PARSONS
ENGINEER OF CHANGE
FOR
THE ROYAL NAVY

BY

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ABSTRACT

The article first defines the particular requirements of naval propulsion plant and discusses the implications of naval procurement strategy on propulsion machinery design. Using these parameters, it describes the impact on warships of PARSONS' development of the steam turbine for marine use and then traces the successive decoupling of prime movers and propulsors, from the reduction gearing devised and proved by PARSONS to the gas turbine and full electric propulsion of today. Finally PARSONS' indirect influence on naval events is deduced, including his probable impact on ADMIRAL Sir John FISHER and his reform of the status of naval engineers.

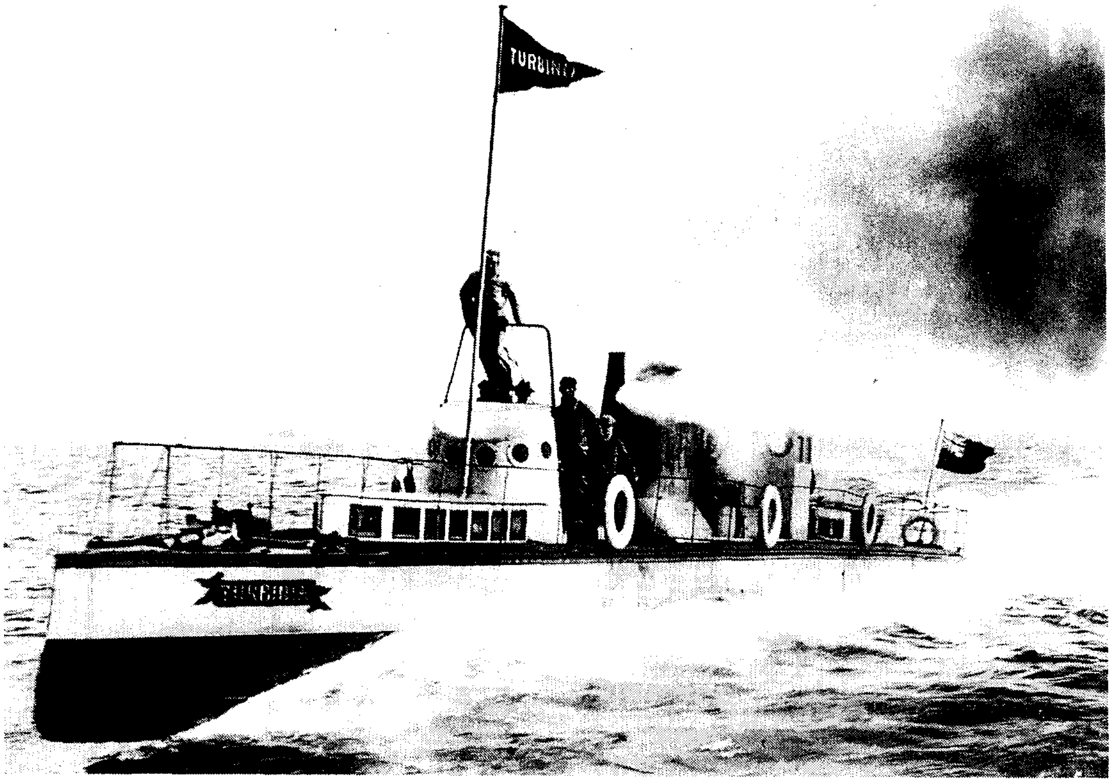

FIG. 1—'TURBINIA'

Introduction

Turbinia's (FIG. 1) extrovert and stylish demonstration at Spithead of the capability of steam turbines marked one of the rare step changes in naval marine engineering propulsion technology. The advent of gas turbine prime

