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THE INSTITUTE OF MARINE ENGINEERS

1949 PARSONS MEMORIAL LECTURE

PROGRESS IN MARINE PROPULSION (1910-1950)

By K. C. BARNABY, O.B.E., B.Sc. (Member of Council I.N.A.)

Read in London on 29th March, 1950, at the I.N.A. Spring Meeting, Sir Maurice E. Denny, Bt., K.B.E., S.B. (Vice-President I.N.A.), in the Chair, supported by Sir A. Murray Stephen, M.C., B.A. President (I.Mar.E.)

Summary

This forty-year period under review covers some highly important changes in marine propulsion. These are traced mainly by reference to the I.N.A. TRANSACTIONS, which cover the introduction into marine practice of geared turbines, ocean-going motorships, and high-pressure boilers. The increasing competition between steam and oil engines is discussed from the more detached viewpoint of a naval architect.

The concluding sections deal with progress in hull and propeller design.

Introduction

At the beginning of 1910, the Jubilee year of our Institution, there were no vessels with geared turbines and there were no ocean-going motorships. The Michell thrust had not won adoption. The Merchant Navy was content with Scotch boilers and coal fuel. It looked on water-tube boilers as temperamental contraptions only suitable for torpedo-boat destroyers and on "liquid fuel" as an unwanted extravagance.

The Royal Navy was as reluctant to abandon large tube boilers and coal firing as it had once been loath to give up masts and sails. If oil was carried at all in large ships, it was only as a convenient method of increasing the endurance. All our submarines ran on petrol. As regards naval warfare, for over half a century our lessons had been mainly academic and learnt from other people's troubles. As far as our own ships were concerned, and apart from the gunnery exercise at Alexandria, there had been little more than a few brushes in China and an indecisive action off Peru.

The machinery output figures for the previous year were 468,000 S.H.P. for direct-drive steam turbines and just over 1,000,000 I.H.P. for reciprocating steam engines. There were thus only these two alternatives before both the private shipowner and the naval authorities. The very fact that there was an alternative to the piston engine at all was mainly due to the work of Sir Charles Parsons. It was only thirteen years since the world had been startled by the spectacular dash of the little grey *Turbinia* through the lines of the assembled warships at Spithead. A dash that had full Admiralty permission—despite many good stories to the contrary and the alleged annoyance of Queen Victoria herself.

Yet by 1910 the Parsons turbine was very firmly established on both land and sea. For marine use alone, over 4,700,000 S.H.P. had been completed or were under construction. In the merchant service, the *Lusitania* and the *Mauretania* had increased the speed of the Atlantic crossing from 23½ knots to over 26 knots. The piston engine was virtually obsolete for naval use, since, barring submarines and certain U.S.N. battleships, all fast or important units that were laid down after 1910 were turbine propelled. This remarkably rapid progress had been achieved within twenty-five years from the trials of the first Parsons turbine. This was a little non-condensing turbo-generator of 4 kilowatts. The blades were cut out of the solid and the steam consumption was the very extravagant figure of 200 lb. per kilowatt-hour. By 1910 the consumption of a 5,000-kW. Parsons turbo-generator had come down to only 13·2 lb. per kilowatt-hour.

Notwithstanding this record of progress, further development of the steam turbine was being gravely hampered by two factors. The revolutions necessary for an efficient turbine were far too high for an efficient screw propeller. The steam consumption at reduced powers was also too high. At full power the turbine could no longer be stigmatized as "a notorious steam eater," but at cruising speeds its consumption exceeded that of the reciprocating engine.

The I.N.A. TRANSACTIONS for the next few years bear witness to numerous methods of harnessing the high speed of the turbine to the low speed of the propeller. In the 1910 meeting itself, one author advocated full electric transmission; the next paper was a description by Sir Charles Parsons of the mechanical gearing he had just fitted in the cargo ship *Vespasian*. In the following year we had an account of the first twelve months running, which was shown to be highly successful. The gear had given no trouble. As compared with a triple-expansion reciprocating engine, 25 per cent of the machinery weight had been saved and there was a 16 per cent reduction in fuel consumption. In the discussions of both papers, the merits of electric transmission and of the Fottinger transformer were strongly urged by various speakers. Both methods gave full astern power and obviated the use of astern turbines. Electric transmission has, of course, survived to this day, but the Fottinger transformer has disappeared in connection with steam turbines. A variant of the same principle is now being used under the name of a "torque converter" for use with gas turbines. Other uses of the principle are the hydraulic coupling and the fluid flywheel.

Rise of the Oil Engine

In the opening year of the period under review there was some evidence in our TRANSACTIONS of the enormous interest being taken in the development of the large oil engine. All over Europe, and to a lesser extent in the U.S.A., engineers were engaged in development work on the large oil engine with much the same zeal and energy as they are now displaying in connection with the gas turbine. Nearly every large engine works seemed at that period to have an experimental "Diesel Shop" from which all visitors were barred. This secrecy was probably due to firms not wanting outsiders to know how badly their diesels were running rather than how well they were doing. At any rate, it is significant of the period that in Linton Hope's 1910 paper on the "Application of the Internal-Combustion Engine to Fishing and Commercial Vessels," the author stated that "at present 100 to 200 B.H.P. seems to be about the limit of power for really practical engines which can be thoroughly relied on." In the discussion, other speakers pointed out that very much larger engines were being built on the continent. They were right. Before the close of the year the Italian ship *Romagna* was running with Sulzer diesels and the *Vulcanus* with Werkspoor diesels. Little seems known about the first ship, but the *Vulcanus* was an outstanding success. Her owners were so pleased that Sir Marcus Samuel told us in 1912 that the *Vulcanus* had "demonstrated beyond any possible doubt that anyone who goes on building steam engines with the knowledge that is now afforded is only courting disaster."

Not everyone took such a favourable view as to the prospects of the heavy oil engine. Thus Mr. J. Hamilton Gibson remarked as late as 1914: "Frankly, I do not like the idea of propelling large vessels by means of a series of explosions in a battery of oil or gas engines. . . . In fact, it had been well said that the problems are more suited to the gunner than to the engineer."

Time supplies the appropriate answer to both optimists and pessimists. The output figures in this country for 1949 are given in Table I.

TABLE I

VESSELS COMPLETED IN THE UNITED KINGDOM IN 1949

Number of ships	Gross tonnage	Type of machinery	Percentage of total
119	198,121	Reciprocating steam	14·5
41	339,926	Geared turbine	25·0
174	823,134	Diesel	60·5
334	1,361,181	All types	100·0

In 1911, Mr. J. T. Milton—then chief engineer surveyor to Lloyd's Register—gave an important paper on "Diesel engines for Sea-going Vessels." He explained that "it had been determined to fit several vessels intended to be classed in Lloyd's Register with these engines." He had, therefore, paid a series of visits to the principal firms engaged in the manufacture of diesel engines. The paper gave not only information gleaned from those visits, but technical data for shaft stresses, etc.

Dr. Diesel himself opened the discussion, and argued that, owing to the reduction of stand-by losses, the saving in fuel should be 80 per cent as compared with coal. Other speakers challenged this saving, and, in terms of cost, the estimates for the 500-H.P. *Vulcanus* varied from a saving of £4 per day to a loss of 21 shillings in the same period. Incidentally, the cost of coal in these estimates was taken at 12 shillings per ton. Diesel oil was taken at 45 shillings per ton. The virtues of gas were also stressed and fears were expressed as to the availability of oil fuel if there were too many motorships.

Progress of the Parsons Turbine

In the summer of 1911 our Institution held its Jubilee meetings. These had been postponed from the previous year owing to the untimely death of King Edward VII. Sir Charles Parsons read a historical paper entitled "The Marine Steam Turbine from 1894 to 1910." He quoted a paragraph from the original prospectus of The Marine Steam Turbine Company. This read: "If successful, it is believed that the new system will revolutionize the present method of utilizing steam as a motive power and also that it will enable much higher rates of speed to be attained than has hitherto been possible with the fastest vessels." Would that the expectations of all company prospectuses were equally faithfully fulfilled.

Sir Charles gave figures which showed that out of 5,841,000 total S.H.P. for Parsons turbines, completed or under construction, 4,869,800 S.H.P. were for war vessels, or nearly 84 per cent. At that time the Parsons turbine was undoubtedly much more popular for naval work than for merchant vessels. In the latter, a combination system was, however, achieving a considerable measure of success. Triple-expansion engines were used on the two wing shafts and a low-pressure turbine on the centre shaft. The system enabled the advantage of the reciprocating engine at high pressures to be combined with the great efficiency of the turbine at low pressures. Typical ships so fitted included the *Otaki*, *Orama*, *Laurentic*, *Megantic*, *Olympic* and the ill-starred *Titanic*.

Monsieur Rateau—the inventor of the turbine bearing his name—contributed what was mainly an argument for the combination type machinery, either as just mentioned or the reverse arrangement of wing turbines and a centre line reciprocating engine. For quadruple-screw battleships, the inner shafts were to be driven by turbines and the outer shafts by reciprocating engines.

It was rather odd to hear an inventor of steam turbines, after of course citing the advantages of the turbine, proceed to say: "Great importance must have been attached to these qualities to justify the adoption of these engines, as they have the grave fault of showing a low efficiency at ordinary speeds which reduces by one-half one of the principal factors contributing to the naval value of ships, viz. the radius of action."

A third paper at the same meeting must be recorded. This was Sir Henry Oram's description of "Fifty Years' Changes in British Warship Machinery." Full details were given of weights and powers, etc. At the close of the period, the machinery of the battleship *Neptune* was developing 13·64 I.H.P. per ton against only 5·67 I.H.P. for the *Warrior* of 1860. The coal consumption per I.H.P. hour was 1·464 lb. in place of from $3\frac{3}{4}$ to 5 lb.

In 1912 there were several papers of great interest. Mr. Ivor Knudsen reported the results of trials of the first ocean-going motorship, the *Selandia*. This was a vessel of 10,000 tons and fitted with Burmeister and Wain diesels of 2,500 I.H.P. (total). The success of this pioneer ship gave a great fillip to the motorship. Mr. A. C. Holzapfel argued the case for the now defunct marine gas engine.

There were two boiler papers by Sir Harold Yarrow and Monsieur G. Hart respectively. Sir J. H. Biles gave particulars of the geared turbine cross-channel vessels *Normannia* and *Hantonia*. He compared these ships with the previous class—the direct-driven *Caesarea* and *Sarnia*. He claimed a 40 per cent improvement in economy. This was not, of course, due to the gearing as a separate entity, but was the sum of a number of consequential changes. The power could be reduced on account of the improved screw efficiency. This meant less weight and a narrower and lighter ship, which again reduced the power.

These two ships were very successful and were the first examples of passenger vessels with geared turbines. The reduction gear ratio was only 5 to 1, as it was necessary to have fairly small screws on account of the restricted draught. The *Normannia* was lost at Dunkerque, but the *Hantonia* is still in regular service. The original main wheels are still in use, but the high-pressure and low-pressure pinions have been renewed during the ship's long years of service.

Sir Charles Parsons and Lord Fisher

In 1912 Sir Charles Parsons was placed in a very invidious position. Only seven years earlier he had been the principal witness at the Admiralty committee called on to decide the machinery for the new battleships and armoured cruisers. Lord Fisher had been his ardent supporter, but had now become converted to the superior merits of the oil engine, despite the unprecedented success of the Dreadnoughts and the fast cruisers. Fisher's main reason for the change was given in a letter to Sir Charles dated August 31, 1912: "The point of the internal-combustion engine for the Navy is the absence of funnels." A little later he wrote: "The ONE SOLE VITAL POINT for the Navy about the internal-combustion engine is that you get rid of a mass of funnels. I've seen a fleet 20 miles off and each ship spelling her name to me by her funnels! And a single jet of black smoke has in my experience disclosed a fleet 40 miles off! And you cannot with the most perfect appliances for steam-raising with oil avoid such accident. It's really a vital fighting question to get rid of the funnels and have a telescopic hollow mast to get rid of the gases and to convey the wireless."

Sir Charles Parsons replied that he would attend the Royal Commission and would bring a "possible arrangement of oil engines for some 30,000 H.P., but before anything on this scale was attempted it would be prudent to try, say, some 10,000 H.P. in a small cruiser." Sir Charles added: "I have come to the conclusion that gearing between engines and screw shafting will be essential. . . . I think the weight can be got down to that of steam propelling machinery by using a large number of small diesel engines, not big cylinder ones, which are not right at present. Again you are aware that a smoky exhaust is not unknown in oil and gas engines —*vide* autocars. Then again have makers of oil-burning apparatus under boilers really directed much trouble to endeavour to make smoke impossible? I do not think they have done so or only half-heartedly. Also the funnels of vessels are at present unnecessarily large, and with a very small increase in fan power one or two telescopic masts could be made to take their place—for the quantity of gases from boilers is NOT DOUBLE the VOLUME of exhaust gases from the diesel engine of the same power."

Lord Fisher's reply was so characteristic that I cannot refrain from quoting it *in extenso*.* The address seems a singularly inappropriate one for a man of Fisher's dynamic temperament.

RESTON LODGE,
PETERSHAM,
SURREY.
October 14*th*, 1912.

DEAR SIR CHARLES,

Your letter this moment come. I am terrified I may not meet you on 17th inst. at 11 a.m. *but I hope I shall.* I've been in bed 4 days with a cold. (Winston Churchill cajoled me to stay late last Thursday and I got a chill coming home here with a beastly East Wind.)

This is a fact: Krupp has for some time had a single-cylinder 4,000 H.P., Vickers is *sure* of the one now under trial at Barrow, being 1,200 H.P.

The German Admiralty have certainly arranged for a battle cruiser with I.C. engines with the Nuremburg firm to be commenced in the near future. We've got to keep ahead of the Germans.

Vickers are absolutely confident they can produce a 25-knot Dreadnought equal to any building or projected ship and capable of going round the earth without re-fuelling. They are prepared to go "nap" on it *with* 68,000 *H.P.*! on 4 shafts. Oram and the Admiralty are timorous—of course they are! They were timorous with the water-tube boiler! They were timorous at the turbine going into the Dreadnought! We've got to push them over the precipice! Half a loaf is better than no bread.

They strain at the gnat of perfection and swallow the camel of the "unready." What breaks my heart is that you can't see your way to associate the turbine with the principle of internal-combustion propulsion. Isn't there some metal that will stand the heat? Dr. Beilby will invent it for you. Can't you see your way to some experiment?

Yours very truly,
FISHER.

It was a very fortunate thing for the country if the Engineer-in-Chief *was* a little "timorous" about the advisability of installing oil engines into battleships. The proper field for the 1912 vintage oil engine was the submarine. Both the British and United States navies had lagged behind other countries in this respect and had held on too long to petrol-driven submarines.

Parsons and the other witnesses seem to have convinced Fisher that steam was the better proposition. At any rate Fisher wrote to Parsons in December 1912: "It's quite wonderful your getting such results with steam and as you say truly it makes the diesel with all its complications retire into the background, but remember there are always those funnels!" At heart Fisher was clearly hankering after oil engines, for his letter went on: "Krupp's representative was in London yesterday and swears they had unmitigated success with their 2,700 H.P. cylinder, and that three of these cylinders have been running unceasingly for months without a hitch —they have three other cylinders completed and the whole six are going into a German battleship."

Eventually—in 1931–33—Germany did get a class of three all-diesel pocket battleships, but they did little in the last war. Two were sunk by R.A.F. bombing and the third, the *Admiral Graf Spee*, did not have much success at the battle of the River Plate. The reason the German Admiralty was so keen on oil engines was, of course, the increased endurance. The British Navy, with relatively closely spaced re-fuelling stations, did not feel it was under the spur of quite the same necessity. This view was somewhat changed in the war, as the chase of the *Scharnhorst* and many actions in the Mediterranean and elsewhere proved that the maximum possible endurance was a very vital problem for all navies.

All large German warships with the exception of the three 54,000-B.H.P. pocket battleships had geared turbines for their main propulsion. To-day, with the greatly increased speeds and powers that are required, an era of oil-engined warships seems even further off than in 1912. The German ships had, however, in many cases auxiliary diesels for cruising speeds. One British destroyer, the *Hardy*, was intended to have a similar arrangement in 1912. The oil engine was never fitted, and it is a curious instance of the nicety of some destroyer calculations that the ship had to be strengthened on account of this omission. The hogging stresses on destroyers are almost always more severe than the sagging stresses, and the former were increased by the absence of weight amidships.

The Last Pre-War Year

In 1913, the only paper dealing with oil engines was Mr. Ivor Knudsen's description of the "Performance on Service of the Motorship *Suecia*. This ship and her machinery were very similar to the original *Selandia*. The rated power was stated as 2,000 I.H.P., but the speed and power curves showed a maximum of 2,500 I.H.P. The length of machinery space was given as 41 ft., and this was compared with a length of 66 ft. for the steam machinery of a very similar vessel. The installed weights were given as 470 for the diesel ship and 570 tons for the steamer.

Three papers dealt with steam turbines. The first was Sir Charles Parsons's "Mechanical Gearing for the Propulsion of Ships." The author described a very ingenious method of overcoming what might be termed "hereditary defects" in gears. This consisted in giving a "creep" of about 5 per cent to the table of a gear hobbing machine.

Dr. Inglis dealt with the trials of the three ferry steamers *Curzon*, *Elgin*, and *Hardinge*. These were shallow-draught geared-turbine vessels built for the Ceylon service of the South Indian Railway Company. The building contract included the unusual condition that the ships were to steam 20 sea miles at the rate of 16½ knots, starting from rest and with no allowance for getting under way. Their distinguished designer was Sir William White, and it was a sad coincidence that the same volume of our TRANSACTIONS also included his obituary notice.

The third paper was Sir Harold Yarrow's "Device to

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* From *Charles Parsons*, by Rollo Appleyard.

Facilitate the Coupling of Cruising Turbines." This was a means of indicating the relative speed of two dog clutches, so that they could be engaged whilst rotating.

Messrs. Reid and Mavor presented "A Case for Electric Propulsion." This concerned oil-engined Canadian lake steamers. These ships are a special design with the maximum dimensions that will pass through the locks of the Welland Canal. It was argued that the vessels had to enter the locks at considerable speed and the consequent necessity for quick stopping justified electric transmission.

At our last spring meeting before the outbreak of the 1914–1918 War, Dr. J. T. Milton gave a valuable paper on "The Present Position of Diesel Engines for Marine Purposes." Various types of engine were described, and an account was given of an accident to the M.S. *Suecia* when one of the high-pressure air receivers burst. This was ascribed to an "oil fog" from deposited lubricating oil becoming overheated. It was one of the first warnings that an explosive mixture can be formed from overheated lubricating oil when mixed with the right amount of air. The much more serious accident to the *Reina del Pacifico* will come to mind as being due to the same general cause.

Another engineering paper was Mr. Harry Gray's "The Use of Superheaters in Mercantile Steamers." One usually looks on superheat as a comparatively modern innovation. It was interesting, therefore, to learn that it had been in considerable use some seventy years ago and then abandoned. It had resulted in considerable economy, but rapid deterioration set in and the repair bills were too heavy. The steam pressure at that time was about 10 lb. to 25 lb. per sq. in. and the superheat about 340 deg.

Our summer meeting of 1914 was held at Newcastle only a month before the outbreak of war. The opening paper was, suitably enough, "The Protection of Battleships against Submarine Attack." This could not be taken as a presage of coming war as our opening paper had so often dealt with warship design. From 1906 onwards every opening paper at our spring meetings had been concerned with this topic.

