Transactions of the INSTITUTE of MARINE ENGINEERS

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Patron: HIS MAJESTY THE KING

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Minutes of Proceedings at the Fifty-seventh Annual General Meeting, March 8th, 1946.

Chairman : Mr. W. LYNN NELSON, O.B.E. (Chairman of Council).

The fifty-seventh Annual General Meeting of the Institute was held at the Connaught Rooms, Great Queen Street, London, on Friday, March 8th, 1946, at 11.30 a.m. Mr. W. Lynn Nelson, O.B.E. (Chairman of Council) was in the Chair, and was supported by Mr. J. A. Rhynas (Vice-Chairman of Council), Mr. A. Robertson, C.C. (Honorary Treasurer) and Mr. B. C. Curling (Secretary).

The Chairman, opening the proceedings, said it was right and proper before turning to the business of the meeting that he should explain why he was occupying the Chair. He felt sure that the Council and all the Members present would learn with deep regret that their highly-esteemed President, Sir William Crawford Currie, would be unable to be present at the meeting due to indisposition. It was the earnest wish of them all that Sir William would speedily be restored to good health. The Chairman then read a letter which he had received from the President as follows :—

"Dear Mr. Lynn Nelson,

I am very sorry I am unable to be present on Friday at the meeting and at the Luncheon, for I have been advised to stay off for some days.

I would wish, however, to thank you and the Members of Council most gratefully and sincerely for the great honour you have done me in having me as your President in this year just finishing. It has been a great privilege, particularly to one like myself who is a layman in all matters appertaining to engineering. Thank you very much indeed.

Yours sincerely,

(Sgd.) William C. Currie".

Mr. T. A. Crompton interposed to suggest that the sentiments of the meeting be conveyed to the President.

Mr. A. Robertson (Hon. Treasurer) proposed that Mr. Crompton's suggestion be adopted by sending a telegram to the President forthwith. Mr. F. W. Youldon (Vice-President) seconded this proposal, and the following telegram was sent to the President :—

"Members assembled at opening of Annual General Meeting unanimously resolved to convey this expression of regret at your indisposition and best wishes for your speedy recovery.

Nelson, Chairman".

The Chairman then requested the Scrutineers to retire and examine the voting papers for the election of Officers and Members of Council, and to report to him the result of the ballot for announcement later in the meeting.

Annual Report.

The Secretary (Mr. B. C. Curling) then read an abstract of the Annual Report (see page ix).

Financial Statement.

The Honorary Treasurer, in presenting the Financial Statement (see page xx), said :—

"The Auditors' Certificate attached to their accounts reads as follows :

'We have verified the Investments and Bank Balances and have inspected the Insurance Policies and Title Deeds, and we have obtained all the information we have required. In our opinion the Balance Sheet of your Institute has been properly drawn up so as to exhibit a true and correct view of the Institute's affairs according to the information and explanations given to us and as shown by the books of the Institute'.

Copies of the Auditors' report, in which will be found detailed those items showing increases or decreases during the past year, are before the meeting.

Whilst our headquarters were evacuated to High Wycombe for the period of the war, certain additional expenses were incurred, covering rent, rates, etc.; these will now be eliminated. As we only returned to the London premises in May, a proportion of the rent, rates and taxes for the High Wycombe premises is covered in our accounts for the period under review. We may, I think, congratulate ourselves that the costs involved through our evacuation to High Wycombe have proved to be very reasonable.

I would draw your attention to the following items in the accounts and will deal first with revenue.

Revenue.

The increase in membership is reflected in very considerable increases in subscriptions from Members, Associates, Graduates and Students, amounting respectively to £436 17s. 10d., £233 13s. 10d., £18 10s. 7d., and £34 1s. 8d., making a total increase of £769 17s. 8d., less subscriptions in advance which bring the total increase down to £628 3s. 1d. Entrance fees are increased by £28 10s.

INCOME FROM ADVERTISEMENTS continues to increase in spite of the fact that we have fewer pages in the Transactions and smaller individual space for each advertiser, the increase on the previous year being £104 9s. 9d.

RENT RECEIVABLE : The amount of £59 13s 9d. for part of the ground floor and first floor covers a portion of the year to the time when the premises were given up by the Home Guard. During the coming year the rent will be £125 for the basement only.