FIG. 2—SIR CHARLES PARSONS

movers marks arguably the only other of comparable significance since then, and it is appropriate on the 100th anniversary of *Turbinia* that the Royal Navy is embarking on yet another that promises to be just as far reaching—the switch to all gas turbine-powered full electric propulsion. It is worth noting in passing that Sir Charles PARSONS (FIG. 2) was fully aware of this propulsion option, both theoretically, which he characterized as 'electrical gearing' in his address to the North-East Coast Institute[1] and in its practical expression in a US Collier and a Tynemouth Coaster at about that time (although its first use was the diesel-electric river steamer *Vandal* in 1903). In his characteristically relentless search for ever-increasing efficiency, he would certainly also have fully approved of the current drive to perfect the advanced cycle gas turbine with its diesel-equivalent fuel consumption. But let us take a step back from today's specific advances and consider the requirements of naval marine propulsion in the broadest and most general sense so that we can review how PARSONS contributed to their fulfilment during his lifetime and, by influence, long afterwards.

REQUIREMENTS OF NAVAL PROPULSION PLANT

Characteristics

To be properly effective, naval propulsion plant requires a particular set of characteristics. Some of these are common to all or most forms of marine application, and some are particularly related to warship operations or the naval environment. These requirements have been perceived as having differing importance during successive periods of recent history, and some, indeed, have even not been recognized at times. Their treatment here is as general as possible, although written in the light of modern knowledge and experience. While this lays itself open to the charge of hindsight, it also makes apparent a remarkable consistency across the years:

Reliability

All engineering plant should be reliable. At sea, unreliability in the commercial world at best loses time and money for the owners and at worst threatens the lives of those in the affected vessel. These dangers apply equally to a warship, but additionally, in war, unreliability threatens the operation of which the unit is a part, putting many more lives at risk and possibly the outcome of a battle or campaign.

Maintainability

Again, all engineering plant should be easily maintained (although the rigorous techniques to prove and improve this attribute are a modern invention). In a warship, together with reliability, this determines operational availability and hence, in a given threat or for a required number of active hulls, the overall number of hulls that must be in theatre.

Low Through Life Cost

Low cost of ownership is a generally beneficial characteristic but with particular resonance when public funds are involved and the budget is cash-capped; although this should be self-evident, through-life costs have often been sacrificed recently on the altar of minimizing acquisition costs.

Minimum Watchkeepers

Watchkeepers in any enterprise have an obvious impact on the cost of ownership of an item of equipment; at sea they also have a significant effect, for warships at least, on ship volume and displacement since each watch-keeping billet requires bunks, food stowage and hotel services for at least three men.

Efficiency

The direct manifestation of increased plant efficiency is obviously in reduced fuel costs, although there are maritime applications, such as oil or gas carriers, where this is not very significant. In a warship, it is most often translated into increased range with tremendous strategic benefit to a blue water navy, although it could equally be applied as reduced tankage in a ship (and therefore reduced displacement) or as a reduced requirement for auxiliary refuelling ships. Even in the one class of ship where it was traditionally irrelevant—the nuclear submarine—the advent of full-boat-life reactor cores will cause increased focus on propulsion plant efficiency.

High Speed

With very few exceptions, warships require high speed for a variety of reasons. For a blue water navy with reducing numbers of hulls, speed is strategically important to allow deployment to trouble spots. It is tactically vital to allow manoeuvring within a group (e.g. around a fast convoy or in support of carrier operations), pursuit of, or withdrawal from, the enemy (accepting that organic air power have reduced the impact of the former), and avoidance of weapons. High speed requires minimum displacement for a given armament fit with appropriately high power, and taken together, these mean high power density plant (and minimum carried fuel for the desired endurance).

Manoeuvrability

Leaving aside the natural aversion of dashing young naval commanding officers to the use of tugs, particularly in public, warships are often required to manoeuvre in close company and, during littoral operations, in navigationally hazardous waters. Speed of manoeuvre has also long been a prerequisite to the successful prosecution of close quarters action and the avoidance of incoming weapons. The required ingredients are acceleration, deceleration and speed of turn.

High Generating Capacity

The weapons and hotel loads in a warship require a high installed generating capacity; these also tend to increase through the life of the ship.

Flexibility and Robustness

Inherent in warship operations is exposure to the risk of battle damage. Machinery must be robust in the first place, and in particular resistant to shock as far as possible, and also be capable of operation in the variety of degraded modes which might result from battle damage or breakdown.