The second Newcastle paper in 1914 was Professor Fottinger's "Recent Development of the Hydraulic Transformer." The author stated that upwards of 225,000 S.H.P. were then in service or under construction and claimed an efficiency of about 92 per cent for the latest type transformer and large powers; 90 per cent of the full horse-power could be used astern. With single-stage transformers the reduction rates varied up to 6 to 1. One of the ships described in the paper—the *Konigin Luise*—was sunk within a month of Fottinger's paper and was the first German sea casualty in the 1914–1918 war.

1914–1918 War

During the war years of 1915 to 1918, little could be said about the progress of warship machinery and design. Our TRANSACTIONS bear the air of a dignified aloofness from the realities of war. This was all the stranger since the design of warships and their propelling machinery had been such a favourite topic from the foundation of the Institution. Now the ideas and principles that had been so often debated at our meetings were being put to the acid test of war. We had to wait till 1919 before much information could be released.

In that year Sir Eustace d'Eyncourt gave a very comprehensive paper on "Naval Construction during the War," and in the following year a description of the *Hood*. From these two papers, and from Sir Philip Watt's 1919 paper, we can glean some interesting sidelights on the progress of marine propulsion in the Navy. The battleships of the *Iron Duke* class were the last to burn coal fuel. Eighteen water-tube B. and W. boilers were required for 29,000 S.H.P. giving 21¼ knots. In the succeeding *Queen Elizabeths* power went up to 75,000 giving 25 knots. Despite the 158 per cent increase in power the number of boilers only went up to twenty-four, that is, an increase of 33 per cent or practically double the power from each boiler.

The battle cruiser *Tiger*, completed in 1914, had thirty-nine large tube boilers arranged for burning either coal or oil. The *Renown* class had the power stepped up to 112,000 S.H.P. with extra boilers. The total length of the boiler rooms was about 197 ft. against about 112 ft. for the engine rooms. That is, on a machinery length of about 309 ft., the boiler rooms took up about 64 per cent and the engine rooms about 36 per cent.

The *Glorious* and *Courageous* class of large light cruiser had the same type of machinery as was being used in the light cruisers, i.e. virtually destroyer type with small tube boilers. The power was 90,000 on eighteen boilers. The length of machinery space was about 205 ft., of which the boilers were responsible for about 58½ per cent. Looked at on a basis of length, which is the measurement which mainly affects the naval architect, 439 S.H.P. were developed per foot of length in lieu of only 363, or a saving of about 19 per cent in length.

In the *Hood*, twenty-four small tube boilers were used for a power of 144,000, that is, an increase of from 5,000 S.H.P. to 6,000 S.H.P. per boiler. In discussing the paper, Sir Philip Watts lamented that he had been restricted to boilers of only about 2,500 S.H.P. when designing the *Tiger*.

The evolution of the light cruisers shows the same picture of a steady decrease in the number of boilers for the same power. Thus the *Weymouth* class laid down in 1910 required twelve water-tube boilers of the small tube type to give 22,000 S.H.P. The *Arethusa*, completed in 1914, had only eight boilers for 40,000 S.H.P. and was the first cruiser in the Royal Navy to burn oil fuel alone. The machinery length was 148 ft., of which the boiler rooms accounted for about 51½ per cent. In the next *Calliope* class, two ships were fitted with Parsons's geared turbines. The *Calliope* had four shafts and the *Champion* two. Sir Eustace d'Eyncourt described this as "at the time a very important experiment, the putting of 20,000 horse-power through gearing being a bold departure from anything which had been hitherto contemplated."

Few details of destroyer development were given in Sir Eustace d'Eyncourt's paper, so Table II has been prepared. This shows the main machinery particulars of certain turbine destroyers from those afloat in 1910 to the latest types. The published particulars of the *Manxman* class of fast minelayers (see *Janes Fighting Ships*) show that the S.H.P. per shaft is 36,000 and that only four Admiralty three-drum boilers are needed for the total power of 72,000 S.H.P. Thus, from the *Weymouth* class of 1910 to the *Manxman* we have gone from 1,833 S.H.P. to 18,000 S.H.P. per boiler.

With the exception of the "Hunt" and "Battle" classes, all destroyers laid down during the last war had a power of 40,000 S.H.P. developed on only two Admiralty-type three-drum boilers.

We are getting "ahead of station," however, and we will return to our 1919 meeting. Besides the naval papers already mentioned, there were two others which we should recall. One was "Investigations into the Causes of Corrosion or Erosion of Propellers," by Sir Charles Parsons and Mr. S. S. Cook. The other was "The Michell Thrust Block," by Mr. J. Hamilton Gibson.

The first paper described the findings of a special subcommittee of the Board of Invention and Research and was set up in 1915. At that time there was considerable doubt as to whether the pitting of propellers that were on the verge of serious cavitation was due to chemical corrosion (from released gases or alternatively from electrolytic action) or from the mechanical effects of water-hammer or from bad material or from undue stressing. The conclusions arrived at were that the corrosion of propellers was very slight and the real trouble was erosion due to the water-hammer action of cavities closing up or "imploding." This action might be due to "cavitation of the propeller itself, occurring more generally when the propeller is in a varying wake, or by the cavities and vortices formed by the action of other propellers

TABLE II

WEIGHTS, ETC., OF DESTROYER MACHINERY

Date	Name	Class	S.H.P. D = Designed T = Trial	R.P.M.	Working pressure	Saturated or superheat	Number of boilers	Weight of machinery lb. per S.H.P.	Weight of boilers lb. per S.H.P.
1907	*Tartar* (3)	Tribal	22,500 T	769 T	220	Saturated	6	41·2	15·1
1909	*Nubian* (3)	Tribal	23,613 T	748 T	220	Saturated	6	40·1	13·1
1910	*Larne* (3)	Acorn	14,250 T	720 T	220	Saturated	4	46·4	15·2
1911	*Acheron*	Impd. Acorn	14,000 T	588 T	250	Saturated	3	47·0	14·7
1912	*Hardy*	Acasta	24,110 T	608 T	250	Saturated	4	33·3	11·3
1914	*Meteor*	Thornycroft "M"	33,120 T	683 T	250	Superheat	4	26·8	9·4
1915	*Michael* (3)	"M"	25,000	740	250	Saturated	3	34·0	10·3
1916	*Patrician*	Thornycroft "M"	27,500	620	250	Saturated	4	33·5	11·2
1917	*Speedy*	Thornycroft "R"	29,000	450	250	Saturated	3	32·2	9·4
1917	*Shakespeare*	Thornycroft Leader	40,000	360	250	Saturated	4	35·0	9·8
1919	*Wishart*	Thornycroft "W"	30,000	370	250	Saturated	3	33·5	10·4
1926	*Amazon*	Thornycroft "A"	36,000	415	260	570° F.	3	36·7	10·0
1928	*Serrano*	Chilean	26,000	375	250	Saturated	3	35·7	9·7
1929	*Acheron*	"A"	34,000	350	500	750° F.	3	35·3	9·3
1930	*Saguenay*	Canadian	32,000	375	300	Saturated	3	34·7	9·0
1932	*Daring*	"D"	36,000	350	300	620° F.	3	32·2	8·7
1934	*Glow-worm*	"G"	34,000	350	300	640° F.	3	31·2	8·1
1935	*Nubian*	Tribal	44,000	350	300	620° F.	3	29·0	7·15
1938	*Kimberley*	"K"	40,000	350	300	640° F.	2	29·6	6·7

(Table by courtesy of Admiralty and Messrs. Thornycroft.)

Notes.

Total machinery weight has altered very little since 1912.
Boiler weights have steadily declined and are less than 50 per cent of 1907 figures.
All boilers are oil-fired.
All ships twin-screw unless marked (3).

ahead of it and the erosive action is generally aggravated upon a propeller which works in the wake of another."

The authors also added: "The water-hammer action is also likely to be produced when violent and abrupt eddies are formed in the water by the form of stern frame, shaft bossing, or 'A' brackets, or when the lines are very full and such as to cause an eddying wake." Time has amply confirmed these findings, though, as pointed out by Sir J. E. Thornycroft, there are many instances of bad corrosion due to unsuitable materials, leading to a strong chemical action. In the case of such corrosion, chemical analysis will show that the material in the eroded areas has become richer in the constituent that is electro-positive to the others—usually the copper. No such alteration can be found in mechanically eroded portions.

Sir Charles Parsons' work on cavitation was fully recorded in Sir Stanley Goodall's 1942 Parsons Memorial Lecture, so that no further notice is necessary. It might, however, be added that it was appropriate that Parsons should have served on the sub-committee, since the troubles being investigated were largely due to his own invention. With the piston-engined *Daring*, the disease could be very readily cured by a simple increase of area. In those days propeller blades were usually extremely narrow and they could be widened without a serious loss of efficiency. The first cavitating propellers of the *Daring* were only 0·298 developed area ratio and the final ones only 0·433 developed area ratio.

With the very full area blades required in turbine ships owing to the high revolutions, further area may be virtually impossible. It was once said that it took a very good engineer to design a bad propeller—Sir Charles made the jest come true. He forced us all to design bad propellers when used for direct turbines. The efficiency of the piston-engined destroyer propellers was high and reached as much as 0·72. That of the early turbine destroyers was about 0·63, falling to about 0·54 on the later and more heavier loaded types. With modern geared destroyers it should be about 0·64. Unfortunately, the modern tendency is to increase all weights, especially those of armament and fittings. Table III gives the relative percentage of weights for early and more recent destroyers and brings out this trend. As a result, propeller design becomes more and more difficult as time goes on.

TABLE III

COMPARISON OF PERCENTAGE WEIGHTS OF DESTROYERS

Date	Ship	Composition of destroyer displacement (percentage of total light displacement)		
		Hull and wood fittings	Machinery	Armament and ammunition
1907	*Tartar*	44·20	54·17	1·63
1910	*Larne*	49·03	47·00	3·97
1916	*Patrician*	46·30	49·24	4·46
1917	*Shakespeare*	49·60	44·20	6·20
1919	*Wishart*	51·74	41·00	7·26
1926	*Amazon*	51·45	41·40	7·15
1930	*Canadian*	52·34	38·10	9·56
1932	*Daring*	52·90	37·89	9·21
1940	*Brecon*	58·70	26·60	14·70

The Michell Thrust

Mr. Gibson's 1919 paper on the Michell thrust was a timely one. This type of thrust had been almost unknown until geared turbines came into use. With direct turbines, the propeller thrust was balanced by the thrust of the steam and there was no heavy loading on the thrust block. This could no longer be done with geared turbines, and the old multi-collar type was far too cumbersome and inefficient. Mr. Gibson gave the relative coefficients of friction as:—

For rocking pads ..	.. 0·0015
For flat thrusts ..	.. 0·03 or 20 times as great.

The Michell thrust could be designed for thrusts of from 200 to 300 lb. per sq. in. instead of only 20 to 50 lb., and this has resulted in an enormous saving of space, weight and cost.

Michell was an Australian consulting engineer, residing in Melbourne. His London agent complained of the conservatism of British engineers, stating that he had been trying for a number of years to get firms to take up the invention but without success. Mr. Hamilton Gibson explained the delay by saying that it was a case of an excellent invention which was born out of due time. It was only when geared turbines came into general use that the necessity for an improved thrust block arose. This was true, but perhaps the best example of an invention born out of due time was the turbine itself. The basic principle had been described by Hero of Alexandria, but for two thousand years it had remained a scientific toy of no more account than the dipping duck of to-day. When Charles Parsons began its practical development in 1884, electric light and power were just coming into use and there was an immense potential market for turbo-generators.

There were three naval papers in our 1920 TRANSACTIONS. That on the *Hood* has already been noted. The others were by Sir Arthur Johns on "German Submarines" and by Eng.-Commdr. Tostevin on "Experience and Practice in Mechanical Reduction Gears in Warships."

Sir Arthur Johns gave details of the various classes of submarine that had been such a menace during the war years. One of the advantages of the German submarines was an engine developing 300 B.H.P. per cylinder. On account of standardization, we had retained the 100 H.P. per cylinder. Despite this handicap we possessed at the end of the war faster underwater boats and faster surface boats. A statement by the author on the reputed speeds of German submarines reminds one of similar reports in the last war about German "E" boats. This was to the effect that "reports as to great speeds obtained by German submarines on trial reached this country in the first year of the war. These were apparently confirmed by our patrols and caused some uneasiness. Information since received showed that the reports had been greatly exaggerated."

Reduction Gearing

Commander Tostevin described the great progress in the fitting of reduction gearing since 1910. In that year, the Admiralty took the first tentative step on two destroyers by fitting gearing between the low-pressure turbines and the high-pressure and cruising turbines. By 1916, sufficient experience had been gained to warrant a complete changeover. From that time on, all-geared turbines became standard naval practice.

The gears in use were all of the single reduction type and had rigid frames. These were considered preferable to the American "floating frames" so strongly advocated by Mr. Macalpine in his 1917 paper. Despite the very large number of reduction gears, fitted or being fitted, in warships, viz. 652 gears transmitting a grand total of 7,828,000 S.H.P., no actual failures had occurred. The nearest approach was in two destroyers, when the gears had become extremely noisy and had developed excessive wear. This was entirely due to relative motion between turbine and gear-case. A very remarkable record of success had been achieved and had resulted in an increase of efficiency of from 16 to 20 per cent.

The position was quite different with double-reduction gears, and when in 1921 two colleagues of Sir Charles Parsons—Messrs. R. J. Walker and S. S. Cook, read their paper, they had to admit "certain troubles." Why did these only occur on double reduction gears and not on single reduction gears? The former obviously demanded even greater care in tooth-cutting and in alignment, but the authors blamed synchronism between the variation in propeller torque and the frequency of the propeller and shafting with relation to the gear as the main cause. The torsional oscillations thus set up were magnified and gave rise to excessive tooth-pressure at certain points.

This explanation would be equally applicable to single reduction gears, but the authors pointed out that such gears were mainly fitted to naval vessels with very fine aft lines and long lengths of shafting. This meant that the periodic impulses due to wake variation would be relatively small and would be damped out by the high flexibility of the long line of shafting. The authors contended strongly that, contrary to prevalent opinion, there was no essential difference between single- and double-reduction gears.

This view was not accepted by all speakers. One rash advocate of electric propulsion remarked: "Anyone seeing the massive monument of 121 tons of cast iron which constitutes the present-day double-reduction gear of 7,000 H.P. at 90 revolutions must realize that it is but a passing phase in ship propulsion."

In the following year (1922), there were two papers dealing with the repeated failures of the double-reduction gears fitted in the *Melmore Head*. No less than six sets of gear-wheels had to be fitted before a satisfactory solution was found. Gear No. 1 covered 25,000 miles before collapsing. At the trial trip, the noise in the engine-room was said to be deafening and, contrary to expectation, the hammering and roaring continued throughout the life of the gear. With the second set of gear-wheels, there was very little improvement in noise and the second-reduction gears stripped after only 14,000 miles.

A new gear-case was designed with lower tooth pressures but was never actually fitted. Mr. Wilkie explained that it was realized that "if satisfactory running of the gears was to be obtained, some consideration would have to be given to the inertia effects of the rotating masses and particularly to the effect of torsional vibrations of the propelling shaft arising from propeller action in a variable wake."

Dr. J. H. Smith, who was called in to examine the dynamics of the problem, gave his findings in a very mathematical paper entitled "Nodal Arrangements of Geared Drives." This "nodal drive," as it became termed, involved tuning the periodicities of the rotating masses to similar values. An alarming set of critical speeds was produced but, if these could be avoided, all would be well.

In the discussion on both papers it was admitted that the troubles had been overcome. A "roarer" had been converted to the "cooing dove type," according to one speaker. On the other hand, almost everyone disagreed with the method of cure. Sir Charles Parsons was very definite in his opinion that the main trouble was in bad gear-cutting. It is interesting to note that Sir Stephen Pigott stated in 1937 that a very similar method to that of Dr. Smith's was used for the single-reduction gearing of the *Queen Mary*.

In the same year (1922) Mr. James Richardson described the single-screw motorship *Pinzon*. This was a vessel of 3,300 tons displacement and fitted with one Beardmore-Tosi 4-cycle engine of 1,250 B.H.P. at 120 R.P.M. The oil consumption of 0·36 lb. per I.H.P. hour was compared with the 1·5 lb. of coal used in a rather similar boat with triple-expansion engines. At that time single-screw motorships were not very common except in very small sizes. In the discussion, Mr. D. B. Morison gave an indication of the state of progress, when he said "the time has arrived when we can confidently accept single-screw diesel-engined vessels up to, say, 3,000 indicated horse-power."

In 1923, Sir Charles Parsons and two of his colleagues presented a further paper on Mechanical Gearing. The authors stated that "the primary object in writing this paper was to remove the slight cloud that has come over mechanical gearings of recent years." Sir Charles blamed undue hardness of the pinion teeth as the main reason why "in the last two or three years, the number of fractures in proportion to the number of gears in operation increased enormously." He particularly condemned the practice of oil-quenching nickel steel when this material was used for pinions. Apparently a milder steel was required which would "bed down" quicker.

At the summer meetings in the same year, Dr. Dresden described "Steam Turbines for Marine Propulsion in Holland." Particulars were given of a number of Dutch ships that were fitted with geared turbines. Six had single-reduction gears and seventeen had double-reduction gears.

Dr. Dresden was able to report very good results, especially with the double-reduction gears. He considered that there was no reason to be afraid of this type and thought that the "time for single-reduction has passed."

A novel proposal was put forward by Colonel Modugno, R.I.N. This was an arrangement of internal combustion engines exhausting into low-pressure turbines. The paper attracted little attention at the time, but in recent years there have been a number of schemes for utilizing diesels in conjunction with either gas or steam turbines.

In our 1924 meeting, Mr. R. W. Allen advocated the "Application of the Steam Turbine for Auxiliary Machinery." He pointed out the very large savings in weight and space that are effected by substituting turbines for reciprocating engines in driving generating sets, centrifugal circulating pumps, salvage and bilge pumps, boiled-feed pumps and boiler-room fans. To-day, we have passed into quite another phase. Reciprocating engines are certainly obsolete for this purpose—but it is usually the electric auxiliary which has gained the day. Turbine drive has survived for boiler-feed pumps owing to the high powers required and in many cases for some, if not all, of the turbo-generators. Electric drive has become the usual system for fans and circulating and bilge pumps, etc.

Steam versus Diesel

In the same year, Engineer-Commander Beeman gave details of "Further Experimental Work on Diesel Engines." The author presented an interesting table of present weights in naval practice and the permissible weight for an oil-engined installation. These were as follows (in pounds per S.H.P.).

TABLE IV

Type	Weight with steam	S.H.P. per shaft	R.P.M.	Permissible weight with oil engine
Battleship ..	—	—	—	130–150
Battle cruiser ..	81	36,000	210	100
Cruiser ..	65	16,000	400	85
Light cruiser ..	54	20,000	275	69
Flotilla leader..	35	20,000	350	42
Destroyer ..	33	13,500	360	40

The "permissible weight" for the oil-engined installation was based on the addition of ¼ of the weight of the fuel carried in existing steam installations. The average displacement, i.e. that at half load, would then remain the same. With the modern practice of using light type high-pressure steam machinery in all classes of naval ships, oil-engined installations will only appeal to the naval architect if they are of the order of 40 lb. per B.H.P. This may become possible with gas turbines but seems impracticable with reciprocating diesels of high power and low R.P.M.

In the same year (1924), Sir Archibald Ross reviewed the "Progress in Marine Propulsion during the Last Ten Years." That decade, despite the war, had seen the spectacular rise of the internal combustion engine. Was it destined to make the geared turbine a museum-piece? Sir Archibald Ross did not think so. He foresaw an improved type of geared turbine able on actual consumption to come within measurable distance of the diesel.

