THORSTEN NORDENFELT'S SUB-MARINES

BY

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In March 1880 *The Scientific American* reported under a heading 'The Garrett Submarine Torpedo Boat':

> This is a new torpedo boat, invented by the Rev. G. W. Garrett, England, and besides being capable of being used as a most formidable weapon afloat has the power of sinking and remaining under water for very many hours, and thus can enter any blockaded port unperceived. No compressed air is carried, but the air in the boat is maintained at its normal composition by a chemical apparatus invented by Mr. Garrett. When under water, also, no smoke or gas is given off, although an engine of considerable power is kept in motion. Various experiements with the vessel have been made in the Great Float, Birkenhead before setting off on a voyage to Portsmouth . . . The boat, the inventor tells us, is in every way a success, and will easily perform what has been expected of her, and thus becomes one of the most deadly weapons of naval warfare.

This report, based on one which appeared originally in the *London Graphic*, referred to Garrett's steam driven submarine *Resurgam* which had been put afloat at Birkenhead in 1879. In this craft, engined with a single cylinder horizontal return connecting rod engine driving a single screw, steam was taken, when running on the surface, at the then high pressure of 150 pounds per square inch (p.s.i.) from a large coal-fired boiler occupying the greater part of the cylindrical centre section of the boat. Preparations for diving involved sealing the furnace and ashpit doors, followed by shutting down the forced draught blower and the conning tower. Thereafter, in diving trim, steam was taken off the boiler utilizing the latent heat in the same manner as Lamm's smoke-free tram, patented in 1872 and subsequently adapted for service as a fireless locomotive in explosive works and depots.

FIG. 1—GARRETT'S 'RESURGAM' AT BIRKENHEAD, 1879

Garrett planned his craft so that a minimum reserve buoyancy of about 100 pounds was maintained as a safety margin but in practice of course the

residual positive buoyancy depended upon the quantity of coal and feed water embarked. There were apparently no ballasting arrangements and the *Resurgam*, which floated more or less awash with only the light casing and conning tower clear of the water, was to be taken down when under way by the action of diving planes positioned either side amidships and controlled manually from the conning tower. With but one pair of planes, and these amidships, there would have been a complete lack of longitudinal stability although the boat might have been able to 'porpoise' along alternately diving and coming awash, a mode of progress made necessary for the purposes of navigation in any case by the lack of any form of periscope.

Built by Cochran & Co., the boiler makers then of Birkenhead, the *Resurgam* was 'launched' all but ready for sea, into the Great Float with the aid of a 50-ton crane on the 10 December 1879, and later the same day moved out into the Mersey under her own power. In the meantime, it had been decided, probably in the hope that the Admiralty might show some interest in the project, that the craft should be steamed round to Portsmouth where a demonstration could be arranged. Thus with Garrett in command the *Resurgam* departed that evening, it being intended that preliminary diving trials should be undertaken in Liverpool Bay en route for the south coast. Planning appears to have been somewhat *ad hoc*, as also was the navigation, but eventually the *Resurgam* reached Rhyl where a base was established to enable certain modifications to be carried out before embarking on further trials. The craft remained in the area for some weeks during which time Garrett used the greater part of his remaining funds to purchase the small steam yacht *Elfin*, both to provide accommodation and to serve as an escort when required. Eventually, late in the evening of 24 February 1880 the *Elfin* left Rhyl with the *Resurgam* in tow bound for Portsmouth. Thirty-six hours later, however, in boisterous weather the tow parted and the *Resurgam*, without crew or power, drifted off in a sinking condition, eventually being lost to view.

In the absence of the submarine the Admiralty quickly lost any interest that might have been aroused and Garrett found himself for the time being without employment and lacking further resources. Thus he approached the Swedish engineer Thorsten Nordenfelt with a proposal that the latter should take over the development of his (Garrett's) submarine patents. Nordenfelt apparently proved enthusiastic in considering Garrett's ideas and saw in the submarine the ideal vehicle for Whitehead's 'locomotive' torpedo. In the event their working relationship was put on a formal basis in 1881 when Garrett became Nordenfelt's assistant in matters of submarine design and construction.

The problem with the primitive locomotive torpedo was to bring it within effective range of the intended target, a task rendered risky albeit even suicidal by the invention of the quick-firing gun and the later development of a more accurate weapon of this type by Nordenfelt himself. Thus he now found himself in a position to take advantage of Garrett's practical experience which he put to good use in the design of his first submarine torpedo boat, laid down at Ekensberg, near Stockholm, in 1882.

Known as *Nordenfelt I*, this 64 foot long craft displaced 60 tons in surface trim and was of cigar-shaped hull form with concentric circular frames made up from wrought iron angle bar of 3 inch by 3 inch by $\frac{3}{8}$ inch section spaced two feet apart. On this frame the hull itself was built up of iron plates $\frac{3}{8}$ inch thick, apart from the bottom plating over the length of the mid-section of the craft which was of $\frac{5}{8}$ inch thickness, the overall strength of the structure being considered adequate to withstand diving to about 50 feet over the keel without distortion. The maximum diameter of the hull was 9 feet but sponsons amidships increased the beam to 11 feet.

