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CONVENTIONAL SUBMARINES

with particular attention to German developments since the War

by U.Gabler

1. History

Up to the middle of World War II, the so-called submersibles generally designed for long surface cruise represented the mainstream of development. For most of the mission period, these submersibles operated on the surface; they only dived to attack the enemy or to evade enemy attacks. They were constructed so as to offer both a high maximum speed as well as a wide cruising range during surface operation. However, their cruising range and maximum speed in submerged condition were comparatively small. In order to reduce their wave-making resistance on surface, they were designed as long as possible (to reduce the Froude's Number). They were provided with twin screws to which the rather high diesel engine output was transmitted on surface. The cruising range on surface was rather large; they had to carry a relatively large amount of fuel. A high percentage of main ballast tank capacity was necessary to obtain favourable sea-going qualities particularly for bad weather conditions. A double hull construction for these boats was normal (with the exception of the German type 7c boat which was an intermediate version between the single-hull and the double-hull types). The outer hull was not pressure-proof. The space between inner and outer hulls was mainly used for main ballast tanks and fuel tanks. The submerged performance of these submersibles was poor. They reached a submerged speed of 7 to 8 knots only, for a period of up to one hour. In order to obtain sufficient submerged static stability, they had to carry stability ballast amounting to 5 to 10 % of the surface displacement.

In the middle of World War II, initial designs were made for true submarines, i.e. boats making their entire trip in submerged condition and surfacing only during approaches to their own naval base. Propulsion of these submarines was effected by very heavy lead batteries. In order to reach a high speed in submerged condition, a powerful electric motor of large capacity was provided. Due to the fact that, in submerged condition, no wave-making resistance exists, the Froude's number was no longer important. Of decisive importance in this concept is the resistance of the friction surface of the outer hull. Consequently, these submarines have to be designed as short as possible and as thick as necessary. The total output could be transmitted via a shaft to a single propeller, the size of which was practically unlimited, thus

Fig. 1

allowing a higher percentage of propulsion efficiency. The large batteries now were charged by separate diesel generator sets. The new submarines consequently required a very much smaller percentage of fuel supply and a smaller percentage of water ballast tanks. Single hull types without any stability ballast often were the result. This design of single hull submarines offers a greater static stability in submerged condition than on the surface. If single hull vessels having the smallest possible length are envisaged, an adequately increased pressure hull diameter is the result, at the bottom of which the heavy lead battery may be arranged and fuel tanks may be fitted in the spaces at the sides as well as forward and aft, so that such submarines do not require any stability ballast. The snorkel system is integrated in the design enabling the submarines to re-charge their batteries practically under all weather conditions at periscope depth.

2. The Hull

The cylinder pressure hull with transverse frames manufactured from high-tensile steel is normal. However, the German submarine hulls of non-magnetic construction are being made of austenitic steel. The pressure hulls are dimensioned for the prediced collapse depth (i.e. the so-called calculation depth) by means of modern mathematical methods. The service diving depth which is the maximum diving depth for a submarine under normal service conditions is related to the abovementioned calculation depth by means of a safety factor which normally is of the order of 2.0.

In addition to the diving pressure, the pressure hulls (just as the other parts of the ship) may also be subjected to shock loads by explosions in the vicinity of the submarines. The modern submarine design aims at all parts of the submarine (including machinery, equipment, outfit and accommodation) withstanding shock loads somewhat larger than the strong pressure hull itself. In the Federal Republic of Germany, a considerable number of underwater explosion shock trials had been performed with 1/1 scaled models.

3. Overall Shape

Single hull submarines often take a cigar-shapped outer contour resulting from the space arrangement in their interior. A comparatively stout bow turns out to be favourable for the arrangement of armament and combined sensors in the ship's forward end. By the arrangement of stabilizing fins, it is possible without any considerable expenditure to establish hydrodynamic stability for practically all submarine shapes so that depth keeping does not offer any difficulties even at maximum speed.

Whereas submarines are dependent only on the effects of their stern hydroplanes for the medium and high speeds, they require both the bow and stern planes for the low speeds (particularly in the vicinity of the water surface at periscope depth). On the German submarines, a "mussel" -shaped outline is used for the bow planes, and always one plane only is rigged out creating either a positive or a negative lifting force. Such a design offers the advantage of both the planes being rigged in at higher speeds; however, at the lower speeds during which the planes are active, they will also be in rigged-in position at zero lift, thus reducing the ship's resistance. If, on the other hand, bow planes are of non-rigging-in-type, they require - due to their destabilizing effect at higher speeds - increased stabilizing fins on the stern, which, in turn create increased resistance. As to the stern plane/rudder assembly, the cross arrangement is generally prevailing now. In this connection, the steering rudders are vertically situated forward of the propeller, and the stern planes are also arranged there in extension of the stabilizing fin. Such an arrangement contributes significantly to high manoeuvrability.

Fig. 3

Fore-and-aft location of the bridge fin principally depends on the subdivision of space in the interior of the submarine. From the hydrodynamic viewpoint, a midship arrangement would be favourable as the submarine is turning on the middle at low speeds and when using the periscope, the periscope is not subjected to any changes in depth in case of trim angles. Furthermore, the bridge fin arranged amidships causes the submarine moving in turning circle to trim by the stern, which should be counteracted by putting the stern plane to below if it is intended to run the ship in a turning circle at constant depth.