In 1925 Sir John Biles read an important paper on "Relative Commercial Efficiency of Internal Combustion and Steam Engines for High-speed Passenger Vessels." Issue was joined between the advocates of the diesel and the supporters of steam. According to the former "only for special purposes would the steam engine be able to hold its place." They were especially annoyed at Sir John's figures, which showed a saving in capital and running expenses for what was derided as a "hypothetical high-pressure scheme."

The Second Report of the Marine Oil-engine Trials Committee appeared in our TRANSACTIONS for 1925. This dealt with the Scott-Still engines of the M.V. *Dolius*. These, it will be remembered, were a combination of the internal combustion engine and the compound steam engine. Steam generated from the exhaust gases and from heat transmitted through the liners of the combustion cylinders acted on the under sides of the pistons, on the upper sides of which the ordinary combustion cycle took place.

The weight of the installation was 775 tons for a designed power of 2,500 S.H.P., i.e. nearly 700 lb. per S.H.P. The fuel consumption for all purposes was 0·338 lb. per I.H.P. hour.

The improvement in economy was so small in relation to the additional complications that the type has now disappeared.

In 1926, steam and oil engines were both represented. Mr. Robert Sulzer discussed the temperature variation and heat stresses in diesels. He was obviously pleased to be able to point out that "in a two-cycle marine engine, the temperatures attained by the piston rings are far lower than the temperatures in a steam-engine cylinder fitted with a steam jacket."

Sir Harold Yarrow took up the cudgels on behalf of steam with his paper "High-Pressure Water-Tube Boilers for Marine Purposes." He pointed out that steam pressures of from 500–600 lb. and superheat temperatures of from 700°–750° F. were now in commercial use in a number of power stations and there was no reason why these figures should not be adopted at sea. Drawings and particulars were given of the two high-pressure boilers that his firm were supplying for the new Clyde passenger vessel *King George V*.

Sir Charles Parsons called this ship a "new pioneer vessel" as the working pressure of the boilers was 550 lb. and the superheat temperature 750°, figures far in excess of those in marine use at that time. The *King George V* had a trial speed of 20·78 knots and a power of 3,500 S.H.P. This was the second time that the owning company had made maritime history. Just twenty-five years earlier, the *King Edward*—the first turbine merchant vessel—had been placed in service. Incidentally the *King Edward* is still in active service. Her present owners—British Railways—report that the original turbines are still in use and in good order.

Engineer-Captain L. M. Hobbs followed Sir Harold Yarrow and dealt with "Some Recent Modifications to Water-Tube Boilers of the Three-Drum Type Fitted in H.M. Navy." One of the changes mentioned was the substitution of circular lower drums for the old D or oval type of drum. Cracks were liable to develop in the D barrels. A consequent change was the abandonment of the all-straight tubes which had been such a feature of Yarrow boilers.

At the summer meeting in the same year (1926), the doughty Sir John Biles returned to the attack and compared the relative efficiency of steam-turbine and diesel machinery for cargo vessels. He gave a number of examples and it may be interesting to take one of these and substitute modern prices for fuels. For instance, Table II of the original paper concerned a cargo ship of 10,000 tons and powered with machinery of 3,000 S.H.P. The cheapest coal price was

23s. per ton, the cheapest boiler oil and the cheapest diesel oil were both taken at 34s. per ton.

The great difficulty in making comparisons of this sort is not merely the difference between various producing and non-producing ports, but also the enormous variation in handling charges. The true price of fuel is not what it costs in trucks, or in barges, or in storage tanks. It is what it has cost when the ship has been actually bunkered. In the case of coal, the additional cost may be only a few shillings or it may run into pounds. For example, a recent quotation was 85s. in trucks alongside or 130/6 trimmed into the bunkers. Oil handling charges are generally much less.

The following costs apply to a company owning coal-burning vessels, oil-burning vessels, and motor-ships and are for the same port. They are therefore comparable for the particular company at the time of writing but do not necessarily apply to other ports or even for other companies with different arrangements at the same port. Nevertheless they afford some picture of the present fuel situation.

Coal	80s. per ton
Bunker oil	122s. 6d. per ton
Diesel oil	182s. per ton

The above figures result in total costs of:—

Coal and high-pressure turbine	£54,900
Oil and high-pressure turbine	£56,500
Oil and diesel ship	£61,000

The assumed rates of 0·67 lb. and 0·42 lb. were for all purposes, and probably the diesel ship would be a little more economical to-day. The figures show that under present conditions a completely up-to-date steamer would cost less for fuel than a motorship. For the company in question, their steamers are, unfortunately, not up to date in their machinery arrangements, and they actually cost per mile about twice as much as the motorships for fuel.

In 1928, Sir John Biles again enlarged on his favourite topic of steam v. diesel and oil v. coal. One of his conclusions was that oil firing is more costly when the price per ton of oil is more than 1·4 times that of coal. Judging by the prices just quoted, the present ratio is about 1·53, but the shipowner is in a very difficult situation. At any moment all his calculations about fuel costs and the most desirable type of vessel for his particular service may be completely upset by the follies of hopelessly unbusinesslike politicians.

In 1929, the protagonists of steam were in full force. We had papers on "Modern Steam Machinery," on the Bauer Wach exhaust turbine, on powdered coal, and two dealing with water-tube boilers.

Mr. John Johnson gave a very complete and well-documented paper, comparing the service results of liners fitted (*a*) with combination machinery, (*b*) with Scotch boilers and low-pressure S.R. geared turbines, (*c*) with high-pressure water-tube boilers and S.R. geared turbines, and (*d*) with D.R. geared turbines.

He showed that the liner *Empress of Canada*, built in 1922, with Scotch boilers and saturated steam operated on 1·05 lb. per S.H.P. hour or 1·13 lb. for all purposes. The corresponding figures for the *Duchess of Bedford*, built in 1928 and fitted with water-tube boilers, were 0·57 lb. and 0·625 lb. respectively. The weights of the two installations were 380 lb. and 282 lb. per S.H.P. The paper was a powerful argument for high-pressure steam and showed that we had travelled a long way since Dr. Diesel's 1912 estimate of an 80 per cent saving in fuel consumption, even if we allow for the change from coal to oil. In fact, Mr. Johnson's ratios for 4,000 to 10,000 S.H.P. installations on oil were as 0·63 to 0·42, that is, a 33 per cent saving.

Admiral Scott-Hill dealt with the advantages of pulverized coal, but the system never obtained wide popularity and now seems to have been dropped. Mr. Spyer, in his paper on water-tube boilers, also looked forward to greater use being made of powdered coal.

In 1930, Dr. W. M. Meijer stated that the consumption of oil on the high-pressure steam installation of the new liner *Statendam* was only 0·618 lb. per S.H.P. hour. An average figure seems, however, to be distinctly higher and nearer 0·64. It was interesting to compare these consumptions with those given by Mr. Belsey for vessels fitted with electric transmission. That on the 17,000 S.H.P. *Viceroy of India* was put at about 0·65 at full power with a transmission efficiency of from 93·5 to 94 per cent. The *Brunswick* was a smaller ship with four oil engines of 750 B.H.P. The overall transmission efficiency was 0·88 per cent and the fuel consumption 0·46 lb. for all purposes.

In the summer of 1930 Sir Charles Parsons made his last appearance at our meetings. Before our next session he had passed away, having died at sea on February 11, 1931. Charles Parsons had been for over forty years the predominant influence behind the development of the steam turbine. In the somewhat parallel development of the oil engine one cannot trace any one individual who wielded a similar influence. As Dr. Blache pointed out in opening his 1931 paper on the present position of the diesel engine, several leading manufacturers had each created their own special type.

Dr. Blache described the improved results with "high-pressure induction," i.e. supercharging and with exhaust turbo-blowers. He gave some particulars of the ten-cylinder supercharged engines for the *Venus*, then building for the Bergen–Newcastle service. The fitting of oil engines in channel steamer types was quite a new departure, and the *Venus* had the distinction of being the fastest diesel ship afloat (excluding warships). Up to then fast channel vessels had been the exclusive prerogative of steam. Dr. Blache had several other hard knocks for steam, and he ended up: "In fact, the diesel engine should be adopted when burning oil and the steam engine only when burning coal."

Sir Harold Yarrow followed with "Water-Tube Boilers in some recent Merchant Ships with Service Results." Some of his opening remarks as to the limitations of Scotch boilers stung one of his hearers to remonstrance. Why did people wish to bury the Scotch boiler for high-grade ships? It "has the finest water-walled furnace that has ever been conceived by the mind of man and you cannot take that quality away from it."

The real answer to this *cri de coeur* is to be found in the tables given in Messrs. Wall and Carey's paper of the same year on "The Effect of Modern Machinery on the Design of Large Ships." The authors showed very clearly that for high speeds the cylindrical boiler imposed impossible handicaps. For example, a 29-knot ship carrying 2,000 tons deadweight and designed for minimum power would have to be 1,011 ft. in length and have 139,000 S.H.P. with Scotch boilers in lieu of only 762 ft. and 92,000 S.H.P. with Johnson water-tube boilers.

The limiting speeds for vessels of the 1,000-ft. express Atlantic liner class may also be recalled in view of the present interest in this type. With Scotch boilers 30·8 knots could be obtained on weight, but the space available would be quite inadequate. With Johnson water-tube boilers the limiting speed would be 36·4 knots. It is to be hoped that no one will want to build such a vessel. The power needed is 362,000 S.H.P., so that the cost of oil fuel for a round voyage to New York and back would be of the order of £100,000 for fuel alone! As Sir Eustace d'Eyncourt said, "This paper gives the *coup de grace* finally to the cylindrical boiler for very big powers."

The final paper in 1931 was by Monsieur Paul Dumanois, "On the Development of Marine Internal-Combustion Engines." A table of relative powers for the same size cylinders was of interest. This was as follows:—

Four-Cycle		*Two-Cycle*	
Single-acting ..	1·0	Single-acting ..	1·8
Single-acting with supercharge ..	1·6	Double-acting ..	3·5
Double-acting ..	1·85	Double-acting with supercharge ..	4·4
Double-acting with supercharge ..	3·0		

The high ratios obtainable with two-cycle engines largely accounts for their present popularity where maximum powers are required at slow speeds.

In 1932 Mr. John Johnson took as his subject "Fuel for Merchant Ships." He instanced the case of 6,500 S.H.P. vessel and arrived at a daily cost of £44 for the motorship, £44 5s. 0d. for the oil-burning steamer, and £39 15s. 0d. for the coal-burner. If we convert these figures to present-day costs on the same basis as used in discussing the Sir John Biles' example, we get £251 for the motorship, £226 for the oil-burning steamer, and £211 for the coal burner. Mr. Johnson also stressed the advantages of either pulverized coal or mechanical stokers, if coal was to be used to full advantage.

The next paper, by Mr. G. A. Brown, on "Recent Improvements in the Efficiency of Small Vessels," was a corrective to any undue complacency about steam—at any rate for low powers. Mr. Brown was dealing with a small 180-I.H.P. coaster. As he took the coal consumption at 2¼ lb. per I.H.P. hour and the diesel oil at 0·40 lb., it was easy to show a saving of about 30 per cent in favour of the motorship. On to-day's prices the saving in favour of the motorship would be still greater and well over 50 per cent.

In 1934 we had a paper entitled "Development of the Auxiliary Propeller Drive." The author, Mr. Carlton Garratt, referred to the various systems of improving the efficiency of the ordinary reciprocating engine. In such types as the Bauer-Wach, the Metropolitan-Vickers, etc., a low-pressure exhaust turbine is coupled mechanically or electrically to the main shaft. Mr. Garratt claimed that advantages would be secured by using in lieu a separate small propeller. The arrangement was tank tested and apparently the propulsive efficiency was quite good. This proposal should not be confused with the early combination type machinery where the power was fairly evenly divided on several shafts.

In 1935 Mr. K. G. Meldahl described some cargo ships having their boilers placed on deck. For certain special purposes this rather odd position had advantages.

Two more boiler papers followed in 1936. The first was a review by Admiral Whayman of the present position for large passenger liners. The dates of the examples chosen were from 1929 to 1935. With the exception of three German ships, the average boiler pressure was 410 lb. The most extreme instance given for an existing ship was the liner *Potsdam* with Benson boilers working at 1,325 lb. per sq. in. A somewhat similar liner, the *Pretoria*, had two Benson boilers working at a maximum pressure of 1,470 lb. per sq. in. Even in German hands this pressure proved too high and had to be reduced to 900 lb. This ship is now the *Empire Orwell* and has two Foster-Wheeler boilers working at 500 lb. per sq. in.

In 1937 Sir Stephen Pigott informed us of many interesting details concerning the *Queen Mary* and the requirements that conditioned her design. The service power of 158,000 S.H.P. was estimated as giving 29 knots, the speed necessary for crossing from Cherbourg to the Ambrose light vessel in 112 hours (by the more southerly route). The designed R.P.M. were 180 and the working pressure 350 lb. The gearing was single reduction. The machinery design was thus considerably more conservative than on many smaller liners then in service. It must, however, be remembered that, owing to the slump, her construction had been held up. The design really dated from 1930 or six years before completion.

In the same year (1937) Mr. W. S. Burn spoke on the "Development of the Two-Stroke Cycle Oil Engine." He claimed it to be a "cheaper, smaller, lighter and more efficient engine than the four-stroke cycle." He would have been a bold man in 1910 to have made such claims. At that date the most successful engines were undoubtedly of the four-stroke type. The author considered that "the chief immediate future of the high-powered two-stroke will rest with the large double-acting type when direct propeller drive is desired; for powers below 2,000 H.P. the single-acting engine is more directly competitive." 1950 has confirmed this view.

Our opening paper in 1938 was Captain Bernard Acworth's extremely controversial "Alternative Firing of British Men-of-War." Captain Acworth had been carrying on a campaign for some time in favour of reverting to coal fuel for the Navy. His main contention was that the increased safety of fuel supplies in time of war was well worth a sacrifice of speed. In any case, he thought it was better to decrease speed and power and to put the saving of weight into armament. It was his conviction that "when the worship of the speed god becomes out of date among seamen, future British men-of-war should rely entirely on coal."

One of his supporters—Commander Bowles—was almost lyrical in his praise of coal. I well remember wondering what he meant when he said, "Coal is progressive, oil is out of date." Commander Bowles ended up: "The present mania for battle-useless extreme speed and excessive fuel mileages has put the British Navy in pawn to people like the Shah of Persia and the politicians of Mexico."

Captain Acworth's arguments were soon riddled with broadsides from all quarters. It was a fallacy to suppose that the supply of coal in war-time would be any more certain than that of oil, while its use would condemn our ships to a position of hopeless inferiority. Coal did not, as was assumed, confirm any real measure of protection, but rather the reverse, since it necessitated wider sub-division and many more water-tight doors.

Few discussions have been so lively for a very long time. It was rather like the early days of this Institution when distinguished sailors would come and deplore the crass folly of omitting masts and sails on our ships of the line.

In the same year Mr. Harry Hunter described the "Reheated Reciprocating Steam Engine." Consumptions of 0·8 lb. per I.H.P. hour were claimed for all purposes on oil and from 1·0 to 1·089 per I.H.P. hour on coal. The following paper was by Mr. Belsey. A comparison was made of a direct-coupled diesel installation with two 12,000 S.H.P. engines at 100 R.P.M. and five 5,700 B.H.P. engines at 225 R.P.M. with A.C. electric transmission. Mr. Belsey arrived at equal costs but a saving in weight of 33 per cent in favour of electric transmission (1,394 tons in lieu of 2,085 tons). The overall efficiency at full power was given as 91·7 per cent and 90·6 per cent at half power.

Mr. Belsey's paper was a useful reminder that if an advantage is to be gained from electric transmission, a light fast-running type of diesel is necessary. Engine-room length can then be saved as well as height.

At the International Conference of Naval Architects and Marine Engineers held in the same year (1938), Mr. John Burkhardt discussed American trends. Dealing with turbo-electric drive, he stated that this had had most of its early development in the United States, but it was not holding its own against the geared turbine. Weight, space and cost were all greater and there was a small loss in efficiency. He foresaw a greater future for small geared diesels, with either mechanical gearing or electric transmission.

Our TRANSACTIONS of 1939 record no arguments on diesels, on turbines, or on reduction gears. The various protagonists seem to have been temporarily silenced by the threat of impending war. More prosaically, they were probably far too busy to prepare technical papers.

The Present Position for Choice of Machinery

During the war, research proceeded on a vast variety of subjects, but the necessity for standardization retarded its application to new designs. Let us turn therefore to the present time when the shipowner has a veritable galaxy of choice instead of the two alternatives of 1910. The rise of the motorship was primarily due to its great fuel economy. The enormous gap of 1910 between the fuel consumption of an oil-engine and a steamer has been greatly reduced. It is still large and it seems unlikely that even with the most modern steam machinery the ratio can be less than 1 to 1·5. Unfortunately for the oil-engine, the differential between the cost of diesel oil and the cost of bunker oil is usually of the same order. Hence there is no saving accruing to the owner unless either this excessive differential is reduced or the engine can be adapted for running on boiler oil. Mr. John Lamb has shown that with suitable precautions, this is usually possible for high powers, so the practice is likely to spread.

The position with regard to coal burning is equally absurd. Owing to its excessive price, it had become more expensive than oil. With de-valuation the position was reversed. With these rapid and enormous fluctuations which can upset all calculation overnight, one is apt to feel that nice and scientific comparisons are merely beating the air. All that can be said is that whatever type of machinery is employed, the very utmost economy in fuel cost is even more vital than in 1910.

Fuel economy is not, of course, the only criterion for choice of power plant. Weight, space, first cost and upkeep must all be considered. For small powers up to say 2,000 B.H.P. the diesel seems in a very strong position on all these counts. It is only in special cases such as harbour tugs, trawlers or local conditions of fuel or labour supply, etc., that one can make out a good case for the reciprocating steam engine. Above about 2,500 S.H.P. the advantage usually lies with the geared turbine on weight and cost if the diesel is direct-coupled. The diesel engineer can, however, restore at any rate equality cost by fitting gearing. These geared diesels were largely used for landing craft, etc., during the war and proved very successful.

For very large powers, the position of the geared turbine is as unassailable as is that of the diesel at low powers. For use on liners it has the additional advantage of greater smoothness and silence.

Geared Diesel Drives

A comparatively recent innovation is the coupling up of two or more diesels to one shaft. For passenger vessels this often enables engines to be tucked under an accommodation deck. The propulsive advantage of a single screw and its greater protection from ice, sloping river banks, etc., can then be retained with two or in some cases four driving units.

The principal methods of coupling up other than the full electric are, (1) magnetic slip couplings such as the B.T.H., (2) Mechanical such as the S.L.M. or the "Air-flex," and (3) hydraulic couplings such as the Vulcan. In type (1) there is a small air-gap between the two rotating rings carrying respectively the secondary pole pieces and the primary magnet coils. The full load slip is about one to two per cent. The "air-flex" type was used extensively in the war for landing craft, etc. The S.L.M. gear was used for M.T.B.s, etc., but has now been developed for larger sizes. With type (3) the slip is about twice that of type (1) at full power but increases at slower speeds.

Gas Turbines

The gas-turbine seems to have reached a stage of development somewhat akin to that of the diesel in 1910. A number of firms are experimenting with their own special types but there is hardly any service experience. In 1910, the new marine diesel had the background of a considerable period of successful use on land. In 1950, the new marine gas-turbine has only a shorter background of successful use in aircraft.

