THE HON. SIR CHARLES A. PARSONS (1854—1931)

This year, which marks the centenary of his birth, it is fitting that we should remember the genius of Sir Charles Parsons. On naval architecture, electrical and mechanical engineering, and optics he left lasting impressions, but for naval engineers his enduring contribution is the marine steam turbine.

The application of the steam engine to ship propulsion advanced with rapid strides during the latter half of the 19th century, and as that century drew to its close, the reciprocating marine engine, a majestic triumph of the engine builders' art, seemed to have reached its zenith in the liners and capital warships of the day. It was at this juncture that Parsons, by the development of the steam turbine, raised the science of ship propulsion to still greater heights.

The appearance of the *Turbinia* at the Naval Review of 1897, in celebration of the Diamond Jubilee of Queen Victoria, initiated the new era of steam propulsion in spectacular fashion. Between the lines of the most powerful and fastest ships of Her Majesty's navy, a minute vessel with mysterious engines raced at a speed greater than that of the fastest destroyer. Such a demonstration could not be ignored, and within two decades, engines of this type drove the battleships and cruisers which were the mainstay of our defence in the First World War.

Many others before Parsons had attempted to make a satisfactory steam turbine. The famous hydrodynamicist Osborne Reynolds constructed a small multi-stage reaction turbine ten years before Parsons' celebrated master patent of 1884. Reynolds discarded this turbine when he discovered its comparatively enormous steam consumption. Had he realized that the effect of tip leakage and other losses became relatively less as the size of the turbine increased, the vessels of the world might now be fitted with ' Reynolds ' turbines.

Parsons possessed this mechanical intuition, and by patient experimental work reached a satisfactory solution to the problem. He also arrived at the conclusion that the division of the expansion into a number of pressure drops would reduce the velocity of the steam to manageable values.

But in spite of extensive subdivision it was still necessary for the turbine to rotate at a very high speed in order that the blade speed might conform to the velocity of the steam. The speed of the rotor was, in fact, of the order of several thousand revolutions per minute and was considerably in excess of that commonly adopted for screw propellers. When in 1893, having after ten years of strenuous effort improved his compound steam turbine to such a degree that it had established its superiority over the reciprocating steam engine, Parsons decided to attempt its introduction into the field of marine propulsion, the problem immediately arising was, therefore, to reduce the speed of revolution of the turbine and to raise that of the screw to a common value without undue loss of efficiency.

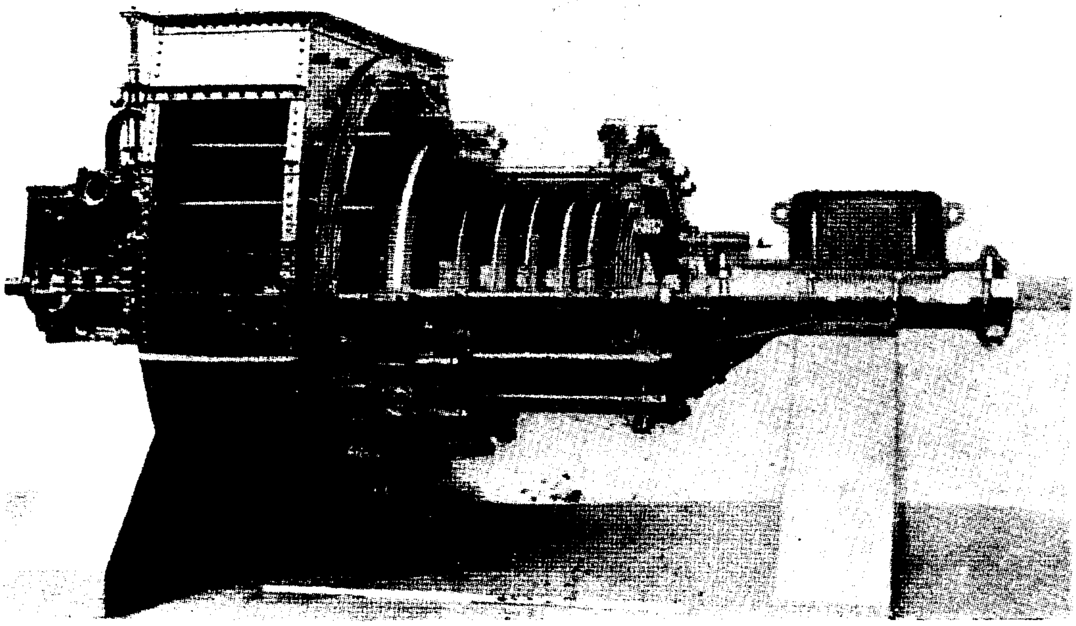
From this point of view the high-speed torpedo boats and torpedo boat destroyers appeared to offer the best scope for the adoption of turbine propulsion and Parsons' mind was attracted to a vessel of that class. It was recognized that many other problems and difficulties were likely to be encountered and many prejudices required to be overcome in installing a turbine as the main propelling engine of a ship, and the only satisfactory means of exploring and surmounting such difficulties was to build an experimental vessel. With characteristic energy Parsons set himself to the task of providing engines, boilers, hull, and all the equipment of a ship, making it his goal to drive it through the water at a record speed.

