initially only provided with two or four of these weapons but by the end of the war, destroyer sized vessels were armed with as many as 50. Such a large weapon posed a problem for the many smaller vessels that characterised the extemporized ASW forces of the day. A 300 pound charge detonated close to a small, slow moving fishing drifter or converted yacht could seriously damage it. Consequently, a small depth charge, the Type G, with 45 pounds of explosive and set to 40 or 80 feet was developed for use as a secondary weapon in large ships and as the principal depth charge in the launches, patrol boats, converted yachts, drifters and trawlers which were just about the only type of vessel found in the RCN in World War 1. The museum's example is therefore a good representation of the state of the art in Canada at the time.


Figure 1: CWM's Type G Depth Charge

The Depth Charge had its first success in March 1916 and by the end of the War was involved in the destruction of about 38 U-boats (none by Canadians) or about 20% of all combat losses. Its main limitation lay in the fact that there was no practical way of locating a submerged U-boat. ASDIC would change all that – sort of….

World War II

The submarine problem had largely been solved by 1939 by the invention of the depth charge coupled with a system of locating a submerged vessel – or so the RN thought. ASDIC[1] transmitted a short supersonic pulse from a circular quartz transmitter and listened for a returning echo. This device (initially fit as the Type 123 ASDIC and later, with a range recorder as the Type 144) could, under good conditions get contact on a U-boat out as far as 2500 yards (although 1300 yards was more typical). The Type D charge was still available in large numbers and had been updated slightly as the Mk VII (weighing 420 lbs with 290 lbs of amatol explosive). This weapon sank at 7 ft/sec, and could be set to detonate at up to 300 ft (later increased to 900 ft). A Mk VII Heavy with a more rapid 17 ft/s sink rate was introduced in 1940 with the simple expedient of adding a 150 lb weight to one end.

Charges were dropped either from launch rails located on the quarterdeck or depth charge throwers situated at the waist of the ship. Depth charge throwers had been developed in WWI

[1] ASDIC does <u>not</u> stand for Allied Submarine Detection Investigation Committee, although that was the Admiralty's cover story as told to Oxford University in 1939. The term first appeared in 1918 and probably was made up from "Anti-Submarine Division – *ics*" from the Admiralty group first investigating an echo transmitter device for detecting U-Boats.

and the model of HMCS Chambly shows her fitted with the Thornycroft Mk II. This device fired a charge strapped to an expendable stick arbor some 50 to 70 yards from the ship's side (depending on the charge weight). Later the Mk IV thrower was introduced which retained the arbor (using lateral recoil chambers either side) throwing the charge another 10 yards and allowing for more rapid loading. (The museum example is a Mk IV thrower armed with a Mk VII light depth charge. The model of HMCS Swansea shows the placement of the Mk IV throwers and associated loading system.)


Figure 2: Mk IV Depth Charge Thrower with a Mk VII light DC loaded

The submarine problem had not been solved of course – for all that the WWII German Type VIIC U-boat was little changed from its WWI ancestor. One change they did make was in the pressure hull by using of lighter framing to allow a thicker pressure hull made with improved, welded steel. The result was not only a boat that could dive deeper (making accurate depth charging much more difficult) but one that could better withstand the shock from a charge. A Mk VII charge could split such a boat only if detonated within 20 feet (though the submarine would probably be forced to the surface by a charge placed twice that distance). This, combined with another limitation of ASDIC, severely limited the potential of the depth charge against a submerged U-boat.


Figure 3: Quarterdeck arrangement of HMCS Swansea set to deliver a 10 charge pattern.

That limitation was inherent in the design of the ASDIC transducer. Unable to tilt in the vertical, the Type 144 ASDIC would lose contact on a submarine as the attacking ship approached it. The further away contact was lost, the deeper the target was. This "dead time" combined with fall time of the depth charge meant that the ship was out of contact for a minute or more before the charge went off – in which time the boat could have moved up to 300 yards. Even with a 'Q' attachment fitted allowing contact to be maintained until much closer, contact was always lost before an attack was made.

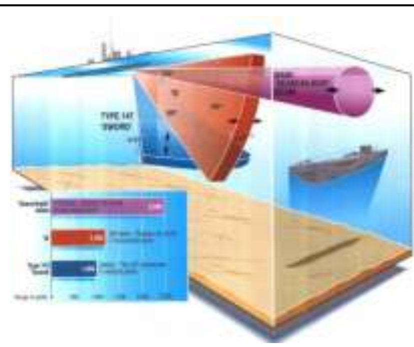
Figure 4: Typical late war ASDIC set coverage

The response to this was to increase the number of charges dropped and to disperse them more widely. The ten charge attack became typical early in the war for vessels equipped with four depth charge throwers and two racks. Against a 75 foot deep target, an attack would be mounted with a launch of a heavy Mk VII charge from a stern rail followed three seconds later by two heavies from the forward throwers and a light Mk VII from the other rail and a heavy from the first rail. Eight seconds later two lights were launched from the after throwers and another heavy and light from the rails. Shortly afterwards, another light charge would be launched from the rails. This produced two diamond pattern charges usually set at different depths, detonating almost simultaneously.