The gas turbine offers a very high power-weight ratio and for this reason is likely to find its chief use on fast naval craft. For commercial vessels it has at present two handicaps, a higher specific fuel consumption than the ordinary diesel and the necessity of using diesel or other distillate oil to prevent fouling and corrosion of the blades. If the latter difficulty can be overcome, its commercial prospects would be very much brighter. No astern turbine can be used with a gas turbine as the windage losses would be excessive if kept running.

It is necessary to have a reducing-reversing gear of some type for marine use. As with geared diesels, this can be full electric, mechanical or hydraulic.

A few particulars of a marine type now on the market may be of interest. This is the Ruston and Hornsby which has a full power rating of 1,070 B.H.P. The 13-stage axial flow compressor is driven by an independent two-stage turbine and not by the main power turbine. This separation is claimed to give greater flexibility and avoid the necessity for a special "torque converter." The weight of the complete gas turbine is about 40 lb. per H.P. and the fuel consumption 0·59 lb/S.P.H. hour.

TABLE V

BOILER AND ENGINE ROOM LENGTHS IN LINERS

Vessel	Date	Length registered	S.H.P.	Engine-room length as percentage of registered length	Boiler-room length as percentage of registered length	Number of boilers
Lusitania	1907	760 M.D.	72,500	21·0	45·0	23 D.E. 2 S.E.
Berengaria	1912	880 B.P.	61,000	18·8	34·3	46 W.T.
Aquitania	1914	868·7	56,000	13·6	39·8	21 D.E.
Empress of Britain	1931	733·4	60,000	18·4	21·1	9 W.T.
Normandie	1935	981·4	160,000	20·0	33·2	29 W.T.
Queen Mary	1936	975·2	158,000*	20·8	31·0	24 W.T.
Queen Elizabeth	1940	987·4	—	26·6	23·1	12 W.T.
Orontes	1929	638	20,000	8·9	18·8	6 D.E. 2 S.E.
Himalaya	1949	681·7	42,500	12·6	8·2	4 W.T.

* Service power.

The ultimate aim for a gas turbine according to Dr. T. W. F. Brown is of the order of 0·33 lb/S.H.P. hour. In order to obtain this high efficiency, increased gas temperatures will be necessary, involving the complication of cooled blades.

It is interesting to note that Lord Fisher's desire "to associate the turbine with the principle of internal combustion propulsion" is being realized. Both Messrs. C. A. Parsons & Co. and the "Pametrada" Research Station are now actively interested in the development of gas turbines. The funnels that Fisher disliked may not have disappeared, but they have been greatly reduced in number on both warships and liners. Most of our destroyers have now only one funnel in place of the three or four that were so common in 1910. In the two-funnelled "Weapons" class, the forward funnel is concealed in the mast structure much as suggested by Sir Charles Parsons in 1912.

The French Navy have gone even further. In 1910, they were building battleships with five funnels and cruisers with six funnels. On their latest battleships the *Jean Bart* and *Richelieu*, it is difficult to detect a funnel at all. Close inspection will show that the one funnel emerges in a sloping position from what appears to be only a massive midship A.A. gun platform.

The same thing has happened with liners. The only four-funnelled British liner left, the veteran *Aquitania*, has made her last voyage. The few three-funnel liners still in service begin to look a little odd, unless they are of extreme dimensions. This reduction in the number of funnels has been rendered possible by the enormous decrease in the number of boilers now needed to develop any given quantity of steam. Thus the *Berengaria* had 46 water-tube boilers, the *Queen Mary* had 24 boilers and the *Queen Elizabeth* only 12 boilers. From the naval architect's standpoint the reduction in weight and number of boilers has been fully as important as the introduction of geared turbines and heavy oil engines.

Table V indicates the changes in boilering for some large liners.

Hull Design and Theory

Progress in hull and propeller design may not have been so clear and obvious in the last four decades as with the main machinery. Nevertheless, it has been equally real and important. Harking back to our date-line of 1910, there were two events of great and enduring importance to all naval architects. It was in our jubilee year that the National Tank was opened at Teddington with Dr. G. S. Baker as its Superintendent. It was in the same year that David W. Taylor published the first edition of his *Speed and Power of Ships*, a book that had an enormous influence on our thinking. It gave for the first time the full results of a family of standard commercial forms. This information which was previously only available for certain limited types, mainly those of warships, enabled designers to decide with some certainty on the best prismatic coefficient for the conditions and on the penalty for excessive fullness.

Looking back on the meagre data that was then available, most designers of merchant ships seem to have been in a state of appalling ignorance as to the residuary resistance of their products. Highly important vessels such as a *Lusitania* were of course tank tested, but the lines of the great majority of commercial ships were settled by rule of thumb or by the repetition of past practice. One of the most common beliefs was that of the overriding advantage of minimum midship area. Another was the assumed benefit of a small prismatic at high speeds. Taylor shattered both ideas. His curves showed conclusively that above a speed length ratio of about 1·0 the optimum prismatic began to increase and not decrease. At slower speeds they showed that it was not minimum midship section that mattered but minimum prismatic.

Forty years ago, the frictional formulations of Froude, or in some cases, Tideman were almost universally accepted as giving sufficient guidance for the calculation of surface friction. To-day Tideman's constants are completely ignored, while the supporters of Froude are fighting a last rearguard action. Even this is not being fought on the ground that Froude's method was correct but for the dual reasons that so much tank and trial data has been accumulated on the Froude basis and because we are not universally agreed on a unique line to take its place.

The first major attack on the accepted methods came from Dr. Stanton in 1912. In a paper on "The Law of Comparison for Surface Friction and Eddy-making Resistances in Fluids," he reminded us that many years earlier Osborne Reynolds had demonstrated the difference between streamline or "laminar" flow and non-streamline or "turbulent" flow. Reynolds had shown that the criterion for this change was a non-dimensional number $= V\,d/v$ where d was the pipe diameter, V the velocity in feet per second and v the kinematic viscosity. For ship work, the governing linear dimension would be length so that this number, afterwards termed the "Reynolds Number," should be written $V\,L/v$. Dr. Stanton also reminded us that Lord Rayleigh had shown that both the Reynolds number and the Froude number $(V/\sqrt{L\,g})$ could be readily obtained in their reciprocal forms by the law of dimensional similarity. If viscosity was ignored, one obtained a function of the Froude number. If one ignored a gravity type resistance, such as wave making, one obtained a function of Reynolds number.

Surface friction, Dr. Stanton argued, ought therefore to be expressed in the form $R = C\,S\,V^2$ where $C = \phi(V\,L/v)$. The accepted Froude formula $R = S\,f\,V^n$ clearly did not comply with this requirement since f was an empiric constant depending on length and type of surface, while the index n was appreciably less than 2. Even more important was the entirely different law of comparison.

Sir Charles Parsons called this paper "A very important advance," a view that was much more far-sighted and accurate than those of R. E. Froude and Sir Arthur Johns—accepted leaders in the theories of hydro-dynamics and naval architecture. Froude pointed out that you could not possibly run a ship model fast enough to comply with the Reynolds law of comparison. On this account alone, he considered that the proposed method had no place in tank technique.

Since Dr. Stanton's 1912 paper, we have had a great many others dealing with this question of surface friction. Notably those by Dr. G. S. Baker and Dr. Kempf, Professors Havelock, Robb and Telfer and by Messrs. Perring, Payne and Lackenby. It was a little confusing for the listener, because Drs. Baker and Kempf seemed to disagree with each other almost automatically, while quite recently Professors Robb and Telfer were equally unable to see eye to eye.

To-day, except for a few die-hards, we are all in agreement that we ought to express surface friction as a function of the Reynolds number, though there is still disagreement as to the precise friction line to be adopted and as to the values of the additional roughness corrections that are needed. There is also a general acceptance of the modern boundary layer theory, which was of course quite unknown to Froude as was Rayleigh's demonstration of the relation between the Reynolds and Froude numbers and to which we have already referred. It seems fair to say that in 1910 naval architects had the idea that the decreasing value of the frictional coefficients with increasing length was due to an increasing frictional wake. We somehow pictured a ship as rubbing against the water near the bow at its full speed and at a reduced speed near the stern.

The modern boundary layer theory gives us a much clearer picture of the mechanism of surface friction. The starting point of the theory is that you cannot insert a plate, however thin, into a moving and real fluid without bringing to rest a thin film. This film will be locked to the surface, presumably by molecular attraction. Pitot tube measurements taken as close as possible to the surface show that the velocity has fallen by about 50 per cent. Measurements taken further from the surface show a much thicker belt of water in which the velocity gradually falls to that of the surrounding stream. There is thus a very thin sub-layer of perhaps $\frac{1}{1000}$ of an inch or less, in which the flow is entirely laminar. The outer boundary of the layer is taken as the point where the velocity is 1 per cent of that of the surrounding stream. Between the laminar sub-layer and the outer boundary, flow will be turbulent. Unless the water upstream from the bow is itself turbulent, the layer near the bow may be entirely or partly laminar outside the laminar sub-layer. At some point very near the bow the laminar flow will break down into the thin laminar sub-layer and a much thicker turbulent portion.

The coefficient of laminar friction is given by the Blasius formula as $Cf = 1 \cdot 327\ (R\ n)^{-\frac{1}{2}}$ and is shown in Fig. 1. It will be noted that all the "smooth-turbulent" coefficients are far greater than the laminar coefficient, so that in order to get true comparison between a model running at a low *R n* and a ship at a much higher *R n*, it is obviously essential to ensure the breakdown of the laminar flow and the setting up of a fully turbulent regime. This was fully recognized by Professor Davidson when he commenced work in his small tank at the Stevens Institute in Hoboken, New Jersey. All models were run with turbulence stimulating devices such as trip wires, struts or sanded strips, and very satisfactory results were obtained. Previously the work of small tanks was regarded with grave suspicion, owing to apparently erratic results which were usually attributed to a vague "scale effect." It was thought that models of from 16 to 20 ft. as used in the large tanks, would be quite free from laminar flow when running at Reynolds numbers above about 5×10^6. Thus the limits at the Spanish El Pardo tank were $R\,n = 3 \cdot 5 \times 10^6$ for full forms and $R\,n = 6 \cdot 5 \times 10^6$ for fine forms. We now know that such limits may be too low and it is probable that all slow speed tank models will be run in future with turbulence stimulators. Not everyone agrees with this procedure. At the 1948 International Conference of Ship Tank Superintendents, Professor Robb remarked: "The (Froude) method was founded on a dogma and extended by empiricism. The adoption of turbulence-producing devices is merely the piling of empiricism, and more complicated empiricism, on empiricism."

At the same ship tank conference, the United States delegation recommended the general adoption of the Schoenherr frictional coefficients in place of the Froude constants. They also suggested the addition of $0 \cdot 0004$ to Cf as a standard roughness correction to cover the change from the smooth surface of a model to the much rougher steel plating of a ship. Agreement could not be reached as many delegates preferred other friction "lines" such as the Prandtl–Schlichting, the Falkner and the Telfer "extrapolator." Fig. 1 shows the general relation of these "lines" as compared with the values obtained from the Froude constants. It will be noted that the differences are very small for all the "smooth turbulent lines" but the variation from Froude is considerable, especially at the longer lengths. This variation is largely due to the fact that the smooth-turbulent lines apply to hydraulically smooth surfaces, that is, to surfaces in which the roughnesses do not pierce through and disturb the inner sub-laminar layer. No actual ship surface can be hydraulically

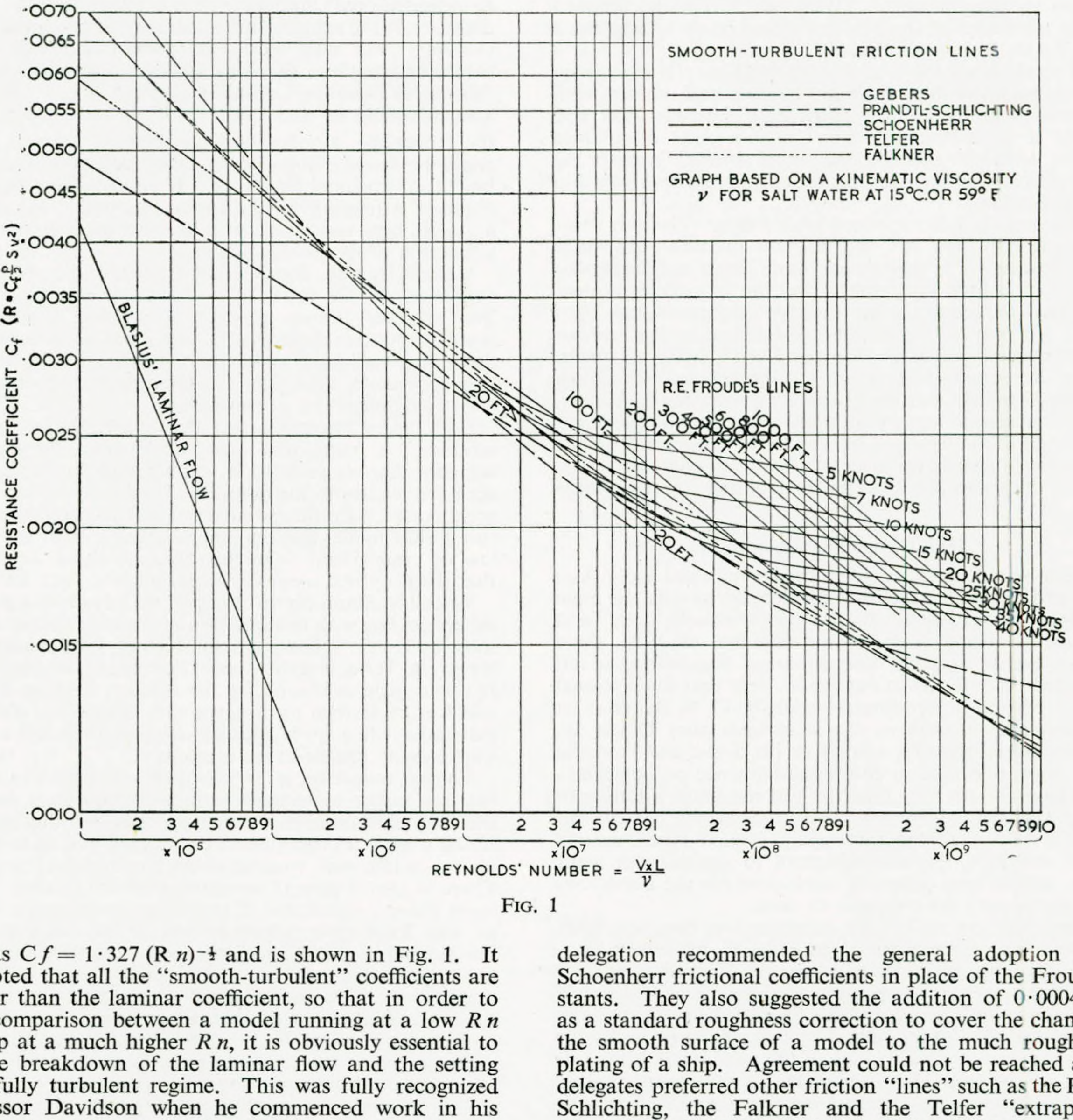

FIG. 1

smooth except perhaps for the racing yachts and boats to be mentioned later.

The precise variation of the roughness addition with different types of surface is still a matter of controversy and this leads to the anomalous result that the Froude constants have often proved to give closer estimates than the newer formulations. It cannot be denied that the Froude constants give results that are not very far wrong when the additional resistance due to a painted steel plate in lieu of an ideal surface is considered.

In 1949, Dr. Telfer read a paper entitled "Frictional Resistance and Ship Resistance Similarity," in which he added to his "extrapolator" line a method of dealing with roughness additions. He also discussed his proposed method for comparing the total resistance of models and ships without having first to split the resistance into frictional and residuary resistances. The first proposal is less controversial than the second and also merits our close attention. The Telfer "extrapolator" line is based on the Gebers results and as will be seen from Fig. 1 lies just below the Gebers line for the middle portion of that line. Now the Gebers results values were the result of very careful tank experiments, but they undoubtedly contained a lot of laminar flow at the lower $R\,n$ numbers. At the higher end, they are like all other lines, an enormous extrapolation from experimental data.

Telfer assumed, not unreasonably, that with correction for edge effect the middle portion could be relied on. He therefore extrapolated this portion in both directions, plotting it on a basis of the inverse cube root of Reynolds number. The equation for this line is $C\,f = 0{\cdot}0012 + 0{\cdot}34\,(R\,n)^{-\frac{1}{2}}$. This is not only a simpler expression than the Schoenherr or the Prandtl–Schlichting but it has the great merit of a limiting value of 0·0012 at $R\,n = \infty$. All other formulations give the absurd answer of $C\,f = 0$, when $R\,n = \infty$. As will be seen from Fig. 1, the differences from the Prandtl–Schlichting and Schoenherr lines at both the model and ship ranges are very small. In view of these advantages there seems a case for pressing the adoption of this line, or something very like it, at the next Ship Tank Conference.

The discovery that laminar flow could persist on large full models under normal test conditions has led to the expression of some mistrust of previous tank results. It must be admitted that experiments dealing with the effect of changes in bow shape or with special bow forms must be regarded with suspicion and should be repeated with turbulence stimulation. In "A Review of Ship Model Data," by Messrs. Emerson and Witney (North-East Coast Institution of Engineers and Shipbuilders, February 24, 1950), a start has been made with such revision. The general run of tank experiments agrees so well with the actual trials that there cannot be much amiss.

Laminar Flow on Ships?

The question will naturally be asked, if you can get such an important reduction of resistance from the presence of laminar flow on a model, why can you not get a reduction on a ship, at any rate at the extreme bow? Aircraft designers are keen on exploring and obtaining its advantage. Why not naval architects? The objections usually raised are that (1) the $R\,n$ value at the ship is likely to be 100–200 times that of the model, so the transition would be too near the bow to have any appreciable influence and (2) even if we could obtain an ideally smooth ship surface, it would soon be spoilt by fouling. As against these objections, laminar flow can be maintained over quite large areas of an aeroplane wing (Perring, Report of 5th Ship Tank Conference). In this case, after allowing for the very much greater kinematic viscosity of air (about 13 times that of water) the Reynolds number must be very much greater than on the normal ship model, especially if a "local" $R\,n$ value is taken to the transition point and not over the whole length.

It is quite true that we cannot maintain the surface of a ship in its pristine smoothness as we can an aeroplane wing or an aircraft propeller. On the other hand there are certain classes of small craft where the question of laminar flow deserves serious consideration. A small racing yacht, for example, when "ghosting" at slow speed, has a Reynolds number very similar to that of many ship models. Its surface can be kept in an almost immaculate condition. With such craft every endeavour should be made to get the maximum amount of laminar flow and to maintain the utmost smoothness of the hull.

The conditions favouring laminar flow seem to be a negative pressure gradient extending as far aft from the bow as possible. This means that the flow is accelerating and this tends to delay the thickening of the boundary layer that occurs on transition from laminar to turbulent flow.

This leads to a topical speculation concerning the Oxford and Cambridge Boat Race. At our 1927 Summer Meeting, Mr. F. H. Alexander read a very interesting paper on the "Propulsive Efficiency of Rowing." He gave the typical figures for a "racing eight" as in Table VI.