Signature

Minimizing warship signature of any kind is crucial to avoiding initial detection by the enemy, subsequent classification and targeting, and, ultimately these days, the homing weapon. Radar cross-section, infra-red and radio emissions, and radiated noise are well-known modern examples, but silhouette and smoke were the early tell-tales to be avoided.

The design process

Naval vessels are traditionally procured in similar batches or classes and, because of the replacement cost which is usually unpalatable to the Treasury, retained in service for a long time. The size and cost of propulsion plant militates against change or modernization, and once installed it is usually permanent. This has implications for the design and selection process which, to be successful, must strike a careful balance between avoiding the opposing risks of unproven technology and obsolescence whilst still choosing the most capable machinery for the task. Within these very broad constraints, lie the difficulties of meeting the range of requirements described above, many of which are usually in conflict with each other. A particular problem at the turn of the century was the continuous chase to integrate the optimum running conditions of the available prime movers of the day with optimum propeller speeds for the desired size and speed of the ships, within the requirements of simplicity and compactness. Having set the scene, it is now appropriate to consider how PARSONS had a direct impact on several specific examples of such problems and a more general influence on the problem itself.

THE ADVENT OF MARINE STEAM TURBINES

Steam Reciprocating Machinery

Naval propulsion towards the end of the 19th century was based firmly on steam reciprocating machinery. Notwithstanding the nostalgia of many seaman officers for sail, in the aftermath of the Crimean War the strategic advantages of mechanical propulsion had been firmly established, although some older vessels were still using it as an auxiliary to sail in the 1880s. However, by that time speed had become recognized as an important warship design parameter, principally in the context of Torpedo Boats and their counter the Torpedo Boat Destroyer. Cruisers were being designed with speeds of 22–24 knots and destroyers of 26 knots. After 150 years of evolution the reciprocating engine was generally held to have been developed to near its maximum potential, and its inherent constraints on expansion and efficiency, and its intense dislike of being 'pushed', placed an effective limit on warship speed. It also had many other disadvantages: it was manpower intensive, led to dismal conditions in machinery spaces, was subject to vibration, and lacked reliability. In this context Dr O PARKES[2] quotes the Committee on Designs as reporting in 1905:

> 'The inherent defects of steam reciprocating machinery meant that the effective speed of the Fleet was no more than 14 knots, and no fleet in the world could steam for 8 hours at full power without ships breaking down.'

Towards the end of the century, several engineers, particularly de LAVAL, were experimenting with rotating steam machinery but the high speeds required seemed to make this option intractable. It was PARSONS who put in place the pieces of the jigsaw in a way that made marine propulsion turbines a practical proposition. It is particularly to his credit that this success was achieved in the face of general opinion that the era of steam was over, as recounted from first hand memory in the first PARSONS Memorial Lecture[3].

Steam turbine propulsion

PARSONS' instinct was that a rotating prime mover (FIG. 3) must provide the most appropriate drive for a rotating application, initially in the context of electrical generation but with the logical extension to marine propulsion. (It should not be forgotten that the first use of turbines at sea was for electrical power generation, and while the immediate naval impact was small, principally because there was not yet the weapon technology to use it, it was a crucial prerequisite for the combat and propulsion systems of the future.) The detailed history of his design and development of the compound turbine is too well covered in a multitude of papers to need repeating, but its impact on the Royal Navy bears consideration in the light of the requirements and constraints outlined above. PARSONS himself, in his description of the compound steam turbine in a lecture to the Institute of Naval Architects[4] lists the advantages of his design over reciprocating machinery as:

Increased:

- Speed
- Economy of steam
- Carrying power of the vessel
- Facilities for navigating shallow waters
- Stability
- Safety of machinery for war purposes.