Some idea of his preliminary studies of the problem can be obtained from the illustrations accompanying the specification for a patent taken out in January, 1894. Preliminary studies, however, were not sufficient for Parsons ; practical tests alone satisfied him, and for these he was full of simple and ingenious expedients. For example, to investigate the best forms of hull he constructed models 2 ft long which he towed by a fishing rod and line in a small pond at his residence at Ryton-on-Tyne. With these models he found that the hull with the rounded stern originally proposed tended to squat too much at the stern and rise at the bow. Later models in which this fault was corrected had propellers driven by clockwork and twisted rubber springs. The rubber springs were twisted at the end remote from the propeller, which was held fixed. After a certain degree of twisting the rubber began to knot ; first a row of single knots extending, as the twisting proceeded, from one end to the other ; then when twisted with greater force double knots ; and finally with still greater force a line of treble knots extending from end to end in the same manner. The twisting handle was then made fast and the propeller released, revolving and propelling the model as the knots untwisted. To each stage of knotting, single, double, or treble, corresponded a given twisting force,which was measured subsequently by substituting for the propeller a light fan surrounded by a cardboard box with internal vanes, a simple form of torsion dynamometer. The resistance of the model was tested by towing it in a pond at the Heaton works with a salmon line and falling weights. The speed of the propeller was estimated by close observation of the time between double and treble knotting of the rubber, which was found to represent a given number of revolutions.

Of particular interest is a 6-foot model, which is still in existence in the Museum of Science and Industry at Newcastle-upon-Tyne : in this model the propeller was driven through reduction gearing. Its lines were later adopted for the hull of the *Turbinia.* A model of the *Turbinia's* hull was tested three years later in the Government tank at Portsmouth, and the effective power differed from that obtained in the simple model only by 2 to 3 per cent, a remarkable example of Parsons' experimental skill with rudimentary apparatus.

Meanwhile, Parsons was consulting with his friends on the all-important question of financing the venture, and early in January 1894 the Marine Steam Turbine Company was formed. This company was a purely pioneer company formed for the purpose of carrying the financial burden and risk of the experiment. Parsons was fortunate in finding such excellent backing for his important venture into the realm of marine propulsion. In the meantime the work of building had already commenced.