INTEREST : The dividends received are in all cases the same as last year with the exception of the 3% Savings Bonds 1960/1970, which show the interest for a full year of £270. It will be remembered that reference was made in my report last year to the sale of £6,000 5% Conversion Loan. This was invested in 3% Savings Bonds 1960/70. We now hold £9,000 of this stock.

Expenditure:

POSTAGES AND TELEGRAMS are up by £40 15s. 8d.

EXAMINATION EXPENSES are considerably lower, from £111 17s. last year to £23 0s. 1d. this year, and the cost of Lloyds' Register Scholarship of £24 11s. 9d. last year does not recur this year owing to this Scholarship being suspended for the time being. We hope it will soon be possible for this Scholarship to be resumed.

AWARDS EXPENSES appear for the first time in the sum of £23 4s. These are now being charged to revenue instead of against income from Awards, thus leaving the total revenue from the various Awards available for distribution as prizes.

We have printed a List of Members for the first time since 1939. This has involved a cost of £176 16s. 11d.

STATIONERY AND GENERAL PRINTING, as might be expected, is very considerably increased, having gone up from £145 17s. 11d. to £237 6s. 11d., an increase of £91 9s.

STAFF SALARIES AND CLERICAL ASSISTANCE are virtually the same. During the coming year this item will go up considerably, due to increase in Staff, the return of Mr. Lambert, and increased salaries.

AFFILIATION SUBSCRIPTIONS, ETC., cover contributions to the following :—

	£	s.	d.
British Electrical and Allied Industries Research Association	31	10	0
British Society for International Bibliography ...	2	2	0
Parliamentary and Scientific Committee (2 years)	21	0	0
British Standards Institution	3	3	0
Joint Committee on Materials and their Testing of Technical Institutions and Societies in Great Britain	1	1	0
Association of Special Libraries and Information Bureaux	3	3	0
British Non-Ferrous Metals Research Association	25	0	0

SUNDRIES : £297 16s. 4d. includes Christmas gratuities to the Staff, sundry travelling expenses, an illuminated register of Honorary Members, removal of furniture, etc., from High Wycombe premises to the Minories, and a number of various smaller items.

RENT, RATES, ETC. This item of £551 13s. 3d. is lower as compared with £597 4s. 5d. last year, but includes £110 4s. for the rental of premises at High Wycombe up to the end of July, when this ceased.

HOUSE ACCOUNT : Staff wages are higher from £359 17s. 8d. last year to £468 8s. 11d., owing partly to our now having an assistant caretaker on the premises; there is also an increase in cost of coal and other items on this account.

REPAIRS : This item shows an increase from £161 17s. 2d. to £236 11s. 11d., and covers the cost of clearing the sand from the roof, renewing and cleaning gutters and downpipes, cleaning up the Lecture Hall and making it ready for use, and a number of small items.

INSURANCE: War Damage Insurance is eliminated, but in spite of this the cost of insurance is heavier, from £27 15s. to £48 5s. 3d., due to the fact that we have had to increase the amount of insurance on the premises at the Minories, owing to increased replacement value.

TRANSACTIONS: Hitherto the total of the figures shown under this heading has been arrived at after deducting the proceeds from sales of Transactions. This year we have shown the total cost of the Transactions at £3,050 6s. 4d. as compared with £2,906 10s. 4d. last year; after deducting the proceeds of sales amounting to £347 6s. 8d., the final figure is £2,702 19s. 8d., being a reduction as compared with last year of £203 10s. 8d.

RESERVE FOR REPAIRS AND RENEWAL OF PREMISES: £1,000 has been put aside for this purpose, as has been done in the previous three years.

The final result of the Revenue Account shows a credit balance of £1,553 2s., as compared with £670 5s. 9d. last year, and this is carried forward to the balance sheet.

Balance Sheet.

Life Subscriptions are up to £231 as against £126 last year.

It will be noted that the Award Funds, from the Sir Archibald Denny Award down to the Lord Inverforth Award, have only the capital amounts shown in each case. The accrued and current interest on these capital amounts are given separately lower down, and show a balance of £111 15s. 6d. They are being dealt with in this way, because under present arrangements combined awards are being made by the Council each year in the names of the donors collectively. This has been done owing to the difficulty of administering so many separate awards. We do, however, preserve the names of the donors in our accounts each year.