TABLE VI

PARTICULARS OF TYPICAL "RACING EIGHT"

Length on L.W.L.	62·0 ft.
Beam, extreme	2·0 ft.
Displacement	0·81 ton
Wetted surface	109·5 sq. ft.
Speed	10·0 knots
Speed length ratio	1·27
Displacement ratio $= \Delta \div \left(\frac{L}{100}\right)^3$ ..	3·5
Resistance of hull	77·0
Resistance including windage	90·0 lb.
E.H.P.	2·76 H.P.
Total H.P. exerted by crew	8·74 H.P.
Propulsive efficiency	0·316
Average output per man	1·09 H.P.

It will be noted from Table IV that the displacement ratio is only 3·5 and that there are thirty-one beams in the length. The draught is about 6 in. With these abnormal proportions it seems probable, or at any rate quite possible, that there is a certain amount of laminar flow under smooth-water conditions. If this extended to, say, 6 ft. from the bow, the saving in frictional resistance would be about 8 per cent. If one boat is following closely in the wake of the other, the second boat will be in relatively turbulent water and may have no laminar flow at all. Thus the work required from the following crew may be well in excess of that exerted by the leading eight. After a race, we usually hear that the defeated crew "appeared much more distressed" than the winners. This is always attributed to the psychological effects of victory and defeat in producing elation or depression. This is no doubt the main reason, but the absence or presence of laminar flow may well be a factor. At an output rate of 1·09 H.P. an oarsman is working at very near the maximum for the human frame and under such conditions will—like the camel—be very sensitive to a small overload.*

Racing crews would no doubt object to the fitting of trip wires to their craft, but this may be about the only way of obtaining complete parity of effort when a following crew is racing just behind a leader in calm water.

A point of interest brought out by Mr. Alexander was the

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* According to information supplied by Professor A. V. Hill, of the Biophysics Research Unit of University College, London, an output of 1·09 H.P. per man would appear exceptionally high and probably over-estimated. Professor Hill states that, for a few seconds, an energetic and well-trained man can develop nearly 2 H.P. (as when running upstairs), but 0·5 H.P. or thereabouts would be a normal figure over a 20-minute period.

increased speed during the return stroke, when the oars are out of the water. The boat is then being propelled by the sternward motion of the oarsmen's bodies on the sliding seats, and is actually moving faster than when the oars are in the water.

When Charles Parsons was an undergraduate at Cambridge, he rowed in college bumping races, but we cannot record that he made any improvement to the design of either boats or oars. An amusing story of this period is, however, told by Sir Alfred Ewing in his book *An Engineer's Outlook*. To quote Sir Alfred, "he was enormously delighted that we had bumped Trinity. The reserve of the shyest undergraduate could not be proof against such events. Parsons was jubilant, and college tradition tells that after the bump-supper he was with difficulty disentangled from a lamp-post to which he clung with the tenacity that afterwards proved to be one of his most valuable characteristics."

In his early youth, Parsons had a good deal of sailing and cruising in yachts belonging to his father, the third Earl of Rosse. In later years he was too absorbed in family and business cares to indulge in sailing, though he seems to have retained a love of the sea that persisted to the end.

Parsons was a very good mechanical craftsman and delighted in making elaborate toys for his children. These contrivances included a "steam pram." This could not have been a very high-pressure job, as we learn that the boiler was constructed from a biscuit tin. A less alarming invention was a model "flying machine." This was steam-propelled and really flew.

Parsons was a convinced believer in the utility of experimental tanks and tested the models of the *Turbinia* in a pond at Ryton-on-Tyne. His towing apparatus was of a very simple character, but results were obtained which checked quite well with subsequent tests at Haslar. A postscript to a letter written in 1899 to Sir Robert Ball (the astronomer and sometime tutor to the Parsons family) read as follows: "Mr. T. Lipton has got his yacht too short and full-bodied for the speeds they go. They seem to design by rule of thumb in England—they should rely on model experiments which would put them right."

Alas, when an America's Cup challenger was tank tested, she was again defeated. Her designer, G. L. Watson, is recorded as having remarked sadly, "I wish Herreshoff had a towing tank." Mentioning this incident to Dr. K. S. M. Davidson a few months ago, he told me that he had been recently examining the records of this test and concluded that Watson had slightly misinterpreted some of the results but that he had been remarkably near the truth.

It is, of course, quite useless to test sailing yacht models in the same way as with power vessels, that is, only in the upright condition. It is more important to test them inclined and to check leeway forces, etc. The great success of so many American yachts when racing against our own craft must be largely attributed to their forms having been tested at the Stevens Tank, where Dr. Davidson has devised a very satisfactory technique. It is very unfortunate that similar facilities are not available in this country—the original home of the experimental tank. In this absence, British designers are working under an almost impossible handicap.

The tremendous changes which have been made in sailing yacht design since 1910 are illustrated by Fig. 2, which shows in dotted lines a cruising yacht of 1912 and in full lines an Ocean Racer of 1949. The cruising yacht is Dr. Claud Worth's *Tern III* and the Ocean Racer is Mr. Rawling's *Gulvain*. *Tern III* was considered in 1912 to be an ideal craft for real sea-going and sea-keeping. *Gulvain*, which to the yachtsman's eye was very obviously designed by Laurent Giles, is a type that has to withstand a much more strenuous time than the average cruising yacht. Leaving aside the special Giles features such as the hogged sheer and the forward raking transom, the other changes are typical. These are the longer bow, enabling the bowsprit to be dispensed with and an all-inboard rig obtained. The short counter will avoid pounding in a following sea. Other changes are the light displacement, giving a more easily driven hull, and the Bermuda rig, giving a better performance to windward owing to the greater aspect ratio and fewer spars.

In recent years the I.N.A. TRANSACTIONS have contained very little about sailing yachts. This is unfortunate in view of the great interest taken in the design and details of racing yachts. Almost the only papers have been by Admiral Turner on his theory of the "Metacentric Shelf." This theory is in refreshing contrast to the many that are so plausible on paper but which fail dismally in practice. The metacentric shelf theory can be demolished on paper with the utmost ease, yet it works in practice. The stated theory is impossible because it treats a matter of dynamics with purely static methods.

Admiral Turner is by no means alone in dealing with statics when he ought to be thinking of dynamics. We are all doing the same thing when we mark our profile plans with two points labelled "C.L.R." and "C.E." respectively and calculate them in the conventional way. They are then merely the centroid of the lateral immersed area and the centroid of the sail area when this is sheeted hard in on the centre line. These centroids have no direct connection with what they purport to be. When a yacht is upright and not making leeway the true C.L.R. is usually between 20 per cent and 25 per cent of the W.L. length abaft the stem. For a thin plate Joessel's early experiments give 19½ per cent, while more recent experiments with symmetrical aerofoil sections show an initial figure of about 22 per cent. If we divide the immersed longitudinal area into a number of parallel longitudinal strips and consider the C.L.R. for each strip at 20 per cent abaft their fore edge, we can then combine these separate centres as for a C.G. We shall then obtain a fair approximation to the true initial C.L.R.

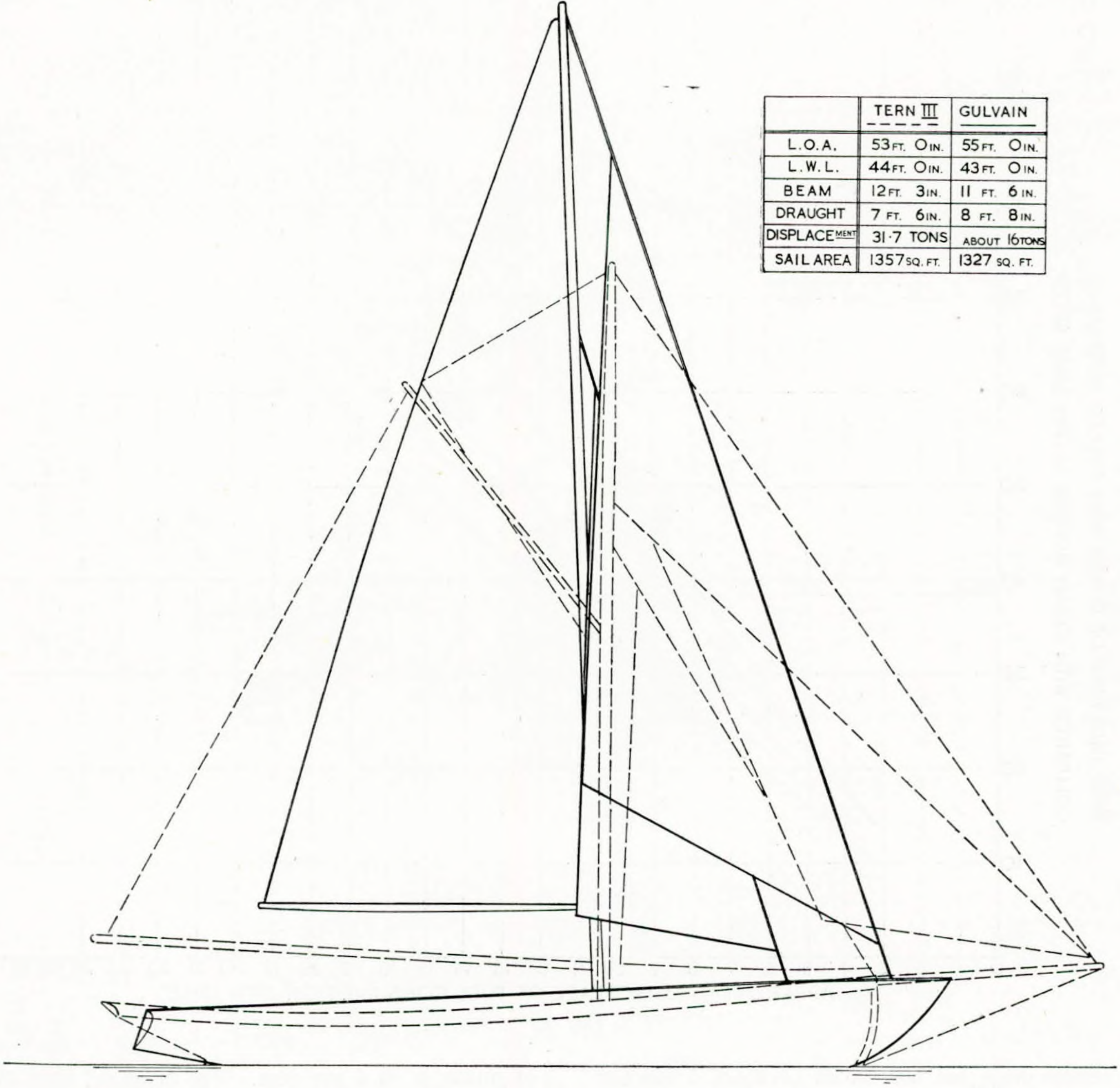
The position of the centre of effort is much more variable, since it depends on the wind direction as well as on the sail setting. When close-hauled, the C.E. is probably also about 20 per cent from the leading edge of the sails and can be calculated as for the C.L.R. When a yacht is running, the erstwhile trailing edge or leech becomes the leading edge, and instead of the C.E. being, say, 20 per cent from the luff, it is now a somewhat similar amount from the leech. There is thus a very considerable shift of the C.E. The more important point of sailing is to windward, and if we calculate the C.L.R. and C.E. position as suggested, we shall find that for a well-balanced sail plan these centres will have changed their relative positions and a "lead" will be converted into a lag. This is, of course, as it should be for a yacht to carry weather helm.

Yacht designers may want to keep their conventional centres for the sake of comparison with past designs. In this case they could at all events label their centres more correctly by marking them "C.L.A." and "C.S.A." respectively. These initials would then stand for Centroid of Lateral Area and Centroid of Sail Area.

A point made by Admiral Turner in describing his metacentric shelf theory is the relative unimportance of sail balance as compared with hull balance. This is quite true. A sailing yacht should at all times be under the control of the rudder at small helm angles. From steering considerations, we know that the hydraulic side pressures that are called into play by the setting up of a drift angle must always be very much more powerful than the initiating rudder pressure. Otherwise a ship could never be forced into, say, a port circle by port rudder which, by itself, would merely push the vessel over to starboard and away from the desired course. It follows that these hydraulic side pressures are more important than wind turning moments, and it is these pressures which must be considered if the metacentric shelf theory is to be put on a sound theoretical basis.

Incidentally, it is these hydraulic side pressures which enable us to beat to windward and not, as is sometimes fondly imagined, our expert sail manipulation. Without sufficient side pressure the weather helm yacht would merely get in "irons" and the lee helm yacht would broach to. Hence the necessity for sufficient way in tacking, however wisely we may trim our sails.

In 1927, Captain C. Blom read a paper on the "Future of Sailing Vessels Fitted with Auxiliary Motors." There were many nostalgic particulars of the old clipper ships, but, alas, time has belied the confident assertions of both Dr. Diesel and Captain Blom. It was Dr. Diesel himself who told us at our 1911 meeting "the diesel engine as an auxiliary engine will give new life to the large sailing vessels." Captain Blom was equally unfortunate in his statement that "the steamer has already reached its highest perfection while the motor sailing vessel is only at the beginning of its development and has big possibilities of improvement." In actual fact, the marriage of sail and power has rarely proved successful in ships of any size.



	TERN III	GULVAIN
L.O.A.	53 FT. 0 IN.	55 FT. 0 IN.
L.W.L.	44 FT. 0 IN.	43 FT. 0 IN.
BEAM	12 FT. 3 IN.	11 FT. 6 IN.
DRAUGHT	7 FT. 6 IN.	8 FT. 8 IN.
DISPLACEMENT	31·7 TONS	ABOUT 16 TONS
SAIL AREA	1357 SQ. FT.	1327 SQ. FT.

Fig. 2

One of the few exceptions was the yacht *Sunbeam*, belonging to Lord Brassey, our President from 1893 to 1896. During her long career this famous yacht logged over half a million miles. On her first voyage of length she covered 14,979 miles under steam and 20,396 under sail. The best noon to noon runs were 230 miles under steam and 299 miles under sail. The *Sunbeam* can be considered as the forebear of the modern "motor sailers," though these are usually very much smaller craft. Few owners to-day can afford a crew of thirty hands.

The Economic Consequences of Fouling

Two notable papers on fouling and corrosion appeared in 1943 and 1946. The earlier paper was by Dr. Bengough and Mr. V. G. Shepheard, and the second by Professor J. E. Harris and Mr. W. A. D. Forbes. Nature solved the problem of fouling many æons ago, and, with a few insignificant exceptions, no healthy fish ever acquires barnacles, seaweed or other unwanted attachments, however long it remains out of dock. Man has yet to master this problem. In British waters and with normal paints, about ¼ per cent a day in winter and about ½ per cent a day in summer seem average rates of increase in frictional resistance owing to fouling. In the tropics the daily increase may be from ½ per cent to as much as 1½ per cent per day.

The serious nature of the economic consequences is not always realized. We are apt to assess the effect of fouling merely by the increase in fuel consumption per mile or per voyage and to lose sight of the increased power we are actually using for the reduced speed.

As a *reductio ad absurdum*, consider the case of a small diesel ship which, when clean, does 12½ knots on 475 B.H.P. The fixed pitch propeller is absorbing the full engine power, and as soon as the R.P.M. fall with the reduced speed there is a corresponding decline in the available power. With 25 per cent fouling this is 436 B.H.P., giving 11·6 knots. The fuel consumption has now fallen to about 0·668 ton per 100 miles in lieu of the original figure of 0·678 ton. There is thus an apparent saving of about 1½ per cent on fuel consumption due to fouling!

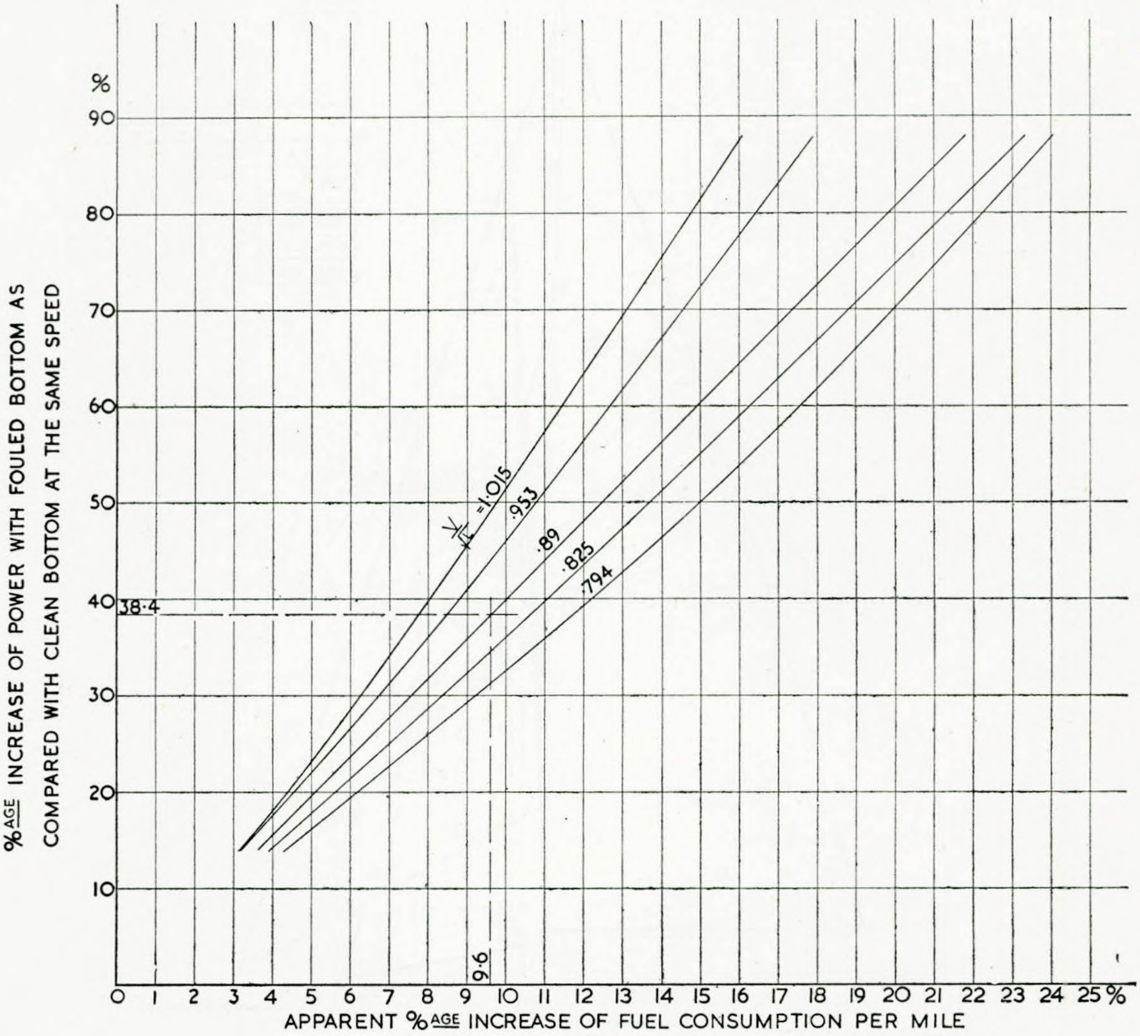


FIG. 3

The true comparison is with what it would cost to run at 11·6 knots with a clean ship and 370 B.H.P. This would be about 0·57 ton per 100 miles, so that there is really an increase of about 17 per cent and not a decrease of 1½ per cent for the assumed displacement.

If we assume a flexible engine, such as the steam turbine, there is no need to allow for the reduced output at slightly fewer R.P.M. Fig. 3 has been prepared on this assumption that the power can be maintained with variable R.P.M. and has been worked out for a typical large liner. The abscissae values show the apparent increase of fuel consumption per mile or per voyage. This is the figure usually noted by the owner and his marine superintendent. The ordinate values show the real increase of fuel consumption per mile for the same speeds clean and fouled.