As first constructed the vessel had a single screw shaft, which was driven by a turbine of the radial flow type, to which type Parsons was for some time restricted on account of the retention of his patents for the parallel flow type by his former partners, Messrs. Clarke, Chapman and Company. The patents



THE FIRST MARINE STEAM TURBINE

were in fact recovered early in 1894, but in consequence of their temporary retention there was no experience of the performance of a parallel-flow turbine working with a condenser. This turbine was being built at Heaton works, which were at that time busily occupied in the construction of turbo-generators. The boiler of the three-drum type, double-ended, was also tubed and tested at Heaton works, the drums being supplied by Messrs. Hawthorn, Leslie and Company. The hull was being built on a slipway at the sheet iron works of Messrs. Brown and Hood at Wallsend, an adjoining shed of which served later as headquarters for the trials. The boiler had 1,100 sq ft of heating surface, made up of straight tubes $\frac{1}{2}$ inch internal diameter, and two down-tubes 7 inches in diameter, thus ensuring intense thermal circulation. It was fitted with a superheater in the smokebox which was later removed, the superheat being found to be uncontrollable on account of flaming. The hull, of torpedo-boat form with U-shaped sections aft, was 100 feet long by 9 feet beam, and its displacement 44 tons at 3 feet draught. It was estimated that with this hull an effective power of 820 h.p. would be sufficient to give a speed of at least 30 knots. On the basis of a propulsive coefficient of 0·5, the boiler and turbine were designed to develop about 1,650 h.p. The adjusting block of the turbine was also the main thrust block of the vessel, the residual steam thrust on the rotor being in the opposite direction to the thrust of the screw. The speed of the shaft was 1,600–1,700 r.p.m., which, it will easily be realized now, was both too low for the turbine and too high for the propeller to obtain a good performance from each. The propeller was 20 inches in diameter.

The work proceeded with great energy, and by November of that year the vessel and machinery were ready for trial. The first preliminary trial carried out on 14th November gave disappointing results. Changes were made in the propeller ; in all it is recorded that 31 different trials were made with different propellers, two-bladed, three-bladed, or four-bladed, and with as many as three propellers on the shaft. The last named gave the best results, but this result was still disappointing. The best speed was just short of 20 knots.

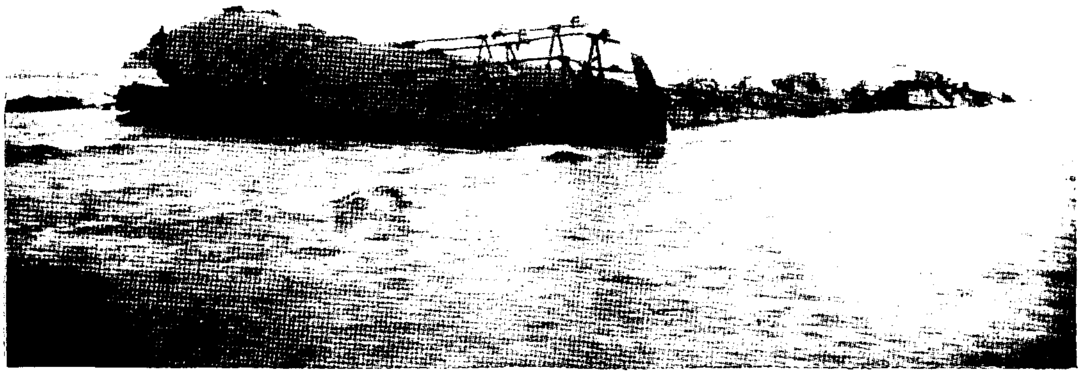
At this stage we cannot fail to admire the indomitable courage of Parsons. One may hazard the opinion that with most engineers the experiments would have ended there. The gap between the estimated speed of 30 knots and the 20 knots actually obtained was an enormous one. The power varying as the cube of the speed, such a difference indicates a shortage of propulsive power in the ratio of 8 to 27. Faced with a failure of this magnitude, most men would have cut their losses.

But Parsons here exhibited the courage and perseverance that later were recognized as outstanding elements of his character. First, to locate the cause of failure, he fitted a torsionmeter to the shaft, in all probability the first marine torsionmeter of any type. The greater part of the loss was found to be in the propeller, and it was soon recognized to be due to a phenomenon which had been just recently observed by Thornycroft and Barnaby during the trials of the 27-knot destroyer *Daring*, namely, cavitation of the water owing to its inability to close up on the back of the propeller blade. When the machinery for the *Turbinia* was designed, the *Daring*'s trials had not taken place, and cavitation did not occur in the models at the reduced speed and pressure which corresponded with their size. Its occurrence in the full-size propeller was therefore unsuspected until it was disclosed by the trials of the *Turbinia* itself.