The publishing of the three books, *viz.*: "Running and Maintenance of Marine Machinery", "Electricity Applied to Marine Engineering", and "Naval Architecture and Ship Construction" has shown very excellent results, the total amount standing to the credit of these three publications in our balance sheet amounting to £642 15s. 4d.

SOCIAL EVENTS ACCOUNT: This has a substantial balance of £317 3s. 1d. A part of this will no doubt be allocated by the Council to the Guild of Benevolence.

RESERVE FOR REPAIR AND RENEWAL OF PREMISES: It will have been noted from my observations on the Revenue Account that £1,000 has been set aside, bringing the total figure for this reserve up to £4,000.

PENSIONS FUND: This has been increased by £100 during the year and will be further increased at the next meeting of the Council.

The balance of £1,553 2s. brought forward from the Revenue Account brings the Capital Account to £36,675 9s.

INVESTMENTS: Last year the accounts showed £2,800 3½% War Loan. This has been reduced by £100, the amount invested under the Lord Inverforth Award, which is shown later under "Investments—Awards".

As will have been noted from the Auditors' printed report, we have invested during the past year £3,500 in 3% Local Loans, bringing our total of investments to £25,408 18s. 8d., with a market value of £25,730. This was on the 31st December, 1945. Since then the £200 Bank of England Stock has been realised, and we now hold £800 Government Stock at 3 per cent. as against £703 17s., the purchase value shown in these accounts.

NEW PREMISES FUND BANK ACCOUNT £142. A separate account has now been opened, and in future this will be treated separately.

FURNITURE: An item of £55 shown under his heading relates to the purchase of an additional Kardex cabinet.

STOCK OF PUBLICATIONS: These are now running low, and further editions of the three books are being prepared.

GUILD OF BENEVOLENCE: The Auditors have not yet completed these accounts owing to pressure of work, but some approximate figures can be given. The Capital Account has been increased by £625 2s. 11d., including Life Subscriptions and donations, the latter amounting to £456 12s. 11d., which includes an amount of 50 guineas received from Messrs. Chadburns, Ltd. This brings the Capital Fund to approximately £25,143 19s. 5d., to which has to be added the John H. Silley Memorial Fund. This Fund has been increased by £2,250, the amount of the covenanted subscriptions from Mr. H. A. J. Silley and Mr. Bernard Silley and recovered Income Tax thereon. The total Capital Fund, therefore, will now be approximately £41,893 19s. 5d. The total received on account of revenue from all sources has been £2,555 14s. 9d., an increase of £560 12s. 10d., and includes subscriptions £379 13s. 10d. and donations £330 (including £250 from King George's Fund for Sailors). The balance comes from dividends and ground rents.

The total amount spent on relief during the period was £1,571 11s. 6d., an increase on the previous year of over £200.

The figures given above may be slightly altered as they are subject to audit.

Marine Engineers' National War Memorial.

Mr. Curling has already referred in his report under the heading of "New Premises" to the decisions of the Council confirming the recommendations made by our President, Sir William Currie, and the Committee. For the information of the Members of the New Premises Committee, as well as those gentlemen whom the President approached with a view to having their names added as signatories to the appeal, I would like to say that one of our Past Presidents suggested that the appeal, as first drafted, was too academical, that it should be phrased in simpler language and aimed at the public as well as ourselves to make it a truly national memorial, with a more human touch. There was no time to call a Committee meeting and I had recourse to an experienced journalist to whom I gave the necessary information, resulting in the appeal letter being couched in totally different language but incorporating all the points contained in our original letter. This was submitted to our President and some Members of the Committee, receiving their full approval. These appeal letters were all posted yesterday morning and most of those present will have received a copy by this time, from which you will note it is supported by several of our Past Presidents and many influential gentlemen.

I note that one of our friendly journals in their desire to anticipate this meeting reported the amount received from those names included in Mr. Curling's report the sum of £142; this should have been £242, as £100 was received early this year and is not included in the 1945 accounts.

I must express on behalf of the Council and my Committee deep gratitude to our President, Sir William C. Currie, for all the assistance he has given and the keen interest he has displayed in this project—one which we hope will prove to be of wide national interest—and also for launching the appeal on the occasion of his Presidential Address. Further to tender our thanks to Mr. H. A. J. Silley for his very able advice and assistance.

The Council hope that there will be an immediate and generous response, and that the target aimed at will be very quickly attained.