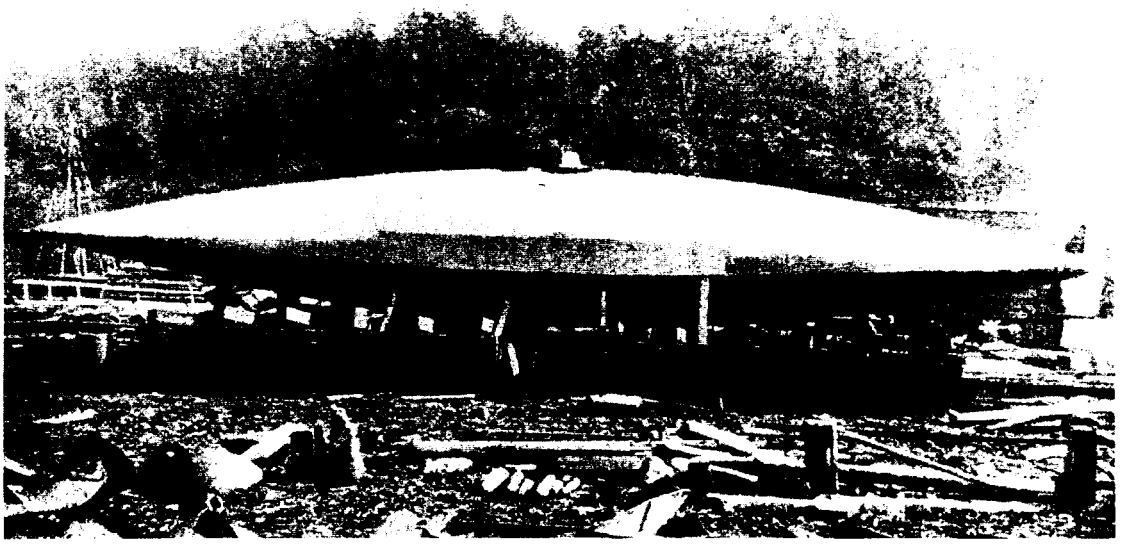

FIG. 2—'NORDENFELT I' READY FOR LAUNCH, 1885

Internally, of course, the thickness of the plating together with the depth of the frame webs restricted the useful space to that available within a maximum diameter of about 8 feet. Forward, the cylindrical return tube marine boiler occupied much of this available space, thus making difficult any communication with the fore end of the craft. Working at a pressure of 100 p.s.i. although designed to withstand 150 p.s.i. this large boiler supplied steam not only to the propulsion and auxiliary machinery but connected also with heat exchangers in the bottoms of a pair of accumulators holding in all some eight tons of hot water at a nominal 150 pounds pressure. Utilizing the latent heat on Lamm's 'fireless' engine principle, as in Garrett's boat, this was claimed to be sufficient for about 14 miles at 4 knots.

The 100 h.p. twin-cylinder compound engine driving a single screw took steam at 100 p.s.i. when running on the surface and exhausted via a surface condenser back to the boiler feed system. When preparing to dive, the funnel was housed and shut off together with all other openings, while the furnace and ash pit doors were sealed to prevent the escape within the craft of noxious combustion gases. With the forward and after accumulators now opened up and connected through to the boiler, steam would be flashed off as the pressure dropped from the nominal 150 p.s.i., thus to enable the engine to continue working. The exhaust condensate returned via the hot well to the feed system in the normal way. In order to extract the maximum stored engergy, the system was fitted with a large capacity air pump thus producing the high degree of vacuum required to work the steam down to below atmospheric pressure. This made necessary in turn an engine with large diameter cylinders to utilize the steam at this low pressure. There remained the problem of heating the eight tons of water in the accumulators which involved, in fact, circulating steam through the heat exchangers for forty-eight hours or more in order to raise the required pressure of 150 p.s.i.! Fore and aft trim could be regulated by adjusting the water levels in the two accumulator cisterns.

In surface trim Nordenfelt's craft lay with some three feet of freeboard amidships but preparations for diving involved first admitting some four

tons of water to a centrally placed ballast tank to bring the boat awash with some 600 to 800 pounds of residual buoyancy. The boat was then to be taken down by the use of small vertical propellers positioned each side amidships in the sponsons mentioned above and driven by a 6 h.p. twin-cylinder engine controlled either by a hand regulator or by an automatic throttle valve. Water pressure via an open ended pipe acted against a weight causing the throttle valve to close as depth increased, hopefully to bring about a measure of stable depth control. With the craft dived and under way it was intended that trim should be assisted by the action of a pair of hydroplanes forward, pendulum controlled via a steam-powered servo system. However, it was found in practice that surging in the ballast tank, boiler and accumulator cisterns, coupled with an inherent lack of longitudinal stability due to the siting of the vertical propellers amidships, rendered that task well nigh impossible for more than a few minutes at a time. When dived, of course, the vessel would have been blind.

A centrifugal blower provided forced draught for the boiler so that when preparing for an attack the tall funnel could be unrigged and stowed before trimming down awash for the initial approach in the direction of the intended target. Smoke and furnace gases were then discharged below the surface, sufficient positive pressure being maintained by the blower, thus reducing the chance of detection.