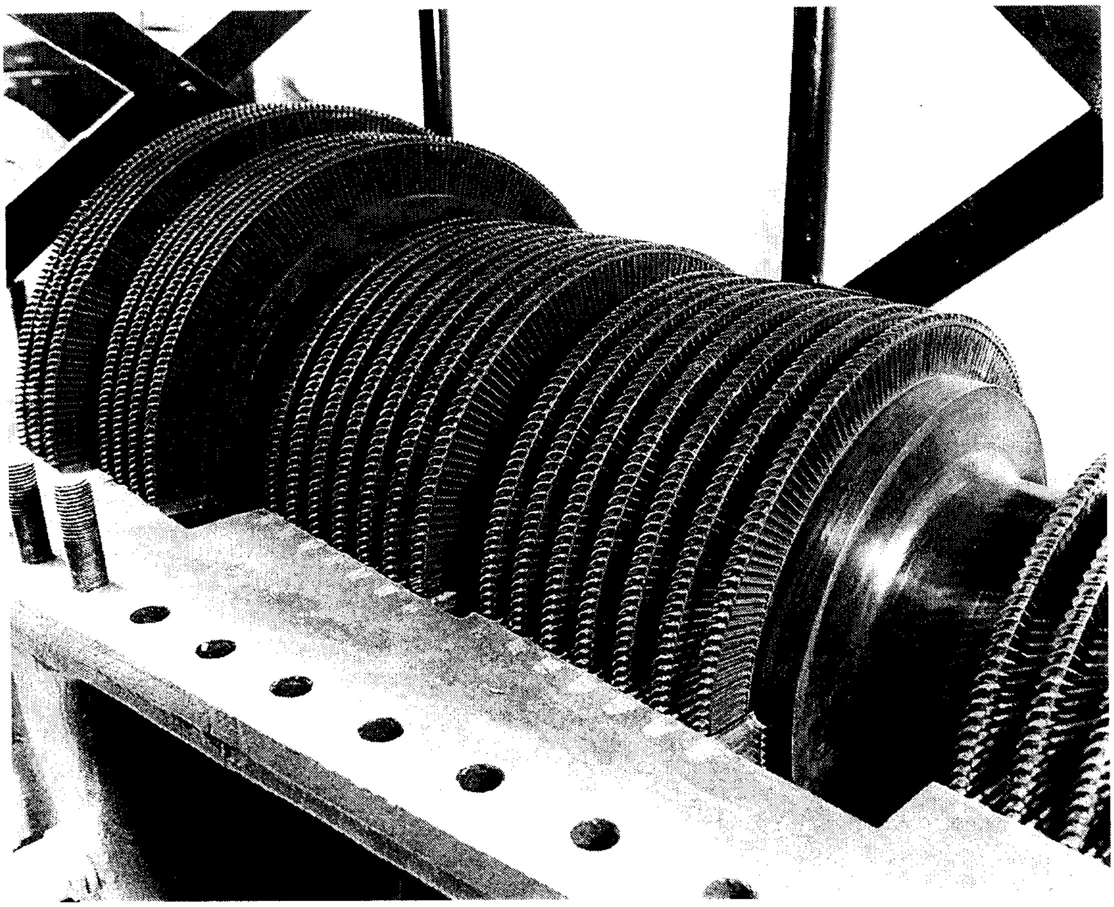

Fig. 3—'Turbinia's' rotating prime mover

Reduced:

- Weight and volume of machinery
- Initial cost
- Cost of attendance on machinery
- Cost of upkeep of machinery
- Vibration
- Size and weight of screw propellers and shafting.

An analysis of the benefits which accords very well with the requirements defined at the beginning of this article. At the time he gave them, these were predictions, and it is worth examining the practical effects, which were subsequently confirmed in summary by Prince Louis of Battenberg as part of deliberations by the Committee on Designs in 1905.

Ship speed

The speed of *Turbinia* had already demonstrated the design superiority of the turbine in this respect, both as a direct design application and in combination with the other benefits of the efficiency and power density of her plant. The experimental destroyers *Cobra* and *Viper* (Fig. 4) in their short lives gave further ample demonstration (and it is particularly interesting to note that the specifications of their contract were exceeded). In the longer term, the retention by *Mauretania* of the Blue Riband for 20 years was the ultimate accolade.