It was quite impossible to include all the details and ideas which we hope will ultimately be incorporated in the proposed building. Members may have ideas to put forward, and it is suggested that they do this in writing. They will then all be considered at the appropriate time.

The Institute of Marine Engineers is without doubt the right and proper authority to establish a Memorial of this kind to all our members and other marine engineers who have given their lives for the very existence of Great Britain and the British Commonwealth of Nations.

The appeal will be energetically pressed during the coming months, and I hope to be able to report at our next Annual Meeting very substantial progress towards the attainment of our target of £100,000".

Adoption of Report and Accounts.

Mr. C. R. Hutchinson (Member), moving the adoption of the Report and Financial Statement, said that it was usually something of a sinecure to undertake this task, but he would like to make one or two observations.

First of all, they must congratulate themselves on the increase in membership which was largely responsible for the very satisfactory financial position detailed by Mr. Robertson. These were very healthy signs.

He must express regret that no Denny Gold Medal had been awarded this year. Members must get on their toes in time for next year's award.

Further efforts should be made, he felt, to get the Junior Section into a more active state, and the junior members should be urged to submit more papers and essays. Regarding essay awards, members would be in agreement with the policy of making the prizes worth while. The explanation of the shortage of essays was like that of the shortage of junior engineers—pay well and they would be forthcoming!

The most exciting item in the Report was that relating to the new premises. This was a golden opportunity to do something useful in memory of the marine engineers who lost their lives during the recent war. The project which the Council had put forward was ambitious, but could, no doubt, be achieved. He thought that many members would send in helpful suggestions on this matter.

He thought that the figure of £643 representing donations to the Guild of Benevolence was disappointing, in view of the Institute's large membership. It was up to members to do better than this.

The reference to the Merchant Navy Training Board was very interesting, but suggested remissness on the part of someone in that the Institute was not brought into the matter in a proper manner. It was highly satisfactory to note that some of the Institute's recommendations had been accepted.

The reports of the various representatives were indicative of a labour of love, and the gratitude of members to these gentlemen should be recorded. He himself had served on some of the Institute's Committees and so had some idea of the arduous work that was entailed. Their thanks were also due to Mr. Robertson for the very considerable duties he undertook in guiding the financial affairs of The Institute, and they all knew what a great deal they owed to Mr. Curling.

It was with much pleasure that he now formally moved the adoption of the Report and Financial Statement.

Mr. R. K. Craig (Member) said that Mr. Hutchinson had carefully reviewed the past year's work and had left him nothing to do other than, in formally seconding the adoption of the Report and Financial Statement, to endorse heartily his remarks.

The Chairman, before putting the motion to the meeting, invited further comments on the Report and Accounts.

Mr. T. A. Crompton, as a Member of the Committee of the Guild of Benevolence, referred to the profit on publications of approximately £400, and expressed the hope that a large proportion of that sum would be allocated to the Guild of Benevolence.

The Honorary Treasurer (Mr. A. Robertson) said that this suggestion would receive due consideration at the next meeting of the Council.

Mr. Crompton then referred to the Pension Fund. He noted that the Staff had increased as had the Membership, but the allocation to the Pension Fund had been decreased as compared with the previous year.

The Honorary Treasurer explained that this was due to the fact that the figures for the two years were overlapping.

Mr. Crompton said that he would like to propose to the meeting that the amount allocated to the Pension Fund be increased to £200 and, further, that as this Fund in a sense belonged to the Staff it be treated as a separate account in which could accrue the interest earned from investment of the moneys.

The Honorary Treasurer, replying, said that this was a matter of considerable interest to the Staff and to the Members, but it had to be borne in mind that however much it was possible to increase the Pension Fund (it now stood at £400) it was bound to be quite inadequate. When the time came for any member of the Staff to retire, it was for the Council to decide upon any increased pension over that which it had been possible to cover by the existing insurances. and any such increases would have to be met out of revenue. Whatever the Pension Fund amounted to, it was unlikely to be sufficient to meet the demand in such an event. His personal view was that the fund might well be abolished as the revenue would have to meet any large sums demanded of it later. The pension policies carried the provision of a definite amount payable on the death of an employee. This was a benefit which they, as an Institute, would find required an enormous sum to carry, and was not a burden which they could undertake by means of a Pension Fund. He really did not see that there was any object in going against the Council's carefully considered decision.