Following her launch and completion of fitting out, *Nordenfelt I* was towed to Landskrona in southern Sweden for preliminary trials which were run between 21 and 25 September 1885 in the presence of a large number of observers including many representing European and other naval powers. Limited success only was achieved, however, although the craft ran well in a semi-submerged condition with little more than the tiny conning tower awash. Once fully dived, stable depth-keeping proved elusive and in general the opinion of the observers was the the craft had, at best, potential as a semi-submersible torpedo boat. The armament comprised a single torpedo tube[1] for launching a Whitehead or a Schwartzkopf torpedo, placed well forward within a fairing external to the pressure hull, and a Nordenfelt 25 mm. quick-firing gun.

Closed down trials showed the air within the boat to be sufficient to meet the needs of the three man crew for some six hours. On the other hand subsequent experience demonstrated that the sealing of the furnace and ash pit doors was far from satisfactory, to the extent that frequently the effects of carbon monoxide and carbon dioxide were to make themselves only too apparent. Drowsiness was noticed amongst the more sensitive crew members and on occasion men became unconscious. Indeed George Garrett himself fell victim to the escaping fumes which left him unfit for duty for some three weeks!

The Landskrona trials were followed by further lengthy trials run in England, in Southampton Water, where a mass of data was gathered to be utilized in new designs of submersibles planned by Nordenfelt. Despite the problems encountered during these prolonged exercises, Lieutenant-General Sir Andrew Clarke, the Inspector General of Fortifications, who had been present at Landskrona, realised the potential of the submarine in a coastal defence role and recommended the purchase of a Nordenfelt boat at a cost of £9,000 to permit a thorough investigation of the matter. The government of the day evinced no further interest, however, and the proposal was quickly forgotten. Nordenfelt was fortunate in 1886, therefore, in being able through the agency of one Basil Zaharoff to dispose of his No. I to the Greek government for the same sum (£9,000), the craft being demonstrated to the apparent satisfaction of her new owners during trials in the Bay of Salamis later in that year. By this time the sealing arrangements for the furnace and

ash pit doors had been substantially improved although in all probability the boat saw little service under the Greek flag other than in a semi-submersible role.

In the meantime, in 1884, with only limited construction resources available in Sweden, it seems probable that Thorsten Nordenfelt had approached the Barrow Shipbuilding Co. with proposals, possibly involving some form of partnership, for the building of submarines incorporating his patents. At a time beset by economic problems and declining trade, the Barrow company had achieved some success in building warships and Nordenfelt's proposals offered a further field for diversification of their interests. Presumably terms were agreed for the construction of a Nordenfelt type submarine as a speculative venture, since records exist of Yard No. 143 (later known as *Nordenfelt II*) which was put afloat at Barrow on the 14 April 1886. In the absence of any prospective purchaser the craft was registered initially as a merchant vessel, presumably while preliminary trials were run.

Larger than her predecessor, the new steel-hulled submarine displaced 160 tons but retained the same cigar-shaped hull form, with a 12 foot diameter circular section amidships and an overall length of 100 feet. In fact, the general design was essentially similar to that of the earlier craft although, in an attempt to improve longitudinal stability, the vertical diving propellers were arranged one forward and one aft, each driven independently by a 6 h.p. engine. The boiler was sited aft of amidships while the two hot water accumulators were replaced by a single cistern forward. Aft of the boiler the twin cylinder compound engine of 250 h.p. taking steam at 100 p.s.i., was mounted in line with the run of the bottom plating at an angle of about 4 degrees to the horizontal, the drive to the single screw being via an inclined propeller shaft and a pair of universal joints. Bunkers abreast the boiler held coal briquettes for ready use in addition to eight tons of fuel stowed in a bunker beside the hot water cistern—sufficient in all for 900 miles at economical speed without refuelling. Designed speeds were 11 knots in surface trim and 5 knots dived.

Preparations for diving included closing all openings and sealing the furnace and ash pit doors while water ballast tanks forward and aft, each of 15 tons capacity, were filled to trim the boat down. An additional 7 ton ballast tank amidships under the central compartment served to regulate buoyancy thus allowing compensation for fuel burned off. Once awash the vertical propellers could be brought into use to take the boat down while maintaining a horizontal attitude, obviously a delicate operation. As in *Nordenfelt I*, bow hydroplanes, worked manually or automatically under the influence of a pendulum, were fitted to help overcome the problem of trim control while running awash or dived. Apart from the commander, the crew numbered six who, with the boat on passage or running closed down for diving, worked in two watches. Unlike Garrett's *Resurgam*, no means were provided in the two Nordenfelt submarines for air purification.

The weapon fit comprised two mechanically launched Whitehead torpedoes carried in a pair of external tubes on the bow and two 25 mm. Nordenfelt machine guns, one forward and the other aft of the conning tower.