Let us check such a diagram with the case of a large Atlantic liner of 1,000 ft. and 28 knots speed. The power clean will be about 113,500 S.H.P. for the assumed displacement. If the fouling is such that the frictional resistance has increased by 50 per cent, the speed will have fallen to 25·6 knots for the original power. The power for this speed when clean is only 82,000 S.H.P., so that the real increase of power is 38·4 per cent. The increased time of voyage represents 9·6 per cent, and this is the apparent increase of fuel consumption for the voyage. In reality the ship is using about four times the apparent increase in fuel consumption.

It is believed that this diagram applies without much alteration to most vessels of the liner class. As an example of the economic consequences, consider a liner of the 1,000-ft. class on the Atlantic service. If the service power is 150,000 S.H.P. and the apparent increase in fuel consumption per voyage is only 5 per cent, the vessel is really using about 20 per cent more fuel than needed for the same speed when clean. This 20 per cent can be taken to represent, say, 8 tons per hour. At present oil prices this means an additional fuel cost of about £11,500 per round voyage.

If we took only half this excess over a year's running, the for this one ship. These figures indicate the very urgent necessity for better anti-fouling paints and for the best possible maintenance of ship surfaces. Admittedly we have used a very special case, but it is only special owing to the high powers involved. The percentage increases are not abnormal.

Screw Propellers

In 1910 the celebrated Froude–Henderson duel was in full swing and, despite the difficulties, provided a very lively discussion. Since then some sixty papers on the design working conditions and ailments of propellers have been presented at our meetings. It is obviously impossible to refer to all these, and in view of the very many valuable contributions from Haslar and the N.P.L. it might seem invidious to single out certain authors.

It is proposed, therefore, to offer only a few very general remarks. Some of the problems discussed at our early meetings are still with us—cavitation, for example—while new ones such as the singing propeller have arisen. The vortex theory first tentatively advanced by Mr. Lanchester in our 1915 meeting has been greatly elaborated and is now generally accepted.

In 1910 the old cast-iron built-up propeller was very much in vogue. It has now been very generally superseded by the solid bronze type with a very appreciable gain in efficiency. Details of blade design have been greatly improved in recent years and has often enabled the incidence of cavitation to be staved off.

The most modern development is that of controllable-pitch propellers.

In certain special instances these propellers offer considerable advantages. Such cases are tugs, trawlers, ice-breakers and mine-sweepers, where the speeds of advance are extremely variable. Other favourable instances are when several engines are geared on to one shaft or there is a very great difference between the loaded and light displacement and it is desired to get the maximum engine output under both conditions.

With non-reversible engines such as gas-turbines and certain land diesels they are also suitable provided the R.P.M. are not too high. On certain fast motorboats there was a loss of over 1 knot as compared with fixed-blade propellers. This was due to the large boss/diameter ratio and the very wide blades. If a controllable-pitch propeller is to operate without serious loss of efficiency the conditions must be such that it is relatively lightly loaded. This greatly militates against its successful use at high R.P.M.

If a controllable-pitch propeller is giving better results than a fixed-pitch propeller at the working condition, then a still better result can be obtained by a new fixed propeller with revised dimensions.

In general, controllable-pitch propellers are only needed if the same, or nearly the same, power is required at widely varying speeds of advance. In connection with the power absorption of fixed pitch screws reference is often made to a supposed "propeller cube law." This is an imaginary law and is putting the cart before the horse. The propeller has to suit the ship and not *vice versa*. If the ship resistance is varying with the square of the speed or the E.H.P. with the cube, then the power absorbed by the propeller is also varying with the cube of the speed of advance or with the R.P.M. If the ship demands more thrust, the propeller will oblige by increasing its real slip and by the absorption of more power. If, on the other hand, the resistance of the ship is going up at less than the square of the speed, the propeller will follow suit by reducing the slip.

These points are shown by the following table.

TABLE VII

POWER ABSORBED BY PROPELLERS. FROM TRIAL RESULTS

Type	Propellers	Result
Destroyer	Solid	$H.P. \propto Va^{3\cdot41}$ $H.P. \propto R.P.M.^{3\cdot14}$
Target-towing launch	Solid	$H.P. \propto Va^{1\cdot88}$ $H.P. \propto R.P.M.^{2\cdot4}$
Target-towing launch	Controllable pitch	$H.P. \propto Va^{1\cdot61}$ $H.P. \propto R.P.M.^{1\cdot18}$

In conclusion, I very greatly appreciate the honour of being invited to prepare this Memorial Lecture. It is a great privilege to be allowed to pay this tribute to the memory of Sir Charles Parsons and to endeavour to illustrate, in some small degree, the enormous influence of his life work on the progress of marine propulsion.

I also feel that I ought to apologise to the Institute of Marine Engineers. This is a joint meeting, and I have infringed their motto "*Nec remis nec velis.*" My only excuse for touching on this forbidden subject is that so many of their members forsake their principles and go a-venturing in sail.

Appendix

Previous Parsons Memorial Lectures

Year	Institution	Lecturer	Title
1936	N.E.C.	Sir Frank Smith, K.C.B., C.B., F.R.S.	"Sir Charles Parsons and Steam"
1937	I.E.E.	Dr. G. Stoney, F.R.S.	"Scientific Activities of the late Honourable Sir Charles Parsons"
1938	I.Mech.E.	Mr. S. S. Cook, F.R.S.	"Sir Charles Parsons and Marine Propulsion"
1939	I.C.E.	Dr. H. L. Guy, F.R.S.	"Some Researches on Steam Turbine Nozzle Efficiency"
1940	N.E.C.	Sir Stephen Pigott	"The Engining of Highly Powered Ships"
1941	I.N.A.	Sir Stanley Goodall	"Sir Charles Parsons and the Royal Navy"
1942	I.Mar.E.	Dr. S. F. Dorey	"Reduction Gearing for Marine Steam Turbines"
1943	The Physical Society	Lord Rayleigh, F.R.S.	"Optical Topics in part connected with Sir Charles Parsons"
1944	N.E.C.	Prof. C. E. Inglis, F.R.S.	"The Determination of Critical Speeds, Natural Frequencies, and Modes of Vibration by means of Basic Functions"
1945	I.E.E.	Mr. R. Davis, M.Sc.	"High Voltage Research at the N.P.L."
1946	I.C.E.	Sir Hugh Chance	"Recent Developments in Optical Glass Manufacture"
1947	I.Mech.E.	Sir Claude Gibb, F.R.S.	"Parsons—the Man and his Work"
1948	N.E.C.	Dr. T. W. F. Brown	"British Marine Gas Turbines"

Presentation of the Parsons Medal

Mr. J. M. McNeill, C.B.E., M.C., LL.D , F.R.S. (Vice-President I.N.A.), said:—On behalf of the Royal Society it is a great pleasure for me to be present to-day, representing the Royal Society, which was responsible for the inauguration of these Memorial Lectures in 1936. This is the fourteenth lecture of the series, but it is only the second which has been presented to the Institution and the Institute, and it is only the second lecture delivered by a naval architect. It is very fitting that the author on this occasion should be Mr. Barnaby, for whilst his claims to present such a lecture may be very strong in his own right, he has the added advantage that he is a grandson of Sir Nathaniel Barnaby, who was a Vice-President of the Institution of Naval Architects and one of its founder members in 1860. It is also worthy of note that Mr. Barnaby himself became a Student member of this Institution in 1911, so that the period covered by his outstanding survey of progress in marine propulsion is almost identical with his period of membership of the Institution.

The work of Sir Charles Parsons as an engineer and a scientist constituted one of the most effective contributions made directly or indirectly to the development of naval architecture. This latest survey serves to acknowledge and enlarge the debt which we members of the two bodies owe to his wonderful performance in the realm of marine propulsion.

On behalf of the Royal Society I have very much pleasure in presenting this medal to Mr. Barnaby as a memento, together with a note of appreciation.

I should like to congratulate him on his very able and comprehensive treatment of his subject. His Lecture will form a most useful and valuable addition to the fine series of Lectures already given.

(The Parsons Medal was then presented to Mr. Barnaby, amid applause.)

Vote of Thanks

Sir A. Murray Stephen, M.C., B.A. (President of I. Mar. E. and Member of Council I.N.A.):—I have seldom listened to a paper which combines interest and humour more admirably than that which we have heard this morning. The author ranged from the Oxford and Cambridge Boat Race to the large battleships and the "Queen" liners, and his attractive light touch contributed notably to what I think is a unique effort.

Your President, Lord Cunningham, this morning made some remarks about people who write and discuss papers, and I think Mr. Barnaby has set an example to us all. It really has been a pleasure to listen to his lecture. I must also pay tribute to Mr. Woollard for the admirable way in which he read it, and which enhanced the lecture's interest and enabled us to follow it quite easily.

I would ask you to accord Mr. Barnaby and Mr. Woollard a very hearty vote of thanks.

Theoretical and Practical Training of the Marine Engineer*

Mr. Logan (Member of Council) who opened the discussion, said that it would be appreciated that the superintendent marine engineer was responsible to the shipowner for the choice of the type of machinery placed in the ships, also for the subsequent operation of the machinery selected. Thus, the training of the marine engineer to operate the machinery successfully and to maintain its economical running was, from the superintendent's viewpoint, of vital importance. The superintendent engineer realized that if he, for instance, recommended a turbo-electric installation with water-tube boilers and a high degree of superheat, he must have a competent engineering staff to operate the plant successfully, therefore men with sufficient theoretical knowledge must be attracted who desired to make the sea their career and not just men who went to sea for a few months to get their certificates.

Recently, it was suggested that the marine engineer of today was the "bottleneck" to marine engineering progress. He did not agree with that view, but he felt that it was right that with the adoption of modern marine plant, they should review the training of the men who were to be placed in charge.

It was, of course, apparent that over the last twenty-five years the practice of marine engineering had changed considerably and was still changing. The slow operating tramp ship, with the reliable old triple expansion steam engine was disappearing and in its place there was the faster 5,000 to 10,000 tons cargo ship with its economical propulsion machinery, electric generators, refrigerators, mechanical ventilation, etc., which the chief engineer of twenty-five to thirty years ago would have considered outside his scope.

Whilst engineers of today were expected as in the past, to be able to carry out the routine servicing of the prime mover and auxiliaries, his own view was that, more and more, the senior engineers were taking their place as executive officers and that the machinery placed in vessels, whether motor or steam driven, was such that satisfactory operation called for men of considerable practical and theoretical knowledge. When one considered the vast sphere of engineering knowledge the certificated marine engineer of today took in his stride, his professional integrity could not be questioned and he considered that he fully deserved the treatment and respect he was now receiving.

He knew it had been said that too few engineers had been available who could combine high theoretical knowledge with first-class craftsmanship, the solution, therefore, lay in a compromise between the two. There also had been advocates for two classes of sea-going engineers, those with high technical qualifications and a tradesman class; whether the adoption of such a scheme would be to advantage was, however, outside the province of this talk.

Practical Training

Mr. Logan considered, provided the theoretical training was given either at evening classes or at part-time day studies, that the works experience in the form of an apprenticeship was the finest training a marine engineer could have, and he advocated that the same method of entry as in the past must form the basis of the engineer's career. His regret was, however, that in many of the marine engine building and repair establishments, the apprentices today were not getting the basic training which was required. The opening-up and the overhauling of machinery was the important side of a young engineer's experience, and, whilst he knew that a lot depended upon the man himself, survey of the workshops made it clear that due to modern workshop practice and certain restrictions the training of the apprentice was not what it was twenty-five to thirty years ago. Under the Ministry of Transport rules the apprentice engineer was required to serve a four years' apprenticeship in a marine engineering building or repair establishment and such a training properly carried out, he thought, equipped a man to meet the requirements of a junior marine engineer. This training, however, did not qualify him for watch-keeping duties, such experience came when he commenced his sea-going career; however, the apprenticeship training combined with day or evening classes enabled him to visualize what happened with the machinery when he became a junior watch-keeper.

It had been asked, was practical training, i.e., the use of the tools, necessary? He would definitely say it was, and many machinery breakdowns had proved, that by the use of tools, the engineer contributed in bringing the ship safely to port. Any endeavours to introduce easy methods of entry to the position of engineer officers of men without the basic training must continue to be resisted. He would suggest that one of the main differences between the commissioned naval engineer and the merchant service engineer was that in the event of breakdowns, etc., the merchantman with his works training was more able to deal with the repairs. He, personally, thought that the Ministry of Transport was wise in adhering to the apprenticeship training as a requirement for certificates of competency.

Practical training, in his view, should consist of: —

(i) Fitting and erection, lathe turning and machine tool work
(ii) Pattern making and foundry
(iii) Boiler making
(iv) Electrical work
(v) and, if possible, actual ship and drydock work.

Unfortunately, due to Trade Union restrictions, he understood it was now difficult for marine engineer apprentices to be employed in the foundry, boiler shop or electrical shop, and he felt that steps should be taken to have the important branches of training again included in the engineer apprentices' curriculum.

Theoretical Training

He held the view that the Junior Technical Schools, as instituted at the present time, should be the main source of supply of marine engineer apprentices, and if he had his way the boys who did well at the Junior School should have preference in entry as apprentices at the works. Unfortunately, as the Trade Unions in many ports limited the number of apprentices to the rate of one apprentice to five or six journeymen, today the number of apprentices coming forward was limited. This was most discouraging and as was known, this Institute had recommended to the Ministry that a "sandwich" system of apprenticeship should immediately be instituted to assist the normal apprenticeship scheme, and in this connexion he under-

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* Discussion following the Annual General Meeting of the Education Group on 14th April 1950. The Minutes of Proceedings of this meeting will be found in the Transactions 1949, Vol. 61, p. xlii.

stood that they were still waiting for the Ministry's comments.

No doubt he would be asked if he considered the present-day schedule of theoretical training adequate. Personally, he thought it was. He had reviewed the careers of twelve chief engineers in his company, all of whom were under thirty-seven years of age, and in charge of machinery up to 8,000 s.h.p., and as a matter of interest he summed-up their school training and qualifications. He would state these men were all keen marine engineers and had obtained either Chief's motor or combined Chief's motor and steam certificates.

Six obtained a National Certificate in Mechanical Engineering at evening school during apprenticeship.

One obtained a National Certificate at evening school but attended a Junior Technical College prior to serving apprenticeship. One obtained a National Certificate at evening school during apprenticeship and after going to sea took a correspendence course and passed the Associate Membership Examination of the Institution of Mechanical Engineers, also obtaining an Extra First Class Certificate.

Four took the National Certificate Course at evening school but did not obtain the certificate.

One attended day college for three six-month sessions, and obtained the Higher National Certificate during apprenticeship; the time spent at college counting as eighteen months of apprenticeship.

From the foregoing he was of the opinion that the National Certificate Course in Mechanical Engineering taken at evening school formed a good grounding for engineers who wished to obtain Ministry of Transport Certificates, as, from the twelve engineers considered, only in one instance had a full-time senior day course been attended. He felt further, that time spent at day school during apprenticeship, whilst it was to be commended, resulted in loss of practical training and under the circumstances extra practical training should be given.

One part of the theoretical training he would stress was electrical technology. The marine engineer of today must be electrically minded, and he personally would advocate, considering the extensive electrical equipment in most ships today, that more attention should be given to the theoretical and practical side of his training.

In conclusion, he would say that the question of opportunities for advancement was not one which today deterred men from going to sea as marine engineers. It is important, however, to impress on the junior engineer on entering his career that it was only by constant attention to his daily work and his studies that his ability would be recognised. After that his promotion followed. He would refer to a few remarks he made recently to the young men who passed highest in the Ministry Transport examination for the current year. He expressed the view that the Ministry examination standard must be maintained at all costs, in fact, he considered it would be by tightening up still further, that superintendent engineers would get the class of engineer the Merchant Service required today. There was little doubt that in the past some superintendent engineers were reluctant to install modern machinery in their ships because they doubted if they would get the engineers with the training and experience required. Today, with the good conditions now being offered he felt sure a larger number of ambitious men would decide to make marine engineering their career.

The CHAIRMAN (MR. T. W. LONGMUIR, Member of Council), before throwing the subject open to discussion, summarized Mr. Logan's remarks to the effect (i) that he preferred the junior technical school as a basis for the recruitment of apprentices; (ii) that he suggested that the apprenticeship system was essential; and (iii) that the minimum requirement before going to sea should be the ordinary National Certificate in Mechanical Engineering.

MR. LOGAN agreed.

The CHAIRMAN said that on that basis no doubt some member would like to open the discussion.

MR. I. S. B. WILSON (Member) said that he entirely agreed with Mr. Logan's comments on the practical training of marine engineers, and endorsed them fully. So far as the theoretical side was concerned, he went to a technical school for three years, and found that it was a very good training.

This training fitted him for a good apprenticeship, because he was given a grounding which always remained with him. Some of the work that he did at school stood out more than anything he did as an apprentice. When one was serving one's time one was working for one's living but at school one learned under happier conditions. He agreed with Mr. Logan that the technical school was by far the most important part of a marine engineer's theoretical training.

The second stage was evening classes and part-time day education, but he would like to leave that for the moment and go on to the last stage, with which he was directly concerned, teaching marine engineers through their various courses. Taking Section A, the mathematics side of the certificate, he thought there would be general agreement that it was rather a crammed section. That was not true of Part B, which was very good.

Having gone from the technical school to the cramming period, with the night school in between them, he thought that that was the point on which attention should be focussed. It was necessary to attract more men of the right calibre into the Merchant Navy, and that could only be done, so far as he could see, at any rate where the night schools were concerned, by such things as the Junior Lectures arranged by the Institute. Not every marine engineer—he did not know what the percentage was—served his time in a marine shop; there were very good marine engineers who had served their time in general shops, and men in general shops ought to be helped to enter the Merchant Navy. By giving Junior Lectures at the various technical colleges men could be interested in going to sea. He thought that more work ought to be done at the night schools.

MR. C. W. TONKIN (Associate Member of Council) feared that some of his observations were bound to be somewhat negative in character. Mention had been made, he said, of what used to be the junior technical schools, but which were now, under the 1944 Act, becoming secondary technical schools, and which were largely being taken from under the wing of the technical colleges and being transferred to secondary control, being housed either in separate buildings or within the compass of other secondary schools, either secondary grammar schools or secondary modern schools, as they were termed—the ex-elementary schools which had now become secondary schools. That being so, the fact had to be faced that inevitably the secondary technical school, the old junior technical school, was being modified. This was bound to be, as it was now to become a section of normal secondary education and came under the control of those responsible for secondary education. Some places had not made the change, but London had already done so to a very considerable extent, and would do so completely in the next few years. Those who, like himself, were concerned with technical education had felt rather concerned about what was to happen to the secondary technical schools, and they were unanimous, he thought, in feeling that the strong bias of the old junior technical schools was going to be watered down appreciably.

With regard to apprenticeship, a lad used to go into an engineering firm as an engineering apprentice, and under those conditions went the whole round of the shops. The trouble was that now a lad entered (as many did in the old days, of course) as an apprentice in a certain trade, and if he entered, for example, as an apprentice engine fitter and turner he was automatically excluded from the boiler shop, the pattern shop, the foundry and so on. Very few in these days entered as engineering apprentices with the fixed intention of going to sea at the end of their apprenticeship. It would however, be agreed that a round of the shops and the different sections of the works during the time of apprenticeship was of considerable importance to a lad who was going to sea and who might have to deal with "the whole outfit".