Mr. Crompton pointed out that if the Pension Fund was increased sufficiently it could obviously meet all requirements. He felt that Members would certainly agree that the Fund should not be abolished. He added that he was only putting forward a recommendation as coming from the present meeting to the Council for consideration, and expressed his satisfaction when the Honorary Treasurer assured him that the matter would be duly considered at the next meeting of the Council.

The Chairman then submitted the motion that the Report and Financial Statement be approved and adopted, and this was carried unanimously.

Presentation of Awards.

The Chairman, turning to the next item—the Awards to be presented for 1945—said that the striking of medals was still not permissible, but they would be provided in due course. As stated in the Annual Report, the Denny Gold Medal had been withheld, but the Institute Silver Medal had been awarded to Mr. J. H.G. Monypenny for his paper "Stainless Steels for Turbine Blading". In presenting the diploma to Mr. H. Allsop, representing Mr. Monypenny, who could not be present due to illness, the Chairman expressed the sympathy of the meeting with Mr. Monypenny and their earnest hope for his recovery.

Mr. Allsop, responding, said that everyone would feel regret that Mr. Monypenny was unable to receive the Institute's award in person. The paper for which the award had been made was written by Mr. Monypenny and completed before he was taken ill, and there was therefore no question that it was entirely his work and the credit for it was solely his.

As a colleague of Mr. Monypenny's, he could say that those who had known him a long time had always had a very high regard for him, and in fact his reputation as an authority on stainless steels was international. The present occasion was therefore a further recognition of his valuable work, and one of which he would be very highly appreciative had not this most unfortunate illness occurred. He would be most gratified by the honour the Institute had accorded him, and he (Mr. Allsop), had much pleasure in accepting the award on his behalf and thanking the Institute as he knew Mr. Monypenny would wish. Mr. Monypenny was still seriously ill, and it might be that he was in no condition to appreciate this occasion. The certificate would be passed on to Mrs. Monypenny, who would derive some small comfort, in these unfortunate circumstances, from the knowledge that Mr. Monypenny was held in such high esteem.

The Chairman then presented to Professor S. J. Davies, D.Sc., Ph.D., on behalf of Dr. M. I. Fawzi and himself, the diploma of the Herbert Akroyd Stuart Award for their paper entitled "Development, Principles and Application of the Combustion Turbine". The presentation was received with acclamation, and Professor Davies suitably responded.

As Mr. M. W. Sydenham (Associate), the winner of the W. W. Marriner Memorial Prize, and Messrs. D. Bruce and P. L. Gaches, the winners of awards for essays, were unable to be present, their awards were being forwarded to them by post.

Vote of Thanks to Retiring President.

The Chairman said that his next duty—a very pleasing one—was to move a vote of thanks to their retiring President, Sir William Currie.

On behalf of the Council, Vice-Presidents and Members, he expressed their deep appreciation of the keen interest displayed by their President, and of the excellent work he had carried out during his year of office. He referred particularly to Sir William's work in connection with the Marine Engineers' National War Memorial Building Fund Committee, and how fully they recognized and appreciated his efforts in this direction. It would be recalled that Sir William launched the initial appeal on the occasion of his Presidential Address on October 9th last, and they were very grateful to him for this and for the unstinted, wholehearted support of the scheme which he had subsequently displayed.

On taking office, Sir William had expressed the hope that victory would be achieved before his presidential term expired. His hope had been realised, but they were all fully aware of the burden entailed by his extra duties as President of the Institute in the light of the heavy, multifarious responsibilities already shouldered by him in his high position, which, of course, were intensified beyond measure by the prevailing conditions.

He, therefore, on behalf of the Council and Members, expressed to their retiring President their very sincere thanks for all he had done. (Applause).

Mr. J. A. Rhynas (Vice-Chairman of Council) seconded the proposal, which was carried with enthusiastic applause.

Report of the Scrutineers.

The Chairman next presented the Report of the Scrutineers (Messrs. G. B. Plows and C. J. Hampshire) on the ballot for the election of Officers and Members of Council, which showed that the following had been elected :—

As President for Session 1946-47 :
Sir Amos Lowrey Ayre, K.B.E.

As Vice-Presidents for Sessions 1946-49 :
London : S. F. Dorey, C.B.E., D.Sc.. Wh.Ex., R. S. Kennedy, A. H. Mather, A. R. T. Woods.