In the meantime the Turkish government, fearful of Russian intentions while at the same time not wishing to be outdone by the nation's neighbour and arch-rival Greece which had purchased *Nordenfelt I*, had shown more than a passing interest in acquiring a pair of submarines to strengthen its defences. Subsequent events remain something of a mystery but it would seem that on the 23 January 1886 the Turkish government placed an order for two submarines with the Des Vignes Co. of Chertsey on the Thames. Whether this company had the facilities for building a submarine is a matter for conjecture but it would appear likely that the order resulted first in the

acquisition from the Barrow Shipbuilding Co. of *Nordenfelt II* which became the Turkish Submarine Boat No. 1, later renamed *Abdul Hamid.*

Dismantled, *Nordenfelt II* was shipped out in sections to Constantinople (Istanbul) and, once assembled, was re-launched on 6 September 1886. In the event the recruitment of a Turkish crew proved a problem and trials in the Golden Horn on 5 February 1887 had to be run as best as Nordenfelt's assistants Captain George Garrett[2], Mr. P. W. D'Alton and a Mr. Lawrie could manage on their own. However, the craft behaved well on the surface and indeed proved successful running awash as a semi-submersible; on the other hand, once dived she proved difficult to handle, suffering the same lack of longitudinal stability as her predecessor. The re-arrangement of the vertical diving screws forward and aft instead of athwartships appears to have done little to improve matters while free surface resulting from the lack of baffles within the boiler and hot water accumulator and lack of adequate sub-division in the ballast tanks served only to compound the issue.

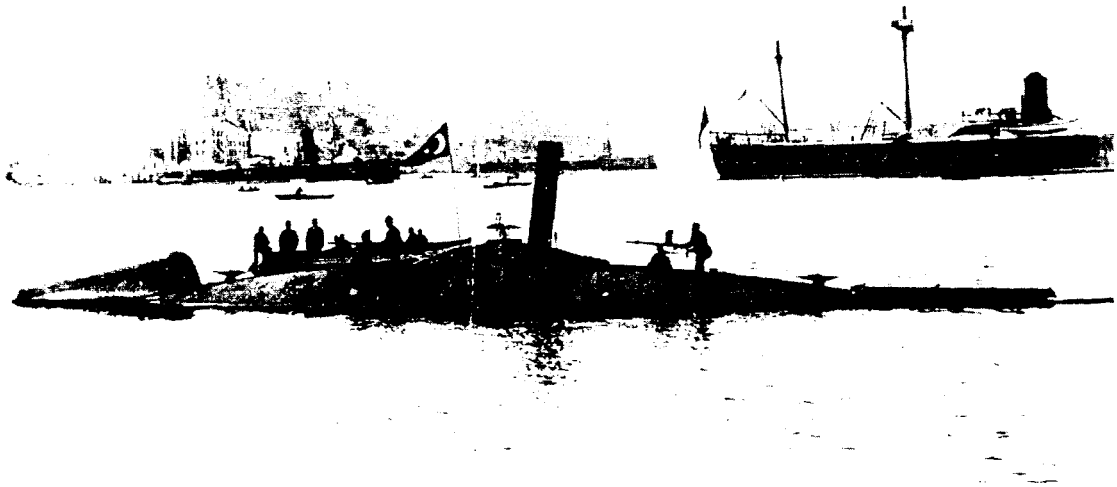

Fig. 3—'NORDENFELT II' DURING TRIALS IN THE GOLDEN HORN, CONSTANTINOPLE, FEBRUARY 1887

Torpedo trials too proved abortive since release of the weapon disturbed the trim of the boat, bringing the bow up violently as the torpedo left its tube. In the event, the trials crew managed to retrieve the situation and bring the craft to the surface but the exercise was not repeated. Although accepted, and indeed eventually paid for, by the Turkish government, Submarine Boat No. 1 (*Abdul Hamid*) never commissioned for service and remained laid up under cover on shore in the Constantinople Naval Arsenal until eventually broken up, probably during the First World War.

Named *Abdul Medjid*, the second submarine too was shipped out in sections to Constantinople and, once re-assembled[3], entered the water on the 4 August 1887. Following a trial run to Ismid some 60 miles distant, however, the lack of a Turkish crew resulted in the boat being laid up with the *Abdul Hamid* in the Naval Arsenal, eventually to be broken up.

Meanwhile back at Barrow, plans had been drawn up for the construction of an improved Nordenfelt submarine, in all probability once again to be built as a speculative venture although it seems likely that the Turkish government made known its interest early as a potential buyer. Whatever

the actual circumstances surrounding the origin of the project, the Turkish government did secure an option on the vessel the keel of which was laid as Yard No. 149 in 1886. The 1887 edition of 'The Naval Annual' (Brassey) includes under Turkish Ships a drawing of the 'Submarine Boat *Nordenfelt*', unmistakeably this craft. The design was a radical departure from that of Nordenfelt's earlier boats, the cigar-shaped configuration being abandoned in favour of a hull form of circular cross-section amidships tapering in plan to a narrow vertical ellipse forward and aft. Thus the draught was the same throughout the length of the craft bringing increased buoyancy at the extremities in an attempt to ease the problem of longitudinal stability. At the same time, in order to minimize surging, the craft was designed with nine separate ballast tanks holding in all 35 tons of water, this being the quantity required, with fuel and all stores embarked, to reduce the residual buoyancy to about 500 pounds in preparation for diving.