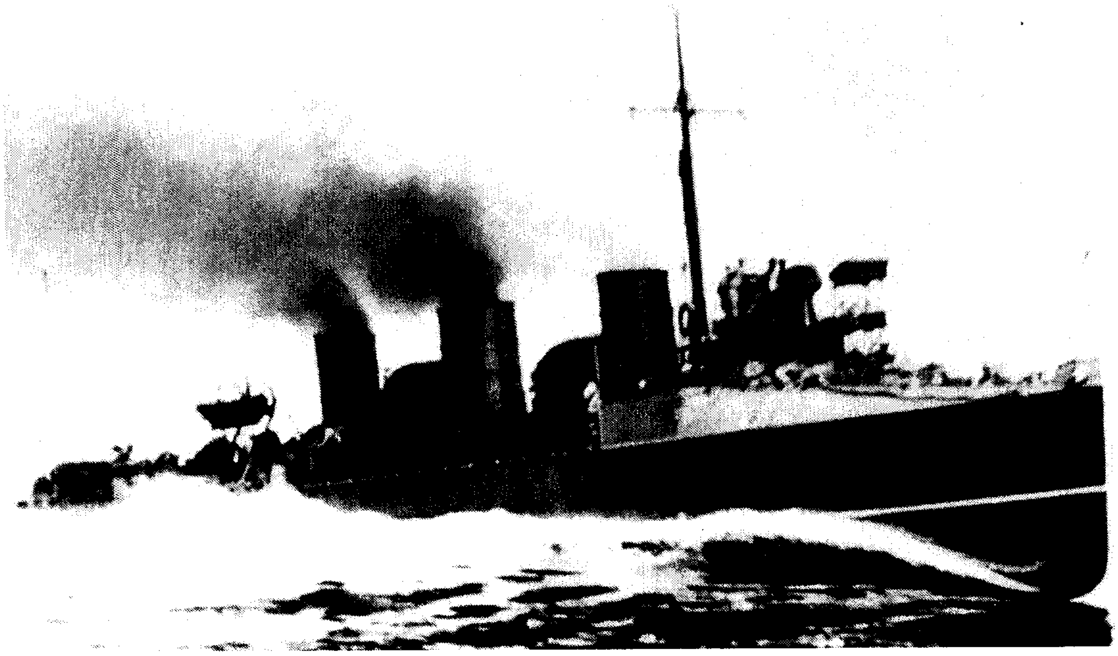

FIG. 4—HMS 'VIPER'

Power

Over the next 10 years warship propulsion power was to increase tenfold from:

1897 *Turbinia* at 2,300 shaft horse power (shp)
1905 The cruiser *Amethyst* (FIG. 5) at 14,000 shp