Cardiff: A. W. Loveridge, B.Sc.
Swansea: Major E. W. B. Kidby, O.B.E., R.E. (ret.).
Newcastle: W. Hamilton.
Manchester: A. P. Traill, O.B.E., Wh.Ex.
Aberdeen: W. P. Hunter.
Belfast: W. E. McConnell.
Royal Navy: Eng. Vice-Admiral Sir J. Kingcome, K.C.B.
Merchant Navy: N. L. Wright, A. J. Harding, O.B.E.
Sydney: A. J. McCowan.
Melbourne: R. Stark.
Buenos Aires: D. H. Nicholson.
Singapore: *F. G. Ritchie.
Rangoon: *W. A. Harrington.
*Dependent on these Vice-Presidents returning to Singapore and Rangoon respectively.

As Honorary Treasurer for Session 1946-47:
Alfred Robertson, C.C.

As Members of Council for Sessions 1946-49:
T. A. Bennett, B.Sc., R. K. Craig, H. S. Humphreys, S. A. Smith, M.Sc., E. Souchotte.

As Associate Member of Council for Sessions 1946-49:
A. C. Hardy, B.Sc.

Induction of the President.

The Chairman said that his next duty found him in a rather paradoxical frame of mind in that while he was extremely sorry that Sir William Currie could not be present to induct their new President, he himself felt immensely pleased and privileged to do so, particularly as Sir Amos was a distinguished Dunelmian and he (the Chairman) had first seen the light of day in that kindred county Northumberland.

There was no need to elaborate on the outstanding capabilities, merits and activities of Sir Amos Ayre. Everyone connected with the shipping industry was, to some extent, conversant with the work he had carried out for the Admiralty during the 1914-1918 war, and above all the tremendous responsibility which he took on in 1939 and held until 1940 in his post of Director of Merchant Shipbuilding and Repairs, and later as Director of Merchant Shipbuilding throughout those most anxious years 1940-1945. They could not assess the full extent of his task and its responsibility, but some day it might be revealed. Meanwhile, most of them could appreciate what a burden he had carried at the time when the production of merchant ships of all sizes and types was of vital importance to this nation and a decisive factor in the success of the Allied cause.

The Members, as engineers, welcomed Sir Amos as a highly esteemed shipbuilder, and he (the Chairman) would assure him of the loyal support of all Members of Council and Officers of the Institute. Sir Amos's nomination by the Council had been unanimous, as also had been his election, and he could be sure that they would all endeavour to make his term of office a pleasant experience.

The Chairman thereupon invited Sir Amos to occupy the Presidential Chair and preside over the meeting to its conclusion.

Sir Amos L. Ayre, K.B.E., on taking the Chair to the accompaniment of loud applause, thanked the meeting for their response to Mr. Nelson's very kind remarks.

He asked them to believe that it was no mere formality when he said that he looked upon his induction as President as a very high honour indeed. He had not accepted the Council's kind invitation to accept nomination for the Presidency because he had a lot of spare time on his hands, but one of the reasons which had moved him to do so was that it would give him an opportunity to come into even closer contact with marine engineers.

The duties carried out by him during the war, to which Mr. Nelson had referred, were carried out with the help of a very small staff indeed, and it had only been made possible by the good feeling which existed at all times, even when there were risks of misunderstandings regarding features that could not be fully divulged. It very often happened that, directly or indirectly, he had had to enlist the help of marine engineers, and many useful jobs had been done by consultation. He had often wondered whether he would ever have an opportunity to thank the profession, and he therefore welcomed the present opportunity of expressing his gratitude. He thanked them all, because directly or indirectly everyone had played a part in the war production.

He would also confess to having accepted nomination with some feeling of temerity, because they were all highly skilled marine engineers, and he came to them as a shipbuilder. All his life he had tried to keep pace with their work, but a recent visit he had paid to the engine room of a modern ship had caused him to cast his mind back to what it would have been 40 years ago, and to reflect how complicated indeed had become marine engineering. He would have to study their papers more closely than ever.

With that excuse for his shortcomings in their profession he would only add the earnest assurance that his duties in the office of President would receive the fullest attention possible. He looked forward to a very happy term of office, particularly in view of the Chairman's encouraging promise that he could anticipate their wholehearted co-operation.