For a practical demonstration of cavitation on a model scale Parsons devised a cavitation tank in which the propeller could be made to work under corresponding cavitating conditions. At first the water in the tank was heated to boiling temperature. In later experiments the surface of the water was exposed to a partial vacuum so that corresponding pressures were obtained as well as corresponding speeds. The tank was fitted with glass windows opposite the propeller and was illuminated by flashes reflected from a mirror revolving at the same speed as the propeller. In this way the phenomenon was brought under observation and it was seen that under certain conditions, usually when the thrust per square inch of area exceeded a certain fraction of the pressure on the surface of the water, the propeller tore a hole in the water and revolved ineffectively.

Having demonstrated that propeller slip, increased through cavitation, was the cause of a serious loss of power, Parsons, with the loyal support of his pioneer company, determined on a fresh attack. The vessel was equipped with a new set of turbines, this time arranged on three shafts and of the parallel-flow type. The shafts were each fitted with three propellers of 18 inches diameter and 24 inches pitch. Thus there were nine propellers of 18 inch diameter instead of the three of 20 inches in the first installation, making the disk area $2\frac{1}{2}$ times as great as before. The three turbines were arranged in series, high pressure, intermediate pressure, and low pressure, so as to obtain the best turbine efficiency. Various devices were tried for the provision of astern power. In the first turbine a row of blades had been fitted in the rim of the last disk to receive steam from a nozzle projecting into the exhaust space. In the second set of turbines, astern blades were at first fitted inside the drum of the low-pressure turbine at the exhaust end, receiving steam from a nozzle projecting within the drum. This was, however, found insufficient, and finally a separate astern turbine was fitted on the centre shaft forward of the low-pressure turbine. In all cases the rotor of the astern turbine or the astern rotor elements revolved in vacuum when going ahead, and likewise the ahead rotors were in vacuum when going astern.

The vessel was ready for trial with the new machinery in February 1896, and after a few changes of propellers succeeded in attaining a speed of $32\frac{3}{4}$ knots, amply justifying the confidence and the perseverance of Parsons and his



' VIPER ' WRECK ON THE ROCKS AT ALDERNEY

helpers. In comparison with performances which are now commonplace, $32\frac{3}{4}$ knots does not appear a great speed, but it was a higher speed than had been reached by any vessel at that time. Later, with a larger funnel fitted to increase the steaming capacity, the speed was increased to 34 knots.

The *Turbinia*'s appearance at the Naval Review later in that year attracted universal attention and interest. The spectators may have been thrilled to see a tiny vessel racing down the lines at such unusual speed, but their feelings of excitement could have been nothing compared with those of the few on board the vessel, with Parsons himself as chief engineer, who had emerged so triumphantly from depressing failure into glorious success.

After a further demonstration had been made with the vessel at the Paris Exhibition of 1900, where, before the French Minister of Marine, full-speed runs were made on a wide reach of the Seine, the *Turbinia* had fulfilled her part in calling worldwide attention to the possibilities of turbine propulsion. She was used some six years later for some special experiments on propellers, and in 1908 was lifted on to the jetty at Turbinia Works, and there remained until 1927, an object of attraction to passengers along the Tyne. In 1927 the after part of the vessel containing the machinery was transported to the Science Museum at South Kensington, where, with a portion of one side of the hull replaced by glass plates to expose the engine room, she remains a striking exhibit.