Mr. Logan had expressed some doubt about the value of day release, fearing that it would cut down the amount of practical training received during apprenticeship. That, how, ever, would be counterbalanced in many respects in these days by the fact that a large number of firms now gave much more methodical attention to their practical training. Many firms had apprentice training bays where they put into practice the experience gained during the war, when it was found that it was possible to teach people to use tools effectively in a much shorter time than had up to then been considered necessary. They were taught to use their tools effectively, and the value of apprenticeship was the breadth of practice given with those tools. If it was possible to speed up the rate of training in the use of the tools, and not leave that to be picked up in haphazard fashion during a long apprenticeship, there was much to be said for the possibility of a slightly shortened apprenticeship without any appreciable loss of practical ability.

The CHAIRMAN observed that it was their experience at Poplar Technical College that, as a result of part-time day release, many employers had become conscious for the first time of the fact that they had apprentices. The keenness which had been shown on the technical college side in trying to engender an interest in the theoretical side of the work had been responded to by the employers, who in their turn had taken a much keener interest in the apprentices and had done something to improve their training in the works. He thought on the whole that it had definitely been helpful.

MR. F. H. REID, B.SC. (Member), said he had been very interested in Mr. Logan's talk, but there were one or two points on which he disagreed with him, and these points had already been mentioned in the discussion. One of them, to which the Chairman had just referred, was part-time day release. Some eight years ago he read a paper on the North-East Coast in which he suggested that the period of apprenticeship could be appreciably reduced. At the time that some of those present served their apprenticeship, it was seven years; then it was reduced to six, and in many cases it was now five. With a properly co-ordinated system of training, a four-year period should be ample. He thought that most firms that had closely co-operated in part-time day release schemes, releasing their apprentices for one day a week, had found that those apprentices had made far greater progress as a result on the practical side, as well as in their theory. Those who, like himself, were concerned with technical education had advocated for thirty years the scheme of part-time day release for the technical education of young employees, and they had no doubt whatever of the benefits derived from it not only by the lads but by industry.

It had been said that the lads did not go through all the various shops. The bigger engineering firms, however, had different types of apprenticeship; they had trade apprentices and engineering apprentices. Most of these firms made it possible for the trade apprentice who showed progress in his technical study to transfer to the category of engineering apprentice, and the engineering apprentice would go through all sections of the works. That was becoming more and more general. A large number of the firms from whom they had day students in South-East London were giving their lads better training. One firm who sent them eighty students insisted on their having two days a week, not simply one day, and allowed them to continue their part-time day education even after they reached the end of their apprenticeship, to enable them to take the Higher National Certificate as part-time day students. A request had been received from one firm for a part-time day endorsement course. He did not think that employers would do that unless they were convinced that they were getting something for it. He believed that a combination of a properly co-ordinated training scheme in the works with the work done in the college would enable a lad to get a proper engineering training.

Mr. Logan also referred to lack of knowledge of electrical work. They gave their part-time day release students an additional optional subject, such as electricity, which gave them what was required. If, however, students came in the evenings only, attending three evenings a week, it was not possible to cram four nights' work into three evenings. Attending only on three evenings a week they could be given only three subjects. His college told the part-time day students that they insisted on their attending also on one evening a week. Unless the firm co-operated that insistence was of no avail, but most firms told their lads that they expected them to attend on one evening in the week in addition to the day release periods.

Mr. Logan mentioned the junior technical schools, and he was glad that Mr. Tonkin took up that point. When the 1944 Act came out he himself gave a talk to the Education Group and said that he felt that the junior technical schools as one had known them in the past were going to cease to exist. He was still struggling to keep a secondary technical school under his wing, but for how long he would continue to win that fight he did not know; he did not think it would be for very long. He was convinced, however, that divorce from the technical college, where they were born and had been nurtured for many years, would be a misfortune. One of the main advantages of association with the technical college and with the technical college staff had been that the boys in the junior technical schools had been taught by engineers and not by handicraft teachers, and by engineers who also dealt with the advanced work, and the boys had had the opportunity to use machines in workshops equipped in a proper manner. It would be a pity if they were transferred to some conglomeration of schools called comprehensive schools, and sometimes known as dual schools, where neither the equipment nor the staffing would be of the standard customary in the old junior technical schools. However, he was afraid that that was something which they could not alter.

Mr. Logan mentioned certain of his chief engineers who had Ordinary National Certificates. It would be interesting to know whether any of them went on to get the Higher National Certificate.

MR. LOGAN said that one of them had done so.

MR. REID said that if these lads were encouraged to continue and take their Higher National Certificate they would be the type who would become chief engineers, and would go on for the Extra First-Class Certificate, because they would have had proper training in more advanced engineering. The Ordinary National Certificate gave them a broad basis of the elements, but in the Higher National course they got further training and more discipline in their studies, enabling them to think and understand their problems. It was that type of man who should be encouraged to go into the marine engineeering service.

MR. H. J. HETHERINGTON (Member) recalled that at the time when he served his apprenticeship in London there were at least four shipping companies that had their own workshops. He did not believe that any of those companies now were so equipped. He often thought, perhaps because he went through it himself, that the ideal method of training was in the company's own workshops, where the company trained men to become engineers in their own vessels, and where the men under training went on the ships and got to know the engineers, who took an interest in them. He himself learned a great deal more on board ship from the engineers than he did at the school.

He served his time during the 1914-18 war, and then, owing to the shortage of engineers, apprentices in their fourth and fifth years were asked to do jobs normally done by the ship's engineers. He thought that shipping companies had lost a great deal by closing down their own workshops. They might adopt a scheme with the builders by which they would take an interest in people who would like to go to sea in the ships of their company, and have an arrangement by which such young men would work on their own company's vessels. The difficulty was that shipyards did not always repair the same company's ships.

On the subject of evening classes, he tended to agree with Mr. Reid and other speakers in the discussion, and not so much with Mr. Logan. Evening classes were all very well in their way, but after a day's work lasting from eight o'clock in the morning until five in the evening to have to rush home, wash, change, have a meal and then dash off to an evening class meant that one did not grasp a great deal of what the lecturer was trying to expound, or at least he himself had not succeeded in doing so, and in his day they used to go to classes four nights a week. He thought that day classes were much to be preferred.

As for day classes detracting from practical training, he did not think that they had that effect at all, because, after all, if one learnt about the job that one was doing one would take much more interest in it and get on much more quickly. In his own experience of marine engineers as a class, he had found that there were two subjects on which they were very much lacking in knowledge: chemistry and electricity. Most of them did not know very much about chemistry or metallurgy, even to the extent of knowing how to use an ordinary testing set for boiler water. A man who served an apprenticeship and combined that with evening classes could not get the necessary training; it needed a proper laboratory where one could get used to things by doing them. It was the same with electricity; there was need for a proper laboratory where one could make measurements and understand what one was doing. Few marine engineers knew how to tackle a real electrical fault in a dynamo. It showed up in motor ships where there were many auxiliaries.

COM'R(E) S. DICKINSON, O.B.E., R.N.(ret.) (Member), expressed appreciation of the fact that so many speakers had said that they believed that a great deal of benefit was derived from part-time day release. Those who were responsible for technical education, he said, were in general agreement on that point, but there was another point which he would like to raise. He had had some experience in the training of marine engineers and he believed that after the war there was a tendency towards cramming in the training, more especially in those private training schools. He had often felt that it would be a good idea if it were possible to allow marine engineers exemptions from the examinations for the Ministry of Transport's Certificates if they had obtained a Higher National Certificate in mechanical engineering. It would be a good thing to allow a student of marine engineering to obtain his Higher National Certificate in the ordinary way, either by part-time day release or evening instruction, and then allow certain exemptions on a subject for subject basis, in the Ministry of Transport's examination of competency. He had the impression that there was more educational value in the National Certificate courses than in the intensive training for the Ministry of Transport's examinations in competency.

MR. G. B. WILLIAMS (Associate) suggested that Commander Dickinson was in error, because the holder of a National Certificate was exempt from part "A" for both the First and Second Class Certificates.

He, himself, he said, took his certificates at Liverpool Technical College, and in those days, which were not far distant, they had of necessity to cram, because they were not paid the considerable sums which were now paid out to junior engineers whilst attending college for their certificates. At present they were paying three months' full pay to a man attending college, with a month's extension, if necessary, and if a man could not take the course reasonably well in four months he was not fit to be a marine engineer. There was no necessity for cramming in that period, provided that the pre-school preparation had been completed.

It must be taken for granted that once a man had completed his apprenticeship, he was a reasonably competent mechanical engineer, and it was at this time that his training as a marine engineer would begin, but a considerable amount of pre-sea service training should have been already completed on the theoretical side, and all had full confidence in the approved Technical Colleges to impart this necessary theoretical knowledge, provided that the man felt some urgent incentive to attend both the day and evening courses, albeit at some inconvenience to himself. But it was very noticeable that advantage was not being taken of the educational facilities offered to these men. These prospective junior engineers came before him and, almost invariably, they were Grade II—in many cases they were Grade III—which meant that they had no night-school attendance to their credit. Grade I men were very scarce; a sad commentary on the system.

Or perhaps it was the very lack of system that had failed, whereby a man arrived at one of the various Technical Colleges to commence his course, entirely ignorant of fundamental principles, and without the faintest idea of the knowledge required by the certificate, a position that was not enhanced when, in the course of the first few days, he glanced at the syllabus of examination as presented in the regulations (a gruesome sight to the novice).

This state of affairs was most unsatisfactory from all viewpoints, particularly that of the shipowner who, of necessity, paid out considerable sums of money annually, in the form of payment for study time, with no tangible result to qualify the circumstance.

Perhaps the answer lay in removing from the junior engineer some of the all-enveloping sense of social security engendered by these conditions, and so applying a very real and conscious incentive to the aspiring marine engineer.

He would suggest that the quality of the junior engineer would improve if a system were adopted which made it impossible for a new entrant to be considered for sea service with either a private company or the establishment, unless he were able to provide a certificate of night-school attendance, showing reasonable progress for a minimum period of three years.

This, of course, would mean that the grading of new entrants would perhaps follow as:—

Grade I. Holders of Higher National Certificate.
Grade II. Holders of Ordinary National Certificate.
Grade III. Holders of 3-year satisfactory progress reports.

The commencing rate of pay would be adjusted according to the man's grade—any applicant below this latter qualification would be rejected.

After acceptance as a junior engineer the man would then serve a probationary period of at least six months before being considered for either an establishment contract or a company's contract. A condition of such contract would be the production of proof that the man had registered for a correspondence course at one of the approved Technical Colleges.

During the term of contract, his enjoyment of the conditions of such contract would, in part, be governed by reports (say, at six monthly intervals) received from the tutors. He felt sure that the colleges would not feel that this was an imposition upon an already burdened staff.

When, in the course of time, the engineer had performed his qualifying sea service, he would present himself at the college of his choice, and pass a minor entrance examination, say, a one hour paper in three subjects, before he was allowed to attend the course proper. The benefits of this would be, at least, two-fold:—

(a) The college staff would have a reasonable estimate of the candidate's potentialities, and that the man would be ultimately capable of obtaining a certificate.
(b) Failure to pass the preliminary examination would not then involve the shipowner in needless expenditure on men who were not really putting some effort into their studies.

He was fully aware that, under present conditions, the law of supply and demand predominated, but in the near future, when younger men completed an apprenticeship that had been unhampered by hostilities, surely it was at least a step in the right direction, whereby the young man was made aware that his progress and livelihood demanded some little effort on his own part, and not a blind acceptance of conditions thrust upon him by reason of the efforts of his Seniors in earlier years.

He realized, of course, that this discourse stressed the theoretical training of the marine engineer, but did it not follow that once a man had really grasped the fundamentals of his profession he would automatically further his education and, in the course of time, become a reasonably knowledgeable marine engineer who, in due course, would be able to impart some real knowledge to his subordinates?

The CHAIRMAN said that one point which Mr. Logan made was very significant. For a shipping company to have twelve chief engineers under thirty-seven years of age and every one of them of National Certificate standard was remarkable. The question of the Higher National Certificate had been raised. If those same men had had the opportunities which were available at present, he was certain that every one of them would have had the Higher National Certificate. They must have served their time in the years 1929 to 1934, when times were bad, unemployment was rife, and there was no part-time day release scheme, so that they had to do all their work at night school. At the present time such boys would all have part-time day release. He agreed that four years' apprenticeship was ample, and that was in effect what the boys had with one day a week off to go to school a four-year apprenticeship was spread over five years.

There was one point which he thought that Mr. Logan had missed. In the dock towns, such as Liverpool and Newcastle, the boy who got part-time release by day would come in contact with instructors who, it was more than likely, had had something to do with ships, and who might have had seagoing experience. The questions which those apprentices would bring to school to be answered, which they could not get answered in the docks or workshops, were surprising—questions such as how to open up turbines, and so on. The school could help the boys on the practical side as well as the theoretical.

Commander Dickinson had suggested that the men who went up for their certificates were crammed. The men who had done a five-year night school course and obtained their Higher National Certificate, or even the Ordinary National Certificate, when they went to day school to get their Ministry of Transport certificate were not crammed; the people who had to be crammed were those with no previous technical training. It was not everybody who could get a Higher National Certificate, but that did not mean that those who could not do so were not good men. If they got even an Ordinary National Certificate, when they came to take their Ministry of Transport certificate they did not have to cram. It was only, as he had said, the boys with no previous technical experience who had to cram, and they were the ones, he thought it would be agreed, who should not go to sea and call themselves marine engineers. Cramming, therefore, was not necessary, unless economic conditions made it necessary to take people to sea who normally would not be taken. He thought that they were the people who had been referred to as Grade 3. There were plenty of Grade 1 men in London.

A MEMBER expressed disagreement.

MR. LONGMUIR pointed out that the effects of the war were still being felt, and war-time-trained men were still coming forward, but Grade 1 men would be coming along.

Mr. Logan had given the meeting something very interesting, and something which was needed, namely what the superintendent engineer thought that he wanted and not what other people thought that he should have. There was one point which perhaps Mr. Logan had missed. Mr. Logan asked for some instruction in electricity. Electricity was not an easy subject for a boy to start on in his first year, but he could at the end of his first year get some electrotechnology, and they tried to give him a little instruction in naval architecture and ship construction as well, which personally he thought was essential for the marine engineer.

MR. R. W. PARSONS (Associate Member) said that there had been quite a lengthy discussion on the technical training of marine engineers in their early days as lads, when serving their apprenticeship, but he thought that there was scope for the practical training to be organized more thoroughly than it was at present. There had been talk about apprentices going from one shop to the other—to the pattern-making shop, the foundry and so on—but he thought that the main point of a marine engineer's training in his youth was at the fitting bench, and erecting on the ships. That was where a man would learn to use his tools. Foundry work was all very well, and would enable him to see how a casting was made, but that section of his training was not carried very far, and he could not afterwards make a casting.

He thought that part-time day release schemes and evening classes for the National Certificate were good, but it would not be possible to extend the evening classes very much; for instance, it would not be reasonable to expect a boy to attend for five nights a week; three nights were quite enough. At the conclusion of his apprenticeship he was not a marine engineer, but still a mechanical engineer, and it would be difficult to give him any practical marine training before he went to sea, because most marine training was purely practical work, that was seeing the job running and having his hands on the job of repair. Possibly the shipowners could co-operate more with the workshops, by organizing some scheme by which the four-year or five-year apprentice could come into actual contact with ships running at sea.

It had been said that some of the engineers who went to sea were not of the right type. He thought that there was scope for making the marine engineer's career at sea more attractive to the right type of young men before they went to sea. As a young man himself, when he first went to sea he did not really know what he was going into. He liked it when he got there, but many good men who served their time with him never went to sea at all; they found what they thought were more attractive jobs elsewhere. If the career of a marine engineer was made more attractive, more men would be ready to consider it as a profession, and the shipowner could then select the right type of man for his needs.

MR. A. W. JONES, B.SC. (Associate Member), said he would like to refer to a point made by a previous speaker, namely, the large number of failures to pass the Second Class and even First Class M.O.T. examinations. A man who was going to become a successful sea-going engineer; the type of man that was wanted to maintain and operate modern machinery installations at their designed efficiency and output; such a man, between the age of twenty-one and (say) twenty-seven years had got to satisfy M.O.T. examiners in several sets of written examinations on both theoretical and practical subjects as well as the vital oral examinations. Furthermore, in order to be truly successful he had to have a trained mind which would always be capable of assimilating new ideas in order to keep himself up to date.

If a young man had a gap in his training between the age of sixteen and twenty-one years when he did nothing at his books it was practically impossible for him to fulfil the above requirements. This period was a very important one in the development of the mind, one in which a boy changed to a man and if technical training was not continued throughout it, the task of picking up bookwork in the twenties was very difficult, as many ex-Service men had found. In those circumstances the courses in the marine schools would have to be crammed, with the resulting high proportion of failures and even when success was attained it was not certain that such a man would develop the mental elasticity which was so desirable.

It appeared to be certain that the best type of engineer would be recruited from young men who had attended a part-time day course at a technical college throughout their apprenticeship. In the Royal Dockyards such a scheme of mixing classes and practical training had been carried out for a great many years and it could not be denied that in this way they turned out a large number of promising young engineers. He had recently come in contact with a number of dockyard-trained apprentices and, while not being in a position to judge their craftsmanship as fitters, he had certainly found them to be mentally alert and receptive. He considered that the continuation of technical training during the apprenticeship by means of part-time day courses was much superior to the older method of night classes taken on top of a full working week.

A marine engineer at sea had to have a certain knowledge and experience of fitting, erecting, boiler-making, and simple turning of steel and brass in order to carry out his duties properly, but any further knowledge of ancillary trades such as pattern making and foundry work was not thought to be necessary. Therefore, if the practical training during apprenticeship was limited to fitting, erecting, boiler-making and simple turning he was sure that an adequate standard of experience in these crafts could be attained during a course consisting of three days a week for four years. Two days a week would then be free for full time day study at a technical college and with such an arrangement it would be possible for an apprentice to obtain his Higher National Certificate in mechanical engineering by the age of twenty-one years. A man thus prepared would have every likelihood of passing the M.O.T. examinations in quick time and of developing into a marine engineer capable of taking the responsibility of the running and maintenance of a modern installation; the kind of chief engineer the superintendent wanted.

He considered that for the intending marine engineer the two day a week part-time release was to be greatly preferred to the one day a week part-time release.

It would indeed take a generous firm to pay its apprentices for two days a week at college and then be quite willing to see a considerable number of them depart and take their knowledge to another concern. There were such firms of course but the reluctance to pay good money for the benefit of others did raise a difficulty in the operation of the part-time release scheme for intending marine engineers. In fact, the necessity of such men receiving their workshop training in an industry different to that in which they found final employment raised a big difficulty in allowing the shipowners to influence the preparatory training of their engineer recruits, particularly under conditions of full employment. A way round this difficulty would be the creation of a special training centre for marine engineers, sponsored and supported by the shipowning companies by means of which they could control the training given to their apprentices.

In connexion with the apprentice gaining a Higher National Certificate by the age of twenty-one years he would like to point out that at King's College, Newcastle-upon-Tyne, such a qualification was accepted as a matriculation exemption giving the student entrance into the Second Year of the University course and enabling a Bachelor's degree to be obtained in two years.

His own main interest at the present time was the university training of men for marine engineering. Such training had not been mentioned in the discussion so far and he hoped that it was not out of order to do so. The institution to which he was attached, King's College, Newcastle-upon-Tyne, was the only college in this country where a University degree was awarded in the particular applied science of marine engineering. The subject matter of the courses leading to the degree covered the fundamental engineering sciences together with specialist courses in chemistry, electrical engineering, ship resistance and propulsion and marine installation design. Those who attained a sufficiently high standard in their pass degree (normally a three-year course) were eligible to continue their training during a fourth year for an honours degree.