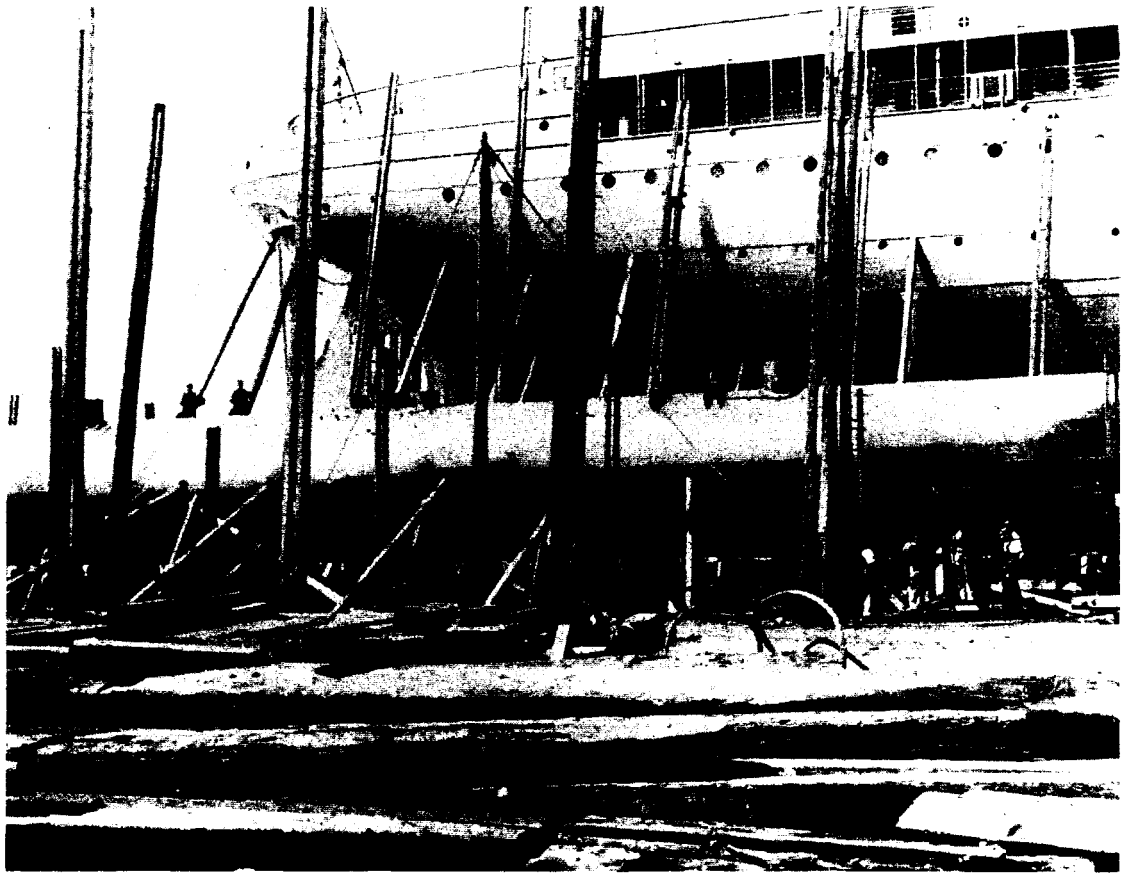

FIG. 4—'NORDENFELT [IV]' ON THE SLIP AT BARROW, 1886
Photograph by courtesy of Vickers Shipbuilding and Engineering Ltd.

Somewhat larger than her predecessors, *Nordenfelt IV*, actually named *Nordenfelt*, was 125 feet long overall with a beam (maximum diameter) amidships of 12 feet. The surface displacement worked out at 160 tons in light condition and that submerged 243 tons. She entered the water at Barrow on 26 March 1887 and immediately demonstrated some miscalculation in her design since she trimmed down heavily by the stern and had to be ballasted forward to correct the error.

With the frames spaced some 20 inches apart and plating 5/16 inch in thickness, the structural strength seems to have been considered adequate to

withstand the pressure at a depth of 100 feet. Over the turtle-backed casing, exposed when running on the surface, plating one inch thick provided protection against small arms and light gunfire. Aft of amidships a tandem pair of two-cylinder compound engines, built by Plenty & Sons of Newbury and designed for 1,000 h.p. at a pressure of 150 p.s.i. drove on to a four-throw crankshaft directly coupled to the four-bladed screw positioned in an aperture forward of the rudder. The estimated speed in surface trim was given as 12 knots. There were two cylindrical locomotive boilers holding in all 27 tons of water, the after one being 10 feet 6 inches long and the forward unit a massive 18 feet in length. Each had two furnaces and the fuel (coal briquettes) was stowed in side bunkers abreast the stokehold between the boilers. As in the earlier boats, once shut down for diving, steam was flashed off at a steadily reducing pressure, although in this case there were no separate hot water cisterns. Preparations for sea involved firing both boilers and then discharging steam, as soon as sufficient pressure became available, direct from the after unit into the lower part of the forward boiler, thus to accelerate heating the mass of water therein. On reaching full working pressure (150 p.s.i.) this forward boiler, with its furnace fires banked, was isolated from the steam system ready for reconnecting when preparing to dive. Thus for running on the surface, the after boiler alone provided steam for the main and auxiliary machinery.