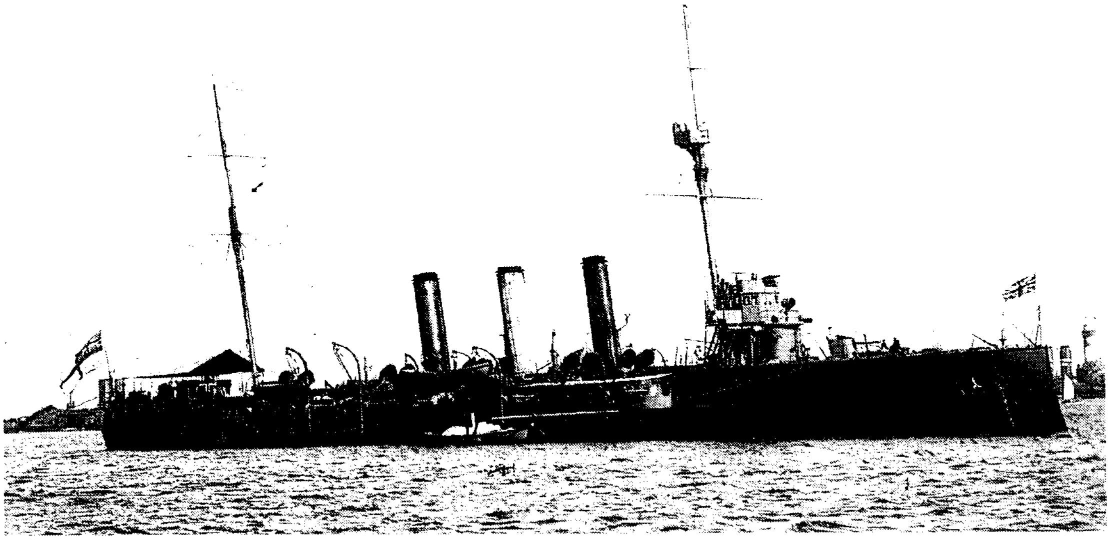

FIG. 5—HMS 'AMETHYST'

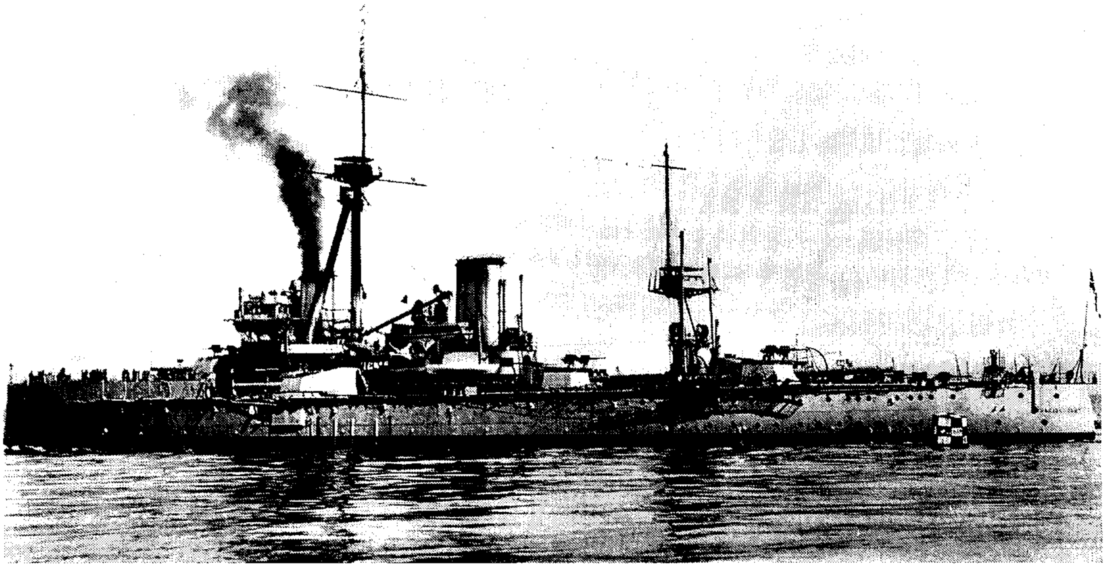

FIG. 6—HMS 'DREADNOUGHT'

1906 The battleship *Dreadnought* (FIG. 6) at 24,500 shp.

Only one year later the *Mauretania* and *Lusitania* were at 74,000 shp. Meanwhile, continuing the warship progression, the battle cruiser *Invincible* had installed 45,000 shp and could steam at 28 knots, and subsequently *Hood* was driven at 32 knots by 150,000 shp.

Power density

At full power, steam turbines were of the order of 30% more efficient than the equivalent reciprocating machinery (cf. the DREADNOUGHT class at 13 lb/shp hour and the INVINCIBLE class at 12 lb/shp hour against comparable reciprocating machinery at 16 lb/shp hour[5]), and thus for a given top speed the turbine installation was significantly lighter and so were the boilers. This weight reduction itself obviously had a potentially beneficial effect on overall ship performance.