Finally, he would like to say that it had caused him a feeling of great regret that Sir William Currie could not be present, due to illness. For a large number of years he had been associated with Sir William in various activities of a public and semi-public character, and he held him in very high esteem.

Mr. A. H. Mather, moving a vote of thanks to the Scrutineers (Messrs. G. B. Plows and C. J. Hampshire) and their reappointment for the ensuing year, said that they had carried out their duties again this year with that commendable efficiency which had marked their work in this office for, he believed, the whole of the war period.

The proposal was seconded by **Mr. T. A. Crompton** and carried unanimously.

Vote of Thanks to the Council and Officers.

Mr. R. J. Welsh (Member) said that his duty was the last but not least item on the agenda, namely, to propose a vote of thanks to the Council and Officers.

The Council and Officers deserved to be congratulated on a great many things, such as the growing membership, their initiative displayed in being the first to resume their social functions, the high standard of the papers, and not least for the great amount of time they had obviously devoted to their duties. Everyone was pressed for time these days, and it meant more than it had in the past. On behalf of all the members, therefore, he would express their great appreciation of the efforts of the Chairman, the Vice-Chairman, the Honorary Treasurer, the Secretary and all the other Officers who had contributed to the excellent results of the year's work which had been brought to their notice that day.

Mr. S. B. Freeman, C.B.E., M.Eng. seconded the proposal, which was carried with loud applause.

Mr. W. Lynn Nelson, O.B.E. (Chairman of Council), replying, said that during the tenure of his office, now coming to a close, there had been many and varied questions discussed by the Council, some of them of vital importance to the interests of the Institute and to the marine engineering profession generally. Decisions had been taken, and he would assure members that the Council in making these decisions on their behalf had acted in accordance with their firm determination to uphold the terms of the Royal Charter and the welfare of the Institute.

Although many Members of Council had found the duties of their responsible positions during the past year a great tax on their energy, and they had had little time for diversion or leisure, they had conscientiously attended the Council meetings, and had given him most generous support, for which he was duly grateful. If a Member of Council was ever absent, then one could rest assured that the reason was beyond that Member's control. He could apply the same remark to the various Committees.

As they had heard from the report, the Institute continued to go steadily forward from strength to strength, and this was due in no small measure to the interest and services rendered by the members who took office. Moreover, one must fully realize the excellent work carried out by the Honorary Treasurer, Mr. Robertson, and the Secretary, Mr. Curling, and his staff. He would take this opportunity to record his personal thanks for their efforts which had made his duties so much easier.

On behalf of the Council, the Members of Committee, the Secretary and the staff, he would express sincere thanks to the meeting for their mark of appreciation of the work done during the past session. He would also avail himself of this opportunity to renew his wish that Sir Amos Ayre would have a happy and interesting term of office as President.

The President then declared the proceedings terminated.

Annual Report of the Council

In their retrospect of 1945, the Council, in common with their fellow members of the Institute who have been intimately associated with the past six years' war effort, rejoice in the triumphant achievement of the greatest task that has ever befallen the British Commonwealth and the Allied Nations.

The part which fell to marine engineers in both the maintenance and defence of sea transport has been most creditably carried out. Their rôle in the transition to peacetime requirements within the framework of the emergent new world order will hardly be less exacting. On their behalf the Institute must not fail to keep its position in the forefront of marine engineering scientific and technical development which it has consistently held up to the present.

Membership.

The changes in the membership, recorded in the accompanying table and chart, show an increase of 267 in the aggregate.

An up-to-date list of members was published in October.

Grade.	1st Jan., 1945.	Transfers From.	Transfers To.	Elected.	Died.	Resigned.	Lapsed.	Total 31st Dec., 1945.
Past Presidents ...	12				1			11
Honorary Members	3				1			2
Members	3,096		34	180	37	22	69	3,182
Companions ...	41	1		3				43
Associate Members	348	9	4	15	1		9	348
Associates	787	25	9	151	5	6	15	896
Graduates	99	6	3	29		1	3	121
Students	97	9		65		1	5	147
Totals ...	4,483	50	50	443	45	30	101	4,750

Obituary.

The losses by death are recorded at the end of this Report. The sympathies of the Council and members are extended to the relatives in their bereavement.

The Council especially regret the deaths of Engineer Vice-Admiral Sir George G. Goodwin, K.C.B., LL.D. (President 1922/3), and Mr. George Heron (formerly Vice-President for Singapore).