The coal bunkers provided stowage for 8 tons of fuel, sufficient for about 1000 miles at 8 knots; for extended passage three of the nine ballast tanks could be pressed into service as temporary bunkers enabling 20 tons to be embarked, presumably adequate for some 2500 miles at an economical speed. There was no electricity, the crew having to rely upon candles and oil lamps for internal lighting although this primitive means would have provided also an indication of any dangerous rise in the carbon dioxide content of the air within the boat. No means were provided for purifying the air.

Glass domed conning towers of one inch thick steel, 2 feet high and 2 feet 6 inches in diameter, served for working the boat when shut down, the forward one as the command position[4] equipped for control of the 'descending' propellers and the after lookout as the engineer watchkeeper's station with an all round view of the horizon. Preparations for diving involved stowing the two funnels and, as in the earlier craft, sealing all openings including the uptakes and the furnace and ash pit doors which were bolted into position against an asbestos seal. With residual buoyancy reduced to about 500 pounds the boat could be forced to submerge by the downward thrust of the vertical propellers. Dived, the maximum speed was about 5 knots.

The weapon fit comprised a pair of internal torpedo tubes mounted one above the other in the bow and protected at their forward (outboard) ends by a hinged door worked from inside the boat and opening to starboard. In all four Whitehead torpedoes were carried. It had been intended in addition that a pair of Nordenfelt 2 pounder quick-firing guns should be added[5] for self-defence but in all probability they were never fitted.

On completion, the *Nordenfelt [IV]* was registered with the Board of Trade as a merchant ship and, following preliminary handling trials, steamed south to Southampton, arriving in the wake of a stormy passage which appears to have been weathered to the satisfaction of those concerned. However, certain modifications were called for, presumably seen to be necessary in the light of sea experience, and this work, which included the provision of a light casing to form a weather deck between the two conning towers, was undertaken locally in June 1887 by Oswald Mordaunt & Co. of Woolston[6].

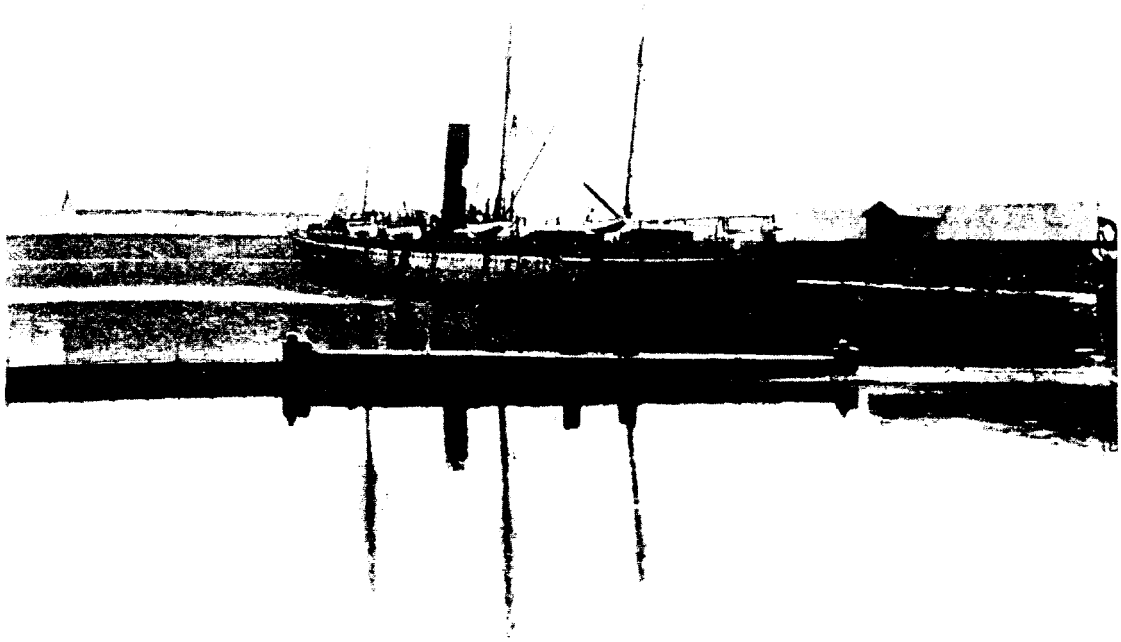

FIG. 5—'NORDENFELT [IV]' DURING BASIN TRIALS AT SOUTHAMPTON, 1887

Basin trials took place within the confines of Southampton's Outer Dock (now the Princess Alexandra Dock) and were followed by open water trials run in the relative shallows over the Mother Bank Shoal off Rye, Isle of Wight. The first demonstration for Service representatives took place on the 26 May 1887 with the craft running awash in the closed down state for an hour and a half, following which it was claimed that stored steam sufficient for 24 miles remained in the boilers. Steaming awash in the course of the demonstration the *Nordenfelt* evoked considerable interest by circling around the ironclad battleship *Invincible* then lying at anchor in Cowes Roads. After surfacing the funnels were erected and the boilers fired, enabling the vessel soon to increase speed to 14 knots. Being painted a neutral grey she showed herself to be a difficult target, in particular while running slowly awash, when the raised casing and two small conning towers proved almost impossible to detect at more than a few hundred yards distance.