However even with all of this high explosive (Amatol was replaced with the more powerful Minol later in the war) the success rate of the depth charge was never much better than about 5%. What was needed was a weapon that could be fired ahead of the ship while it was still in contact. Various weapons were tried but the most ubiquitous in World War II was Hedgehog. This was a 24 pin spigot mortar firing a pattern of 65 pound bombs armed with contact fuses some 200 yards ahead of the ship in a 40 yard circle. It took the RN a while to learn how to use this weapon properly but by the end of the war a 20% success rate was being achieved[2]. The museum model of *Swansea* shows her fo'c'sle mounted Hedgehog weapon.

Figure 5: HMCS Swansea's Hedgehog mounting. Some mountings were roll stabilized

Hedgehog was not popular as it did not produce an explosion unless a hit was obtained which did not provide for much deterrent effect. What was wanted was a weapon that combined the advantages of an ahead throwing weapon and the depth charge. The late-war solution took the form of the Squid depth charge mortar. Squid had an additional advantage in that it was slaved to an attack system fed by a new ASDIC, the Type 147. This was a short range set which generated a horizontal acoustic fan-shaped beam that was angled up or down depending on the depth of the target. The angle and range data from this set were resolved to provide depth information that was used to set a clockwork time fuse in the 390 lb Squid bomb. The three barrelled mortar (an example of which is in the Lebreton Gallery) was offset so that the bombs would land in a 40 yard triangle some 270 yards ahead of the firing ship

Figure 6: The CWM's Squid mounting

[2] Indeed the most successful ASW mission of all was that of the destroyer escort *USS England* which sank six Japanese submarines with 12 Hedgehog salvoes over the course of eleven days.

(the bombs were aimed by pointing the ship). Castle class corvettes had a single mounting but Loch class frigates had two such mountings which allowed the fuses to be set with a 60 ft difference in depth to bracket the victim. Squid had a 30 to 50% success rate depending on whether a single or double mounting was used.

Ironically, given that almost half of the U-boats sunk by enemy action during World War II were sunk by aircraft, there is little in the museum on the RCAF effort (which is now thought to have accounted for some 17 boats). Initially aircraft were provided with depth bombs which failed to work properly and had fuses that were set too deep (given that an aircraft typically surprised a U-boat on the surface). This was corrected during the war and new fuses, together with the Minol explosive gave aircraft a deadly weapon. The museum does have a nice model of David Hornell's Canso (a Canadian built version of the PBY Catalina flying boat) which accounted for many of the RCAF's successes. Sunderland flying boats, Wellingtons, Liberators, Hudsons and Digbys (the Canadian version of the B-18) also scored some Canadian victories. However the most revolutionary airborne ASW weapon (introduced by the US but used by the RAF and RCAF late in the war) was the Mk 24 mine. Nicknamed 'Fido' this was not a mine at all but a passive acoustic homing torpedo with a speed of 12 knots and a range of 4000 yards. Armed with a 92 lb Torpex warhead it was first deployed in 1943. Some 346 were deployed resulting in 68 submarines sunk and a further 33 damaged – about three times as effective as airborne depth charges.

Figure 7: An RCAF Canso flying boat. Typically armed with aircraft depth bombs, it was the most common RCAF ASW aircraft of WWII. It was manufactured in Canada under licence.

Post-War

Naturally, the advances made in war time carried over into the Cold War period. The large, high speed German Type XXI boat never made it into production during the war (fortunately for the Allies) but the technology, much better executed, found its way into the navies of both NATO and the Warsaw Pact. The depth charge therefore rapidly became obsolete and weapons like Squid and Fido had to be upgraded to meet the new threat. The Canadian Navy backfit Squid into its surviving frigates but an improved version was supplied to the follow-on Canadian-designed St Laurent class destroyers. This was the Mk 10 'Limbo' ASW mortar which can be seen in the museum's models of HMCS Mackenzie, Nipigon and Assiniboine. Limbo fires the same bomb as Squid from a mortar slaved to an attack ASDIC (the Type 190) that is free to move in elevation and azimuth providing fire control data to the weapon through a large analog computer. With a range of 400 to 1000 yards it was able to fire in any direction to bracket the target with an interlocking pattern of bombs set to explode above and below the estimated depth.