Such a trim by the stern may be a safety measure against unintentional trim by the bow in case of stern plane jam.

Submarines of single hull construction provided with the smallest possible overall length offer a comparatively small sonar echo area, and their behaviour is clearly more favourable than that of double hull submarines.

4. Armament

Main armament of modern submarines is the wire-guided torpedo. The torpedo tubes usually are arranged in the forward end. The tubes on the German submarines are of the swim-out type, i.e. tubes from which the torpedo leaves under its own power after flooding. The sensors are part of the weapon system submarine. The main sensor is the passive sonar which, today, allows target contacts at great distances. Classification and identification of detected targets is also possible. As against that, the active sonar is of smaller importance, as the use of active sound propagation always includes the danger of revealing the own submarine position. The passive sensor should most favourably be arranged in the forward end of the submarine providing the best omnidirectional characteristics and smallest possible disturbing influence of the propeller.

5. Propulsion

Modern submarines are being driven by electric motors being fed from large lead/acid batteries during submerged operation. These batteries, in turn, are supplied with energy by diesel generator sets to be operated during snorkling and during surface cruise as well.

Two new developments concerning batteries have recently been made known, one of which is the so-called "Double Decker" plate structure in the cell. This arrangement provides for parallel extraction of power on top of the cells as well as at mid-height of cells in a special lead-coated bus bar made of copper. The other new development provides for copper strips laid into the negative grid plates, which results in a decisive reduction of the internal resistance of battery.

The generators are driven by high-speed four-stroke V-type diesel engines which are remarkable by their particular insensibility to counterpressures at the exhaust end and to underpressures at the inlet end.

The unmanned machinery room is remotely controlled and supervised from outside the room.

The smaller the number of crew, the easier it is to provide comfortable living conditions for them.

6. Safety and Rescue

A comparatively advanced stage has nowadays been reached concerning safety and rescue equipment on submarines. In this connection, safety precautions comprise all measures allowing the submarine to be brought to the water surface in the case of emergency and, possibly, to her naval base. Rescue measures comprise crew salvage out of the damaged submarines laying on the seabed. Two new developments are worth mentioning, as follows :

In the Federal Republic of Germany, a device for quick blowing of main ballast tanks, i.e. the so-called gas generator, has been developed, which is arranged in the main ballast tanks. The gas generator is operated on the basis of hydrazine ($N_2 H_4$) which is forced through a catalyzer by means of nitrogen as a power gas and is spontaneously decomposed into hydrogen (H_2), nitrogen (N_2), and ammonia (NH_3).

By using such gas generators, it is possible within a very short period to completely blow out the forward ballast tanks of a submarine cruising at the greatest possible depth; by this measure, the submarine
Fig. 4 trimming heavily by the stern and developing high speed may then be brought to the water surface.

Another rescue means currently under preparation is the so-called rescue sphere which may be used for all submarines provided with pressure-proof subdivision. This development means that during the submerged mission, the submarine can now effectively carry her own lifeboat. The rescue sphere is situated above the pressure-proof bulkhead and may be entered
Fig. 5 from the spaces forward as well as aft of the pressure-proof bulkhead.

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Dimensions of the rescue sphere are such that the total number of crew may be accommodated. After the crew have entered the rescue sphere, it is released from the submarine and surfaces under its own buoyancy. Its behaviour on the water surface is similar to that of a normal lifeboat.

7. Future Aspects

If the Great Powers USA and USSR as well as part of submarine forces of Great Britain and France are excluded, the submarines provided with the classical propulsion system are the standard submarines of most Navies, still to-day. Considerable numbers of them are under construction or will be built in the near future, and improvements are continuously included.

List of Illustrations

Fig. 1:- "Type 21" submarine (general arrangement plan);
Fig. 2:- "U 1" collapse test in pressure dock;
Fig. 3:- Mussel-shaped hydroplane;
Fig. 4:- "U 19" during quick surfacing test;
Fig. 5:- Rescue sphere (general arrangement).

BRIEF BIOGRAPHY

PROFESSOR ULRICH GABLER

Born :	1 October 1913.
1932 - 38 :	Studies in Naval Architecture at Technische Hochschule of Berlin - Charlottenburg.
1934 - 35 :	Military Service in German Navy as Technical Officer.
1938 - 39 :	Design Engineer with INGENIEURKONTOR FUER SCHIFFBAU GmbH, LUEBECK.
1939 :	Compulsory Military Service in Supreme Naval Command, Berlin.
1939 - 45 :	WWII Service - Chief Engineer and Diving Officer on various submarines - (6 missions in Atlantic). - Head of Design office of HELLMUTH WALTER GmbH, KIEL. - Main Department Head of Central Submarine Design Office.
1946 :	Founder of Company INGENIEURKONTO LUEBECK (IKL) superseding and incorporating INGENIEURKONTOR FUER SCHIFFBAU GmbH. IKL now employs a staff of 250 personnel.
1954 - 55 :	Activities in Rome, Italy concerning Italian submarine design.
1958 seq. :	Lecturer in Naval Architecture (Warships) at INSTITUT FUER SCHIFFBAU DER UNIVERSITAET HAMBURG.
1963 :	Founder of Company MASCHINENBAU GABLER GmbH. This Company now employs a staff of 110 personnel.
1963 :	Professor at UNIVERSATAET HAMBURG.

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