In surface trim too the performance of the *Nordenfelt [IV]* appears to have been completely satisfactory, a speed of 14 knots being maintained over the measured mile in Stokes Bay without difficulty at 1300 indicated horse power (i.h.p.). On 23 July 1887 she put in an appearance at the Naval Review held at Spithead to honour Queen Victoria's Golden Jubilee and there created considerable excitement in the midst of the ironclads and the few remaining wooden men-of-war, albeit all of which except the small training brigs were fitted with full powered steam machinery. Amongst other guests on this occasion the Tsar of Russia was evidently impressed by what he saw!

. Once fully submerged, however, the performance of the *Nordenfelt [IV]* was much less favourable, all the faults in her predecessors being repeated. These included the violent changes of trim due to the effects of free surface in the boilers and to a lesser extent in the tanks, so that while undergoing trials in the vicinity of the Mother Bank she frequently touched bottom. As demonstrated by Nordenfelt's first submarine the hydroplanes, in this boat

fitted both forward and aft, did little to control trim or to assist effective depth-keeping.

Trials continued intermittently throughout the summer of 1887 and culminated in a semi-official demonstration of the submarine's capabilities on 19 December. Despite the problems encountered when dived, *The Engineer* in its issue of 23 December 1887 followed up these trials with an enthusiastic leading article lyrical in its praise of the Nordenfelt submarine concept. The writer looked to the future with a suggestion that:

> We may—we hope we shall—have quite a little fleet of *Nordenfelts* when Christmas comes round again. When once Columbus had shown the way to America, the water was freely traversed.

Two months later[7] the same journal reported that the United States government had '. . . decided in favour of Nordenfelt boats as a permanent arm.'

The *Army and Navy Gazette* too had no hesitation in telling its readers that the Nordenfelt submarine had:

> . . . a great and assured future before it, that with a gun or two on her turtle back and working as an above water torpedo boat, she certainly possessed many advantages over the ordinary first class torpedo boat, and that her powers of submerging should make her the more valuable craft . . .

In the meantime, in a move aimed at improving future prospects by diversifying their armament interests, the directors of the Barrow Shipbuilding Co. had invited Thorsten Nordenfelt to join the company, which in the ensuing reorganization of 1888 became the Naval Construction & Armaments Co. Ltd. The new organization acquired Nordenfelt's patents by purchase, although in fact no further submarines to his designs were to be built at Barrow or indeed anywhere in the United Kingdom.

By this time the Turkish government appears to have lost interest in submarines and Nordenfelt was fortunate in being able to persuade the Russian government to consider the purchase of his latest submersible. Despite continuing problems with depth and trim control the Russians appear to have been satisfied with her performance during trials although they did stipulate that completion of the sale should be subject to a demonstration of the capabilities of the craft in the deeper waters off Kronstadt, commenting that 'Any boat might undertake trials in shallow water which could not be repeated in deep water!'[8]

Escorted by Nordenfelt's yacht *Lodestar*, the submarine left Southampton en route for the Baltic and Kronstadt in November 1888. For much of the time the *Nordenfelt* towed the *Lodestar* and it was when steaming thus that the former stranded on the Horne Reef off Jutland on an ebbing tide, apparently through mistaking lights on the Danish coast. Attempts were made to refloat the submarine at high water but these and subsequent efforts proved of no avail and with the *Lodestar* herself grinding her bottom on the reef there seemed little chance of success. Leaving the wreck for the time being, Captain Garrett and the crew made their way as best they could to Esbjerg.

Refloated some two weeks later, the battered *Nordenfelt* was brought into Esbjerg where her owners[9] hoped to have the boat declared a constructive total loss on the grounds that in the circumstances the prospective buyer would be most unlikely to complete the purchase. Eventually the submarine was abandoned to the insurers although this had to await the settlement of a dispute over the payment of salvage dues. Attempts made to find a buyer proved unavailing and a few years later, the insurers having settled with the Naval Construction and Armaments Co., the now derelict hulk was broken up for scrap. In the meantime, being once again without work, George Garrett abandoned his submarine interests and migrated to the United States where he died in 1902.

Nordenfelt continued his association with the Barrow company but, like Garrett, took little further interest in submarine development although two boats, reputedly of Nordenfelt type although designed by a Frenchman named d'Equevilley, were built in 1890 for the German Navy which seems to have negotiated a licence in 1885 to make use of Nordenfelt's submarine patents. Presumably this arrangement followed in the wake of the Landskrona trials at which *Nordenfelt I* had been demonstrated in September of that year. Built at Kiel (Howaldtswerke) and Danzig (Kaiserlichen Werften) respectively, these two submarines were attached to the local torpedo flotillas at Kiel and Wilhelmshaven but little is known of their performance apart from a statement that 'In a semi-submerged condition these boats were moderately good, but their speed did not come up to expectations . . .'[10]. The Howaldt boat was 114 feet long with a maximum diameter of a little under 11 feet, the hull form like the early *Nordenfelt*s being cigar-shaped. In surface trim she displaced 212 tons. A photograph believed to show this craft has appeared in a number of works since it was first published by Alan H. Burgoyne in 1903[11].