Fido too, went through a number of improvements resulting in a ship launched version. The Mk 43 ASW torpedo was a small 12" diameter electric torpedo that was either dropped over the side of a ship or pitched out using a modified depth charge thrower to execute a helical spiral in the water searching for a target using its own active homing sonar. This device was soon replaced by a more sophisticated Mk 44 weapon now fired by compressed air from a triple torpedo tube (the Mk 32 included in the museum's Gallery IV collection). This too has been replaced by a liquid fuel Mk 46 weapon still in use today (fired from fixed tubes in the hanger of the Halifax class ships).

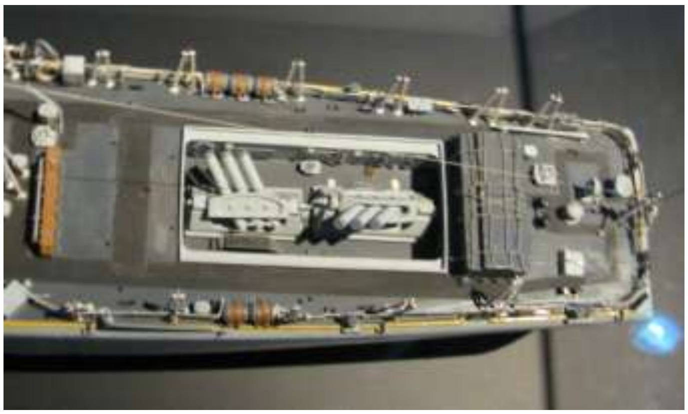
Figure 8: HMCS Mackenzie's twin Limbo mounting

Unfortunately for ASW forces, submarine technology has not stood still either. Submarine torpedoes now have sophisticated active and passive homing systems, wire guidance to defeat countermeasures, and wake homing capabilities that permit shots to be fired at surface ships over 20 miles away. The game really changed in 1954 with the launch of *USS Nautilus* – the world's first nuclear submarine. Not only does such a vessel have unlimited endurance and high speed, but its vast increase in electrical power generation means that it can create its own oxygen and support very large and sophisticated sensor and weapon systems. Within a few years of their launch, the RCN's Cold War St Laurent class destroyers were obsolete – attempting to engage a nuclear submarine with Limbo or short ranged ship-launched anti-submarine torpedoes was little short of suicide.


Figure 9: The CWM's Mk 32 ASW Torpedo tube launcher backfit into t he St Laurent classes and the DDH 280 ships

However, the St Laurent class was unusual for a small ship in that there was enough weight and space margin in the original design to permit a radical redesign. After a series of trials, HMCS Ottawa was re-launched in 1961 with the ability to launch and recover the Sea King helicopter in the typically rough North Atlantic operating conditions. The remaining ships in the class were similarly modified. The Sea King differed from the smaller helicopters then operated from allied destroyers in that it was able to operate its own dipping sonar and launch ASW torpedoes (like the Mk 46) independently of ship control. The destroyer could stand far off from the submarine danger area and launch its helicopter to attack the threat either alone or in conjunction with other helicopters and fixed wing aircraft. The device that made this possible was a Canadian invention called the Beartrap – a mobile helicopter haul down apparatus that winched the helicopter out of the hover and onto the rapidly pitching and heaving destroyer flight deck and trapping it securely on landing. It could then traverse it safely into the hanger where it could be tied down out of the weather. The museum has an example of one – unremarked and unlabelled – in the Lebreton gallery. The Beartrap and Sea King combination kept the Canadian navy in the ASW business long after the 20 year expected life span of its ships.

Figure 10: A CG 124BSea King Helicopter. This version is equipped with a radar and sonobuoys as well as an active dipping sonar