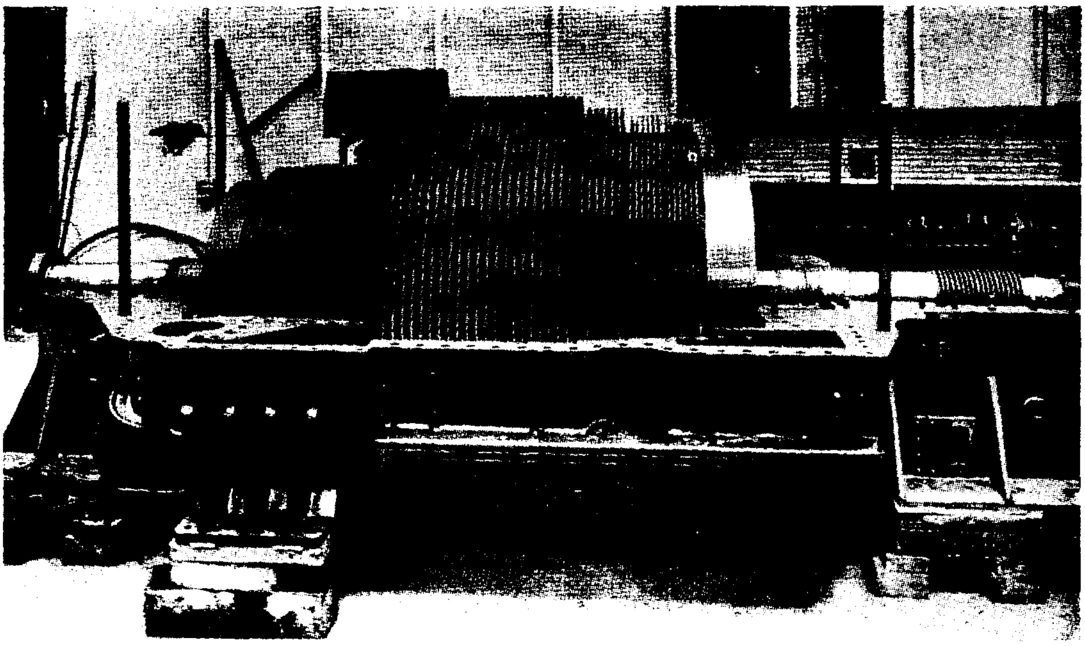
The recovery of the patents for parallel-flow turbines and the success of the *Turbinia*'s latest trials, prepared the way for the application of the turbine mode of propulsion to warships. A new company was formed with the title of 'The Parsons Marine Steam Turbine Company'. This company took over by purchase from the pioneer company the right to use the Parsons patents for marine propulsion, the *Turbinia*, and all effects. Of this new company Parsons was managing director. The Admiralty, whose attention had been drawn to the possibilities of turbine propulsion by the entry of the *Turbinia* into the Naval Review of 1897, showed keen interest in the matter, and after a few further demonstration runs with that vessel attended by prominent representatives of the Engineer-in-Chief's Department, placed an order with the new company for the destroyer *Viper*, a 31-knot vessel of the same dimensions as the 30-knot destroyers then building, namely, 370 tons displacement, 210 feet length, and 21 feet beam, but with machinery of somewhat greater power to give increased speed. Illustrative of the difficulties which beset a great inventor and also of the confidence which Parsons had inspired in the members of his pioneer company, it may be related that at the meeting at which this contract was decided, the hopes of Parsons were considerably dashed when the Admiralty demanded an indemnity against failure in the sum of £100,000, but were restored again when Christopher Leyland, a fellow director, went quietly across to him and said ' All right, Parsons, I'll back you.'

At the same time Sir W. G. Armstrong, Whitworth and Company also ordered from the company a set of machinery of similar power for a torpedo boat destroyer which they were building and which was afterwards named the *Cobra*. These vessels each had four shafts, with duplicate sets of turbines on each side of the vessel, consisting of a high-pressure and low-pressure turbine in series to the steam flow but on separate propeller shafts. They were equipped with boilers of a greater aggregate power than the other destroyers of the Class, a greater weight being available for the boilers on account of the reduced weight of the machinery.