Availability and reliability

The simplicity and reduction in moving parts of the turbine led to greatly enhanced reliability (and hence ship availability to the Command). Two separate pieces of evidence give practical expression to the improvement in this respect over the reciprocating engine. ADMIRAL OF THE FLEET Sir Charles MADDEN in an address to the Institute of Marine Engineers in April 1931 is quoted in APPLEYARD's Biography of PARSONS[6] as saying:

> '. . . turbine cruisers were so reliable that the turbine cases were not lifted for 5 years . . . [whereas] . . . reciprocating engines . . . required one day in ten with engines cooled for machinery adjustment . . .".

Dr PARKES[7] again compares reciprocating and turbine machinery reliability:

> '[The turbine's] reliability was demonstrated during *Dreadnought*'s return trip from the West Indies (7,000 miles) after a months steaming and calibrating trials when she maintained an average of 17½ knots without any machinery defects. This compares with the Second Cruiser Squadron's run from New York to Gibraltar in November 1905 when, out of six ships, only three got across at 18½ knots with empty bunkers and requiring extensive repairs to their engines."

Machinery environment

The better reliability attested to above is also related to an overall improvement in conditions below decks which is summed up in ADMIRAL BACON's biography of LORD FISHER (borrowed again from PARKES[8]) in a description worth quoting in full:

> 'When steaming in a man-o-war fitted with reciprocating engines, the engine room was always a glorified snipe-marsh; water lay on the floor plates and was splashed about everywhere; the officers often were clad in oilskins to avoid being wetted to the skin [author's note: presumably the men got wet]. The water was necessary to keep the bearings cool. Further, the noise was deafening; so much so that telephones were useless and even voice pipes of doubtful value. In the *Dreadnought*, when steaming at full speed, it was only possible to tell that the engines were working, and not stopped, by looking at certain gauges. The whole engine room was as clean as if the ship was lying at anchor, and not the faintest hum could be heard.'

Even if slightly exaggerated, this was eloquent testimony to the lasting benefits of turbine machinery.

Machinery configuration

The much higher speed of steam turbines led initially (in *Turbinia*) to problems of incompatibility with existing propeller shapes, and PARSONS' investigation of propeller design and cavitation (then a little recognizd phenomenon) are well reported elsewhere. In direct drive turbine machinery, such as *Turbinia* and other early designs, these problems were overcome by adopting more effective high speed propeller designs (FIG. 7) but also by the