Very little information concerning the results of trials with the Nordenfelt boats, other than that made public by Nordenfelt himself, reached the press or contemporary technical journals at the time and it was not until 1901 that P. W. D'Alton, Nordenfelt's former assistant but subsequently Chief Engineer to the Central London Railway, was able at last to comment on the performance of the Turkish *Abdul Hamid* (*Nordenfelt II*):

> She had the fault of all submarine boats, viz. a total lack of longitudinal stability. All submarines are practically devoid of weight when under water. The *Nordenfelt*, for example, weighed by a couple of hundredweights less than nothing when submerged, and had to be kept down by screw propellers provided for the purpose. The Turkish boat was submerged by admitting water to tanks aided by horizontal propellers, and raised by blowing the ballast out again and reversing the propellers. Nothing could be imagined more unstable than this Turkish boat. The moment she left the horizontal position the water in her boiler and the tanks surged forwards and backwards and increased the angle of inclination. She was perpetually working up and down like a scale beam, and no human vigilance could keep her on an even keel for half a minute at a time. Once, and we believe only once, she fired a torpedo, with the result that she was nearly as possible stood up vertically on her tail and proceeded to plunge to the bottom stern first. On another occasion all hands were nearly lost. Mr. Garrett was in the little conning-tower. The boat was being slowly submerged—an operation of the utmost delicacy—before a committee of Ottoman officers, when a boat came alongside without warning. Her wash sent a considerable quantity of water down the conning tower, the lid of which was not closed, and the submarine boat instantly began to sink like a stone. Fortunately Mr. Garrett got the lid closed just in time, and Mr. Lawrie, the engineer, without waiting for orders, blew some water ballast out. It was an exceedingly narrow escape.[12]

The Engineer, likewise, having abandoned its former enthusiastic stance, was now scathing in its criticism of *Nordenfelt IV*:

> To all intents and purposes the *Nordenfelt* was a total failure as a submarine boat. She began badly. As soon as she was launched from the stocks at Barrow it was seen that a mistake had been made in calculating weight, as she was down by the stern, drawing 9 feet aft and about 4 feet 6 inches forward. This would have been partially rectified by her torpedoes, but she never had one on board. Extra ballast had to be put in forward, and it was always held, rightly or wrongly, that this made it all the more difficult to keep her on an even keel when submerged. The extra weight carried militated greatly against her speed as a surface boat. Another mistake was that the water-ballast tanks were too large, or perhaps it would be more correct to say that they were not sufficiently subdivided. When she was in just the proper condition to be manoeuvred by her horizontal propellers the ballast tanks were only about three quarters full, and the water being left free surges backwards and forwards in them. It must not be forgotten, however, that ample tank capacity was necessary because the quantity of ballast needed depended on the number of tons of coal and stores on board. Sub-division would, however, have prevented the surging of the ballast water. If, for example, the boat was moving forward on an even keel at, say, two knots, if a greaser walked forward a couple of feet in his engine room, her head would go down a little. Then the water surged forward in the tank and she would proceed to plunge, unless checked, and in shallow water would touch

the bottom, as she did on the Mother Bank in the Solent. . . The *Nordenfelt* was always rising or falling, and required the greatest care in handling[12].

Probably Nordenfelt himself had been over-optimistic while being at the same time obstinate in failing to learn by experience, so that the same faults were repeated in each boat in turn until eventually he lost interest in the submarine. During the period of his involvement in submarine design he lectured at length to the Royal United Service Institution and also took part in discussions at the Institution of Naval Architects where in 1888 he soundly condemned proposals by Lieutenant G. W. Hovgaard of the Danish Navy that battery/electric motor propulsion should be employed under water rather than stored steam.

Despite the fact that Nordenfelt's association with 'diving boats' marked but a brief digression in his long career as an engineer and entrepreneur, his involvement remains significant by virtue of the fact that the *Nordenfelt II*, launched nearly one hundred years ago, was the first submarine to be built at Barrow. In 1897 the Naval Construction & Armament Co. Ltd. became Vickers, Sons & Maxim Ltd. whose successors, Vickers Shipbuilding & Engineering Ltd., continue in business today, building submarines, as part of British Shipbuilders. Nordenfelt himself died in 1920 but he is probably remembered more for his machine gun rather than for the submarines which featured prominently in the technical press of the eighteen-eighties.

Notes

1. Installed during the period that *Nordenfelt I* was in United Kingdom waters for further trials.
2. Garrett had been granted a temporary commission as a Commander in the Imperial Ottoman Navy although he appears to have worn the uniform of a Captain, complete with fez.
3. Although some accounts claim that the second Turkish boat was not reassembled, *The Engineer* for the 24 February 1888 refers to the '. . .two submarines. . .' leaving Constantinople.
4. Accounts differ concerning the respective roles of the two conning towers.
5. *The Scientific American*, 21 January 1888.
6. *The Scientific American*, 21 January 1888.
7. *The Engineer*, 24 February 1888.
8. *Submarine Warfare* by Herbert C. Fyfe (second edition); London, 1907.
9. Naval Construction & Armaments Co. Ltd.
10. *The Evolution of the Submarine Boat, Mine and Torpedo* by Commander Murray Sueter, R.N.; Portsmouth. 1907.
11. *Submarine Navigation, Past and Present* by Alan H. Burgoyne; London, 1903. (cf. Murray Sueter, who claims this photograph to show a later Howaldt boat of 1897.)
12. *Submarine Warfare* by Herbert C. Fyfe (second edition); London, 1907.