The *Cobra*, which was the first of these two vessels to be completed, was subjected to a large number of trials, including fuel consumption trials and special astern-going trials. She attained a maximum speed ahead of 34·32 knots and was eventually bought by the Admiralty. The *Viper* when completed with full trial weights on board achieved a speed of 36·58 knots, more than 5 knots above the contract speed. As regard the coal consumption, which was guaranteed at 2·5 lb of coal per indicated horse-power-hour at 31 knots, she easily registered a consumption of 2·38 lb. The smooth running of the turbines in both vessels, and the absence of the usual fuss and bother in the engine room during trials of reciprocating engines, favourably impressed all the Admiralty officials present, who reported the trials as entirely satisfactory. Calamity however befell when these vessels were handed over. The *Viper*, which although later in completion was the first to be put into commission, ran on the rocks of Alderney in a dense fog in August 1901 during reconnaissance work in the Channel Islands and became a total wreck. A month later the *Cobra*, while being taken by a navigating party from Newcastle to Portsmouth, broke her back and foundered in the North Sea.

This double misfortune within so short a period might have destroyed all the patient work of the preceding four years, and leaving them without a single example of turbine propulsion, would have threatened the collapse of the whole undertaking. But actually after this catastrophe there was still a turbine-propelled vessel, the *King Edward*, which had just completed its trials. This vessel attracted great attention by its performance in service as a Clyde river steamer, and the interest in turbine propulsion was maintained in the mercantile sphere ; while interest was revived in naval circles with the trials of the second *Viper* which had been put in hand by the company, and which, named the *Velox*, was later purchased by the Admiralty.

After the loss of the *Viper* and the *Cobra* attention was concentrated on the destroyer *Velox*. It is a special requirement of naval vessels that they should not only operate economically at full speed, but also have a large cruising radius, which implies economy of steam consumption at a speed much below the full. To meet this condition Parsons first fitted to the inner shafts of the *Velox*, small high-speed triple-expansion engines which could be disconnected from the propeller shafts above a certain speed. The steam from these triple-expansion engines exhausted through the turbines to the condensers of the main engines, developing additional power in the latter. This is noteworthy also as being the first application of the combination of reciprocating and turbine engines, afterwards more extensively applied in low-speed ships. The triple-expansion