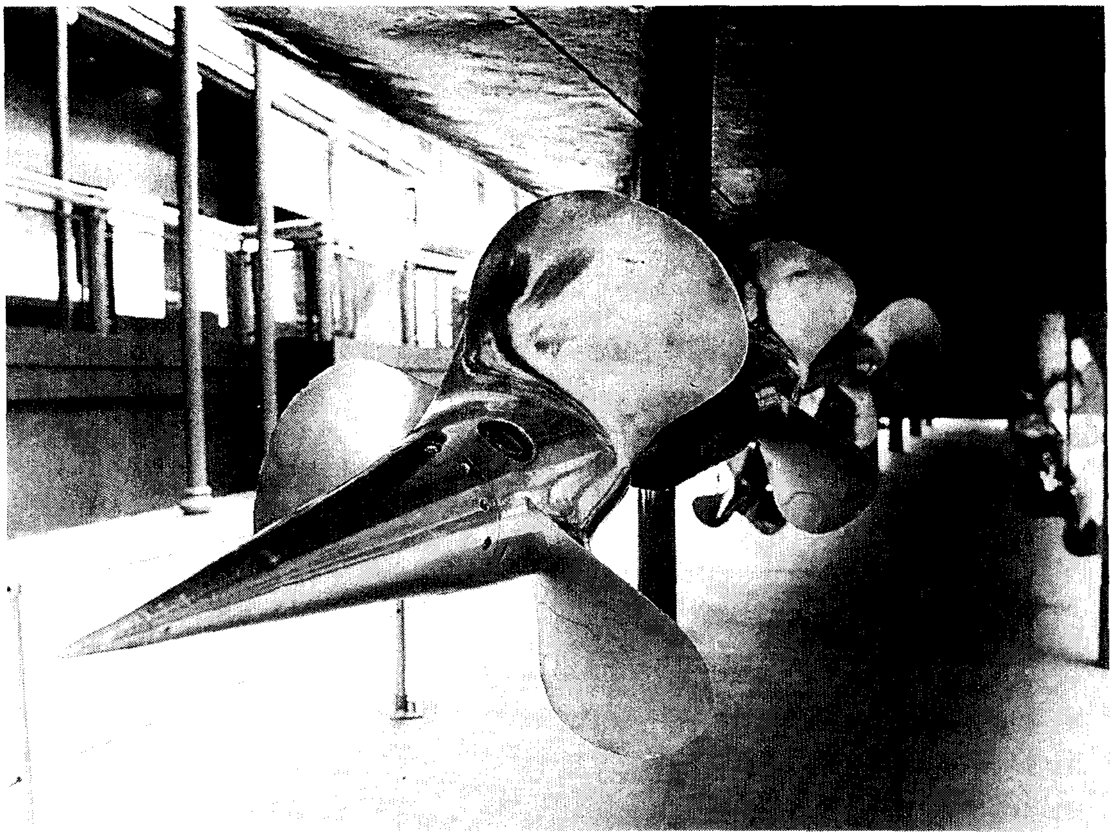

FIG. 7—'TURBINIA'S' PROPELLER

general principle of reducing the power transmitted through each propeller. The latter was achieved by increasing the number of shafts (which was inherently compatible with PARSONS reaction turbine principles of large numbers of discs which translate easily into several stages of turbine—each one to a shaft) and by increasing the number of propellers per shaft. This need to match prime mover speed directly to propeller speed actually marginally reduced the turbine advantages and required a further major design step.

THE IMPACT OF GEARING

Development of geared turbine propulsion

After the steam turbine, PARSONS' second major gift to marine, and particularly naval, propulsion was the introduction of reliable and uniform reduction gearing capable of transmitting significant power—a geared steam turbine set of the type designed for the destroyers *Badger* and *Beaver* (FIG. 8) is shown at (FIG. 9). His initial trial in *Vespasian* (and it was typical of the man that he first refitted her steam reciprocating machinery to provide a valid baseline for comparison) allowed steam turbines to be applied to lower speed merchant vessels such as tramp steamers. His further invention of creep machining to minimize the effect of errors in the master wheel on production gears was an essential step on the road to large marine gear trains. The important general principle was to start to decouple optimization of prime mover speed from optimization of propeller speed with major long term consequences for freedom of choice in propulsion system design which are still being felt today. In the short term he paved the way for an increase in the power transmitted per shaft and the ability to combine the output of different turbines optimised at different speeds (or indeed compound turbine and reciprocating systems) on the same shaft. Early direct drive turbine ships had three or four shafts; in due course two shafts became the preferred option to simplify machinery and ship layout, but this carried much lower propulsive efficiencies. The introduction of reduction gearing restored the ship performance while maintaining these benefits, and direct drive was abandoned for good. It is also ironical that this partial decoupling of optimization contained the seeds of the death of the PARSONS turbine since it allowed the introduction of higher machine speeds and the much more compact combination of Curtis and Rateau stages. In the much longer term, reduction gearing was the essential prerequisite to mechanically coupled gas turbine propulsion and also the very quiet low speed submarine propulsors driven by nuclear steam plant.

LONG TERM TECHNICAL LEGACY

PARSONS' technical legacy was diverse and far-reaching, and touches us still today. In the near term he continued to press with vigour for increased turbine efficiencies, identifying the four principal means of regenerative feed water heating, ever increasing boiler pressures (and improved boiler design), steam re-heating, and increased condenser vacuum (with improved condenser design). Had he retained his vigour and lived longer, it is possible that Royal Navy machinery design might not have fallen into the state of complacency which marked the late 20s and 30s and which was maintained by the licensing system which he had instituted.

Parsons Marine Steam Turbine Company and Licences

It is entirely understandable that PARSONS should have been deeply affected by having to abandon his patents for axial flow turbines and by having to persist, during the four year struggle to regain them, with a radial flow system that he must have known was inherently inferior. Given this experience, and with the limited capacity of his own factory in the face of the very large