He considered that the greatest value was obtained from the University course if it was arranged to come between the workshop experience and the sea-going time. One of the main endeavours of the course was to provide the student with a mental training and discipline together with a sufficient fundamental knowledge to enable him eventually to fit himself to take a place on a superintendent's staff or to specialize in one of the other branches of marine engineering. As far as possible, the enthusiasm to go to sea to complete the training was stimulated and it was hoped that the sea-going experience would be the richer for the time spent at the University. However, by the time the workshop experience and the University course was completed, the young man was about twenty-three or four years of age. At such an age, with two years workshop experience and an honours degree there were attractive opportunities for employment in such institutions as the scientific civil service or the research associations and by comparison, the outlook of five years sea-going experience (as a minimum) in the unknown environment of a ship's engine room was a little bleak. It was at this stage that there was a considerable wastage in the number of graduates who got to sea.

He felt sure that the experience of a voyage in a well-run ship during the summer vacation just prior to their honours course would be very helpful in maintaining the keenness of these young men to continue with their training and to qualify for the M.O.T. certificates. Some twenty years ago there was a scheme whereby engineering graduates were enabled to make an ocean going voyage and he would be glad to know what support there would be from superintendent engineers for the re-introduction of such a scheme specifically for graduates of marine engineering. He considered that shipowners ought to be willing to make some such overture to the graduate if they wanted him, and of course once the plunge was taken and the young man was embarked on his sea-going experience it was up to the owner to train and use him for their mutual advantage.

COM'R(E) J. I. T. GREEN, R.N. (Associate Member), said that he was not fully acquainted with all the methods of recruitment and training of marine engineers but he thought as regards recruitment that there was not much attraction in these "soft" days for a training which involved so much extra work at night. He suggested that it would be worth while to give them the equivalent of one year's daytime theoretical instruction spread over the four years apprenticeship, particularly in view of the advancing complexity of machinery which they would eventually control.

It seemed important also to provide an avenue through the medium of advanced study for eventual promotion to the higher posts. In this connexion a young man at sea might be aided by the further guidance of a University trained man if one was available in his ship.

MR. T. A. BENNETT (Member) said that Mr. Logan's opening remarks fitted in so well with his own views that they did not call for any comments, but he had been surprised to hear them. He thought that Mr. Logan was going to make many complaints, instead of which he seemed to be quite happy with the existing system.

Mr. Logan required 200 engineers a year, which was a large number, and it was not a question of a few excellently trained men with National Certificates but of the mass of trained brains that were needed. Personally, he thought that the shortage of marine engineers, and indeed of engineers in general, was due to the trade union restriction of one apprentice for five journeymen. When he served his apprenticeship, the proportion was about one to one, there being about as many apprentices as there were men working in the shop. The result of the present restriction was that there were insufficient engineers to supply all the requirements on shore and at sea, and he did not know how that difficulty was to be overcome.

He thought that on the whole sufficient recruits were being obtained for marine engineering, but then came the leakage to the shore again. The leakage took place after the men had had, perhaps, one voyage, especially in some tankers, where they were sent to sea for two years out East. The young engineer on going to sea should if possible be sent on a short voyage the first time; if he was away for two years on his first voyage he might feel that he had had enough of it.

Then there were the men with First Class Certificates who wanted to come ashore and get a shore job. He did not know how that could be stopped, or if it was desirable to stop it, but it might right itself in time. At present industry was working at full pressure, but would slacken down and although they did not want that to happen the possibility was there.

For the marine engineering industry, he thought that there was a great deal of hope in part-time day release to attend school. Many of the students who came to him to prepare for their certificate, when he asked them whether they had the National Certificate, told him that they had worked for it for a year, or for two years, or that they sat for it but did not pass. This was the first leakage from organized training and it might be possible to avoid or reduce this state of affairs. Possibly the National Certificate course was too stiff and although some could do it in three years, others could not keep the pace, and if after one year they had not got hold of it they were apt to give up. Part-time day study would do a great deal to keep them, and if they had to go to school for one day a week there should be much better results in the future—they could not drop out as they did with evening classes. He was very keen on part-time day release and thought that it was a great innovation.

The question of cramming had been raised. No doubt the universities considered that the technical schools did a great deal of cramming, but everybody crammed for an examination. He had worked out the hours of work. The evening class student with three classes a week for thirty weeks in the year did 180 hours, or 540 hours in three years.

A MEMBER: 750 hours.

Mr. Bennett said it might be 750 hours nowadays, but he was going back a little, because he did not know so much about the present position. Some of his students did fully that number of hours, they did 30 hours a week, and students who had little previous training might attend for six months. He would agree, however, that training spread over a longer time was better than intensified courses—knowledge took time to be absorbed. With an intensified course that was not possible.

He had over 100 students at present, and 75 per cent of them would possibly get their certificates. Examining results he found that 60 per cent for second class passed before returning to sea, but those who did not pass would return and eventually over 75 per cent passed. For the first class the figure was as high as 90 per cent in the end. About 75 per cent would pass on first attendance, and 90 per cent eventually. There might be some cramming, which was only hard work by student and teacher, but it did produce results, and it was results that were wanted.

He hoped that they would not be asked to send the shipowners fortnightly or monthly reports; they had enough forms to fill in at present, and any increase would require a clerical staff.

MR. B. C. CURLING (Secretary), referring to what Mr. Jones had said about university students going to sea during their course, recalled that a few years before the war arrangements were made through the Liverpool Engineering Society and Liverpool University whereby the engineering undergraduates of Liverpool went on vacation courses at sea in ships of the Cunard White Star Company. On a number of occasions university students came to him from London and elsewhere who wanted a vacation course of that kind, but it was never possible to arrange it, because the only company doing it were the Cunard, and the Cunard Company took engineering students, including electrical engineering students, who were never going to sea.

MR. LOGAN, in reply, said he had found the discussion both interesting and enlightening. He would like to emphasize that he felt that engineers who had completed the National Certificate Course should eventually, with the necessary sea experience, make competent Chief Engineers. In his view, it had been proved that it was the studies carried out, both in evening classes and in part-time day classes, which had brought men to the fore, whilst others of the same age were still sailing in lower grades. Quite a number of engineers were sailing and would sail in ships having big turbo-electric installations, and to cope with that type of machinery it was advocated that electrical training must be good.

He was glad that the question of part-time day release had been raised, because he must confess that he had not appreciated its value; he had thought that the boys were probably losing something by going to school during the day time. He could, however, appreciate the points which had been made. With regard to cramming, he was of the opinion that boys who had taken the National Certificate Course should not have to cram when they came to sit for their Certificates.

The Institute had advocated to the Ministry of Transport that there should be an alternative scheme to the present apprenticeship system, whereby there would be a sandwich course for boys, selected by the shipowners, who would do a certain time in the college. They hoped that that would be approved. It should increase the number of boys coming in and get over the trade union restriction on the number of apprentices in other words, ship-owners would put them into works as premium apprentices. This scheme put forward by the Institute to the Ministry was as follows:—

"*Recommendation 1*

(a) that paragraph 15 of the 'Ministry of Transport Regulations relating to the Examination of Engineers in the Mercantile Marine, Exn. Ia' be so interpreted that entrants who have been apprenticed with firms not classed as marine establishments should be given an opportunity of going to sea as junior engineers on the completion of four years' apprenticeship in general engineering, provided they have received technical education up to Ordinary National Certificate standard at an educational establishment which has been approved under the scheme of countersignature for Marine Engineering by the President of the Institute of Marine Engineers. Should an entrant not have reached the above standard, he should be allowed to take a full-time course of six months duration approved by the Ministry of Education, the Ministry of Transport and the Institute of Marine Engineers at an approved technical college*.

(b) that the provisions laid down in paragraph 14 of the M. of T. Regulations above-mentioned be extended to allow apprentices who have served three years in approved workshops and have reached Ordinary National Certificate standard of technical education to proceed to sea as Assistant Engineers. It was proposed that these entrants be allowed to sit for their Second Class M. of T. Certificates of Competency after two years' qualifying sea service.

It was suggested that the above recommendations, if adopted, should be subject to review after two years' trial period. It was considered that the Ministry of Transport should be urged to adopt recommendation (b) as a short-term policy and only during the present acute shortage of engineers.

Recommendation 2

That in addition to the present system of intake of junior marine engineers as set out in M. of. T. Regulations Exn. Ia, paragraphs 14-17 inclusive, a scheme based on paragraph 19 of those Regulations be instituted on the following lines:

Youths of the ages of 16 to 17 years who have reached a satisfactory educational standard to be enrolled by a shipping company or by a shipowners' organization for a 4½ years' sandwich course of training as a marine engineer, consisting of alternating periods of six months full time attendance at a recognized technical college* and at a works of the description specified in paragraph 14 of the above Regulations.

The course of training would consist of five college sessions with four sandwich works sessions, and would cover ground for the requisite two years essential basic craft training, plus a technical educational standard of not less than Higher National Diploma. It is suggested that the cadets be given an opportunity of obtaining watch-keeping experience at sea during vacation periods".

There was always room in the marine engineering profession for men from the Universities and at the present time he had two boys with B.Sc. degrees sailing as Second Engineers. He, himself, however, had advocated a compromise. What they wanted at sea was neither the man with high academic qualification or the man with merely practical knowledge, but a sound man whose education was based on the National Engineering Course.

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* As listed in Appendix E of the above-mentioned Regulations.

MEMBERSHIP ELECTIONS

Elected 4th September 1950

MEMBERS

Hardy Frederick Ablitt
Archibald Macgregor Alexander
James Edward Barrett
George Percy Bennett, Lt.-Com'r(E), R.N.
Eric George Davis
John de Wolf
Maurice Donaldson
Robert Stevenson Ferris
Matthew Dobie Gordon
Albert Edward Hollamby, Com'r(E), R.N.
Thomas Hunter
Claude Francis Jackson, Lt.-Com'r(E), R.N.
Neil S. Jones
William Baden Lewis
Lewis D. MacBean
Kerr Paxton
Remigio Elias Perez, Lt.-Com'r, V.N.
David William Reid
Robert Templeton Robertson-Hudson
William Rowles
George Vernon Steel, Lt.-Com'r(E), R.N.
Niel Lawrence Taylor-Jones
Robert William Tyzack
Ronald Mensforth
Malcolm Morrison
Thomas Louis Ryan O'Hare
Trevor Gordon Pearce
Nathanael Afolabi Pearse
Alexander John Burnett Pirie
Barry Reeves
J. C. van Reenen
Leslie Ridland Wilson

ASSOCIATE MEMBERS

George Kenneth Beard, B.Sc.
James Hall
Ronald Leslie Young

ASSOCIATES

Dennis George William Allsop
Ahmad Mian Ansari
Cyril Beason
Cyril David Binns
Donald McCoy Blackwood
William Harland John Coates
William Owen Crosbie
Jan Theodorus Endert
William Cockburn Frame
James Fulthorpe
Charles Harry Gurr
Desmond John Haley
Richard John Hepburn
Peter Herbert Hulks
Robert Kenny
Ronald Ernest Kilby
Thomas Edward Larmont

GRADUATES

Madhusudan Acharya
Thomas Walter Clucas
Thomas Sproull Heatly
James Mathew
George Stanley Mole, B.Sc.
Robert Charles Stephens

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

Robert Mack, Com'r(E), D.S.C., R.N.

TRANSFER FROM ASSOCIATE TO MEMBER

James Robert Pierce Conolly
Armand Lambert Covell
Laurence Francis Gatzias
John Simpson Irvine
James Stephen Rowley
Victor Ronald Welch

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Donald Ormrod Carmichael
Noel Strafford Fowler
John William Utting

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Hugh Grills Beck
James Stewart McAllister
David Bryce Stables

TRANSFER FROM GRADUATE TO ASSOCIATE

Alan Walter John Lissenden
Roy Cecil Wilson

TRANSFER FROM STUDENT TO ASSOCIATE MEMBER

Brian Roxberry Bland, Lieut.(E), R.N.

TRANSFER FROM STUDENT TO GRADUATE

John Frederick Notman

Crankcase Explosions

Correspondence*

MR. H. D. ADAM (Member) wrote that he had helped for many years in the avoidance of breakdowns on Diesel engines which were insured against this risk. The result was that he had a few hundred engines under constant supervision, and having co-operated with those in charge since plant was first installed, first-hand reliable information was obtainable. A number of crankcase explosions had been experienced, but due to the normal lack of oxygen in the crank chambers they had been reported as "just a puff" or a "big puff".

Increased ventilation of crank chambers had been proposed but the risk of explosive mixtures must be considered. The main causes of ignition temperature occurring seemed to be piston seizure after an engine had been dismantled for overhaul, in these cases fitting of small end bearing and gudgeon pins causing piston distortion was suspected. Other known causes had been cracked piston heads, hot carbon under piston heads due to faulty splash guards, blow-by due to ring failure, or distorted liner or piston. Hot bearings and overheated parts had caused explosions when oxygen had been supplied by early removal of crank-chamber doors. In his opinion the main causes of the apparent increase in crank chamber explosions was that in recent years working temperatures had been increased resulting in higher lubricating oil temperatures, and greater risk of seizures or ignition of oil vapour from hot spots. In many cases no interest was taken in the temperature of the lubricating oil and thermometers were not fitted; most coolers were small and inefficient. If cooling water was supplied at a very low temperature, some oil became cooled and clung to cooling surfaces, the main supply of lubricating oil then passed through a small area in a hot stream. The difficulty was increased by the high temperature of the circulating water inlet temperature to the engine.

The piston head was the hottest spot and it would appear that heat was conducted from this to the connecting rod bearings. It had been found that the big end bearing was always higher in temperature than surrounding parts. When hand pumping lubricating oil it had been noted that little oil flowed from the big end bearing, and therefore it did not act as a coolant as well as lubricant. When bearings were not so accurately machined, hand scraping was necessary which resulted in an increased clearance at the joints of the bearings through which oil passed out without affecting running clearance that had rightly been decreased, and had prevented the "crazed" fractures which occurred due to hammer and crystallization of the whitemetal. The line cracks which were sometimes seen appeared to be due to excessive surface heating of oil retained in bearings.

He had proved to his satisfaction that, if a liberal quantity of clean lubricating oil of correct quality and suitable viscosity, cooled to the right temperature, was allowed to pass through the bearings in lubricating the system, it made for a smooth quiet-running engine and decreased the possibility of crank chamber explosions due to hot spots and ignitable oil vapour. Incidentally, this oil vapour, which was generally vented into the air induction system, increased the lubricating oil consumption, also a hot engine formed carbon in and outside the piston; little trouble was experienced with oil cooled pistons.

He hoped to prove, by long periods of running of two engines of the same type, working under the same conditions, that fuel consumption did not increase when the crank chamber of one engine was kept cool.

Tests would be carried out in water pumping plant where conditions remained identical during night and day, running for thousands of hours. This was the only way to obtain practical results. The tests, he hoped, would prove the many benefits of cool crank chambers. He had run plant for many years without having to remove bearings for any cause; he also naturally hoped to avoid any explosions by the methods adopted.

MR. I. J. GRAY (Member) wrote that in the consideration of crankcase explosions, the importance of the period covering their inception, growth and decline, was not, he suggested, fully realized. Its duration would seem to determine the effect of explosions, whether slow or detonating, upon engine structures and such safety devices as might be fitted thereto.

There seemed but remote possibility of arriving at a measure of the effects of pressure waves, inseparable from explosions, either in terms of vibrations or of equivalent static pressures. Designers of safeguards could therefore be guided only by practical considerations.

A point in the design of safety doors seemed to have been overlooked, and that was, for want of a better term, the "force-absorbability" of their material. If of a soft material, they might not react to explosive effect sufficiently quickly to avoid lag behind the period of explosion. In two instances at least on which he had been advised, safety doors, or disks (where sheet lead and thin millboard were used respectively) resisted an explosive effect which fractured normal crankcase doors.

He believed certain users favoured large, light crankcase doors, held in position by springs. But, however effective they might prove against "slow" explosions, he feared that their cumulative inertia would annul their usefulness against a detonation.

He favoured most those who stressed the importance of cool lubricant, and he deprecated most keenly the idea of using exhaust gas. The availability of carbon-dioxide for emergency use would seem a worthy precaution, and it might serve as a useful coolant too.

In trunk type engines, the salient danger zone was, he suggested, the piston surface in way of its pin. The need for great improvement in gear for drawing and assembling piston pins without incurring surface damage to the pistons, or variance of their forms, would doubtless be realized by many users.

On the matter of personnel, he did not favour more gauges than were absolutely necessary as their presence seemed to nullify the development of that intangible sixth sense so important in watch-keeping.

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* Additional contributions received after publication of this discussion (see TRANSACTIONS, Vol. 62, No. 7, p. 267).

OBITUARY

James Armstrong (Member 7916) was born in 1898. He served his apprenticeship from 1914 to 1919 with Messrs. Hawthorn Leslie and Co., and for one year after this was assistant in a firm of consulting engineers in Newcastle-on-Tyne. He then went to sea, serving with various companies and rising to the position of Chief Engineer. He joined the India Steamship Co., Ltd., in 1948 and was serving in that company's vessel, the s.s. *Indian Enterprise,* when it exploded in the Red Sea on 19th June 1950 and he was presumed to have lost his life. He was elected a Member of the Institute in 1935.

R. Doust (Member 1240) was born in 1860 and educated at the Roan School, Greenwich. He served his apprenticeship with Messrs. John Penn and Sons, Greenwich, and then saw sea service on a collier. He later joined the P. and O. Steam Navigation Co., becoming a Chief Engineer in 1897. He remained with that company rising to the post of Deputy Superintendent of engineering at Tilbury Dock. He was awarded the Marine Medal for the South African War. Mr. Doust was elected a Member of the Institute in 1897. He died on 30th April 1950 in his ninety-first year.

Emil Aitken Quack (Member 2485) was born in 1873 at Liverpool. He served his apprenticeship with Messrs. Geo. Rollo and Co., Ltd., Birkenhead, and then spent a year at University College, Liverpool. He saw sea service for five and a half years, obtaining his First Class Board of Trade Certificate. He then joined the staff of Messrs. C. H. Bailey, Ltd., ship repairers, Barry Dock, as Assistant Manager, later transferring to Messrs. Smith's Dock Co., Ltd., South Shields, as Manager. In 1911 he became General Manager of Messrs. Clover, Clayton and Co., Ltd., Birkenhead, and three years later he was made Managing Director of The Ardrossan Dry Dock and Shipbuilding Co., Ltd., Ardrossan. Some years later he set up in business in London as a consulting engineer and representative, retiring in 1947 owing to illness. As well as being a Member of the Institute, Mr. Aitken Quack was a Member of the Institution of Engineers and Shipbuilders in Scotland and a Member of the North East Coast Institution of Engineers and Shipbuilders. He died on the 10th July 1950.

William Waddell (Associate 12355) was born in 1882 and educated at Paisley. He served his apprenticeship with Messrs. George Robertson and Sons, Paisley, and in 1902 he joined the staff of Messrs. Estler Bros., Canning Town, Engineers and Steel Equipment Manufacturers. He remained with that firm until 1919 attaining the position of Manager. In 1919 he formed the company Waddell's Stratford Steel Equipment Ltd., being a founder-director. In 1933 Mr. Waddell was made a Freeman of the City of London. He was elected an Associate of the Institute in 1949. He died in February 1950.