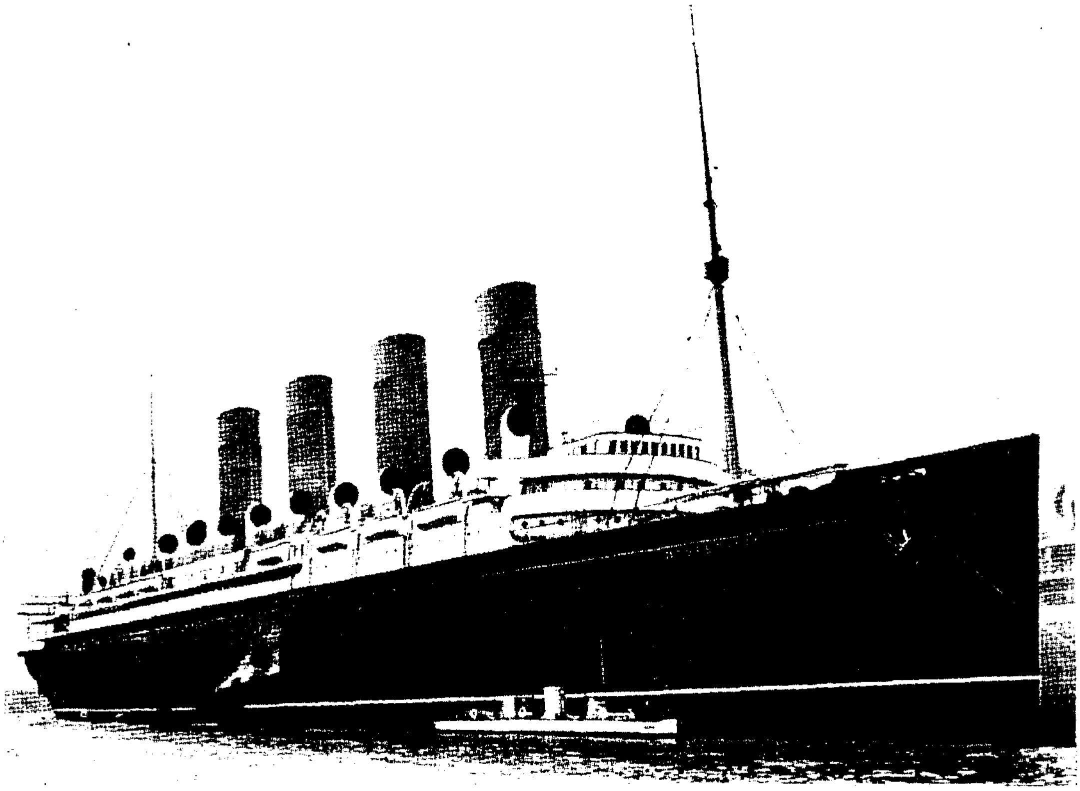


LOW PRESSURE TURBINE OF THE 'DREADNOUGHT'

engines in the *Velox* were however replaced, on account of vibration, by high-pressure turbines, which became a normal feature in naval vessels, under the name of 'cruising' turbines.

In 1902 the Admiralty ordered another destroyer, the *Eden*, which also had cruising turbines in addition to its main turbines. This destroyer was of the same size as the *Velox*, but unlike the *Viper* and the *Velox* it had a three-shaft installation of turbines similar to that of the *King Edward.* The cruising turbines, of which there were two, were coupled one to each outer shaft, and taking steam in series before exhausting it into the main turbines, were designated respectively the high-pressure cruising and intermediate-pressure cruising turbines. The Admiralty also decided as an experiment to adopt Parsons turbines in the *Amethyst*, one of four third-class cruisers of 10,000 i.h.p. then building, so that again the turbine was afforded an opportunity of showing its paces against its rival the reciprocating engine. The arrangement of the machinery in the *Amethyst* was similar to that of the *Eden.*

The introduction of the turbine for the propulsion of capital ships in the Navy was the outcome of a committee of investigation appointed by the Admiralty in December 1904 and presided over by the First Sea Lord, Admiral Sir John Fisher. This committee had available for investigation not only the turbine-driven channel steamers then on service, but also the newly built *Eden* and *Amethyst.* Exhaustive trials of these vessels in comparison with their sister ships established the superiority of the turbines in economy at all but the lowest powers. Taking this fact in conjunction with other obvious advantages of the turbine, such as reduced weight and consequent reduction in displacement, absence of vibration giving a steadier gun platform, lower centre of gravity of machinery and economy of personnel, the committee had no difficulty in recommending its adoption in cruisers and battleships, with the result that an order was placed with the Parsons company for turbine machinery for a battleship, the *Dreadnought*, under subcontract with Messrs. Vickers, Sons and Maxim of Barrow, who were the main contractors for the whole of the machinery, the ship itself being built at Portsmouth Dockyard. In anticipation of reduced



THE ' MAURETANIA ' WITH THE ' TURBINIA ' ALONGSIDE

steam consumption a reduction of about 15 per cent was made in the usual boiler proportions, an action which was fully justified afterwards by the trial results, the consumption of steam at full power for turbines only being 13·48 lb per s.h.p.-hr.

The fitting of the *Dreadnought* with Parsons turbines marked the final and wholehearted adoption of the steam turbine by the Admiralty and from 1905 war vessels of all classes were equipped with turbines. It is not intended to describe Parsons' work in reviving the use of gearing, or the second revolution which this brought about in marine propelling machinery.

With the knowledge which we have today of turbine design and operation, largely derived from the work of Parsons, we cannot but be filled with admiration for the complete grasp of the fundamental requirements, and the provision made for their solution, in his earlier attempts with the *Turbinia*. The world is his debtor for his courage and perseverance in the face of difficulties to make the turbine adaptable to all spheres of marine propulsion, and for the wise provisions he made for the dissemination of his knowledge and experience.

The substance and illustrations of this memoir are derived mainly from the third Parsons Memorial Lecture by S. S. Cook, B.A., F.R.S., to the Institution of Mechanical Engineers on 2nd December, 1938.