Figure 11: A Beartrap – to catch helicopters

The RCN sank some 32 Axis submarines during the War (either on its own or in cooperation with aircraft and/or Allied ships) – none of them in Canadian waters. It’s not that the U-boats did not operate there. Indeed they succeeded in shutting down shipping operations in the Gulf of St Lawrence in 1943. The reason for this lack of success lay partly in training, partly in poor equipment, and in some cases to downright bad luck. However a significant factor is the peculiar oceanographic conditions which persist in the Gulf and off the Atlantic coast. Large quantities of relatively fresh water either coming down from the St Lawrence or as coastal run-off overlie the saltier (and therefore more dense) oceanic water below and the two don't mix much no matter how cold the surface temperature gets. The result is that in summer time sonar beams from a hull-mounted sonar (like the Type 144 ASDIC) are bent up to the surface and remain trapped in a thin layer near the top of the water. In winter the beams are bent down sharply to be absorbed and scattered in the ocean bottom. ASDIC performance under these conditions is extremely poor. Indeed in one case a U-boat (*U-1232*) in the course of a submerged attack on a convoy at the entrance to Halifax harbour was rammed by the frigate *HMCS Ettrick*. The U-boat's conning tower was damaged but it returned home safely while Ettrick was unaware that it had actually been "in contact", quite literally, with a submarine. The solution to this problem is to get the submarine and the sonar in the same layer of water. Consequently a focus of post war research by the Defence Research Board was the development of a sonar set that could be towed at depth below the confounding surface layer. In some cases alternating negative and positive sound speed gradients focus the sonar beam like a searchlight mirror and detection ranges of over 10 miles can be obtained. The trick though is designing a system that will move quickly but smoothly through the water while being towed by a ship that is pitching violently in the typical operating conditions of the Canadian North Atlantic. An early version of this Canadian sonar development, the SQS 504 variable depth sonar, can be seen in the models of *HMCS Nipigon* and *Assiniboine* in the LeBreton Gallery. Later, a much more powerful sonar (the SQS 505), was also put in a bigger towed body operated from the DDH-280 and Improved Restigouche class frigates. This body, which looks like a large bomb, can also be seen in the LeBreton Gallery.

Stern of the CWM model of HMCS Nipigon showing the SQS 504 sonar (the orange body). The boom bobbing gear designed to reduce the impact of pitch and heave on the towed body and the reel of cable attaching it to the ship is shown along with the Sea King helicopter and the Limbo Mortar

SQA 502 VDS body housing the SQS 505 sonar on the DDH 280 destroyers and Improved Restigouche class frigates.

Of course another way of getting the sonar down at the depth where the enemy is operating is to submerge the entire ASW platform – that is by using a submarine to hunt other submarines. This is not new – even for the RCN. Indeed the first warships flying the White Ensign to transit the Panama Canal were the submarines

HMCS/M CC1 and *CC2*. These American designed boats had been hurriedly acquired for operations on the West Coast in the first week of World War One and when the situation in the Pacific had stabilized, were transferred via the Canal for patrol operations on the East Coast. They were too worn out to be much use however, and it would not be until the Cold War that the RCN got back into submarine operations in any serious way. The British did make successful use of submarines to sink U-boats in both world wars but this was only because the submarines of the day spent most of their time on the surface and could be hunted by another boat just like any other surface vessel.[3] The RCN got back into the submarine business with the acquisition of three British designed Oberon-class conventional submarines in the mid 1960's (and the later acquisition of a US WWII boat, HMCS Rainbow for operations out of Esquimalt). The primary purpose of the boats was as a "clockwork mouse" for training surface and airborne ASW forces but gradually Canadian submariners also learned to use their craft for offensive purposes. For while a conventional (i.e. diesel electric) submarine is at a great disadvantage against a nuclear boat in many ways, when it is operating submerged on battery power, it is usually much quieter and therefore harder to detect. With modern passive (i.e. listening only) sonars, wire-guided torpedoes, and fire control computers, a submarine never has to see its target. Operated in constricted waters therefore, a conventional submarine is a significant threat to a nuclear powered vessel. Indeed the Upholder class submarines (which Canada acquired from Britain in the 1990s and renamed the Victoria class) were expressly designed as ambush boats to plug the narrow passage way through the Greenland-Iceland-UK gap against Soviet nuclear submarines in the Cold War.

The Future.

In some ways the RCN has gone "back to the future" in its ASW equipment. The only acoustic system that had any chance of detecting a U-boat in 1917 was a passive system – hydrophones hung over the side of a stationary (and therefore suicidally minded) ship or eventually a string of such phones towed at slow speed hoping to hear the noise made by the primitive motors of the day. Ranges were extremely short. However, even modern nuclear submarines, with extensive noise insulation technologies cannot help but make detectable noise when operating at high speed. Consequently the modern signal processing system developed at (the then) Defence Research Establishment Atlantic coupled with a long towed array of passive hydrophones mounted in a thin plastic tube was developed as the Canadian SQR-501 passive sonar. Potentially capable of detecting a high speed submarine at many ten's of miles this system, is found in today's Halifax class frigates which are also equipped with an updated version of the Beartrap (and hopefully of the helicopter)– a combination which is essential in today's ASW

[3] In only one case in was a submerged submarine (*U-864*) sunk by another submerged boat (*HMS/M Venturer*) which did so by tracking its target's periscope.

environment. How effective is the new technology against today's submarines? Hopefully we'll never have to find out.

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