Council.

At the meeting of the Council held on 20th March, Mr. W. Lynn Nelson, O.B.E., was elected Chairman of Council and Mr. J. A. Rhynas, Vice-Chairman for the 1945/46 Session. Mr. S. A. Smith, M.Sc., the immediate Past-Chairman, was co-opted to serve on the Council for the Session.

Vice-Presidents.

Sunderland.—Eng'r. Com'r. A. J. Berry, R.N.(ret.), was elected to succeed Mr. F. H. Reid on his return to London.

San Francisco.—Mr. F. G. Archbold was re-appointed to succeed Mr. C. E. Petersen (deceased).

Wellington, New Zealand.—Mr. R. L. Gillies was elected vice the late Mr. D. K. Blair.

Calcutta.—Mr. J. Routledge was elected to succeed Mr. C. S. McCaskie on his retirement and return to this country.

Representation of the Institute on Outside Organisations.

Engineering Joint Council.

The Council, at their February meeting, unanimously decided that the Institute should withdraw from constituent membership of the Engineering Joint Council.

Parliamentary and Scientific Committee.

Mr. S. A. Smith was appointed as an *additional representative of the Institute on this Committee, in succession to and in the same capacity as Mr. R. Rainie (retired).

Lloyd's Register of Shipping: Technical Committee.

Mr. H. S. Humphreys was elected to succeed Mr. Sterry B. Freeman as the Institute's representative on this Committee, upon Mr. Freeman's retirement in June last.

*To Mr. H. S. Humphreys.

British Standards Institution.

Solid Fuel Industry Committee:

SF/1, Nomenclature and Definitions for Solid Fuel Burning Appliances.

SF/1/2, Steam Generators and Boilers.

Mr. W. Dowling was appointed to succeed Mr. E. W. Green, as representative on the above Committees, on the latter's retirement.

Technical Committee ME/94, Revolution Indicators.

Dr. R. A. Collacott was appointed as representative of the Institute on this newly-formed Committee.

Technical Committee ME/81, Dimensional Standardisation of Valves: Sub-Committee on Valves for Steam.

Mr. H. Scott was appointed to represent the Institute on the above Committee.

Technical Committee on Fans.

Mr. J. K. MacVicar was appointed to succeed Mr. T. A. Bennett on his retirement from this Committee.

Committee on Standardisation of Pressure Gauges.

Dr. R. A. Collacott and Mr. A. R. Mann were appointed to represent the Institute on this newly-formed Committee.

Papers.

The following papers have been published in the Transactions during 1945, those marked * after reading and discussion:

Issue.	*Subject.*	*Author.*
January.	*Development, Principles and Application of the Combustion Turbine.	Professor S. J. Davies, D.Sc., (Eng.), Ph.D., M.I.Mech.E., and M. I. Fawzi, Ph.D. A.M.I. Mech.E.
February.	*The Fundamentals of Ship Form.	F. H. Todd, B.Sc., Ph.D., M.I.N.A.
March	*Light Alloys for Marine Engines.	A. J. Murphy, M.Sc.
April.	The Steam Jet Air Ejector.	W. P. Scott, B.Sc.
May.	The Design and Production of Pressure Gauges.	R. A. Collacott, Ph.D., B.Sc.(Eng.).
July.	The Proper Care of Lubricating Oil in Service.	Marine Lubricants Committee of the Petroleum Board.
August.	The Failure of Auxiliary Diesel Engine Connecting Rod Bolts. A Survey of Cause and Prevention.	Messrs. W. S. Burn, J. Calderwood and H. J. Wheadon.
September.	Bulk Oil Measurement.	E. Stokoe (Member, Institute of Petroleum).
October.	*The Operation of Water-Tube Boilers at Sea.	Major W. Gregson, M.Sc.(Eng.). M.Inst.C.E., M.I.N.A., M.I.Mar.E.
November.	The President's Address.	Sir William C. Currie.
	The New Atlas Diesel Fuel Injection System for Diesel Engines.	H. T. Pyk (Member).
December.	*Stainless Steels for Turbine Blading.	J. H. G. Monypenny, F.Inst.P.

Institute Awards.

The Denny Gold Medal, for the best paper contributed by a Member during 1945. On the recommendation of the Committee of Adjudicators the Council have decided to withhold the Award of the Medal on this occasion.

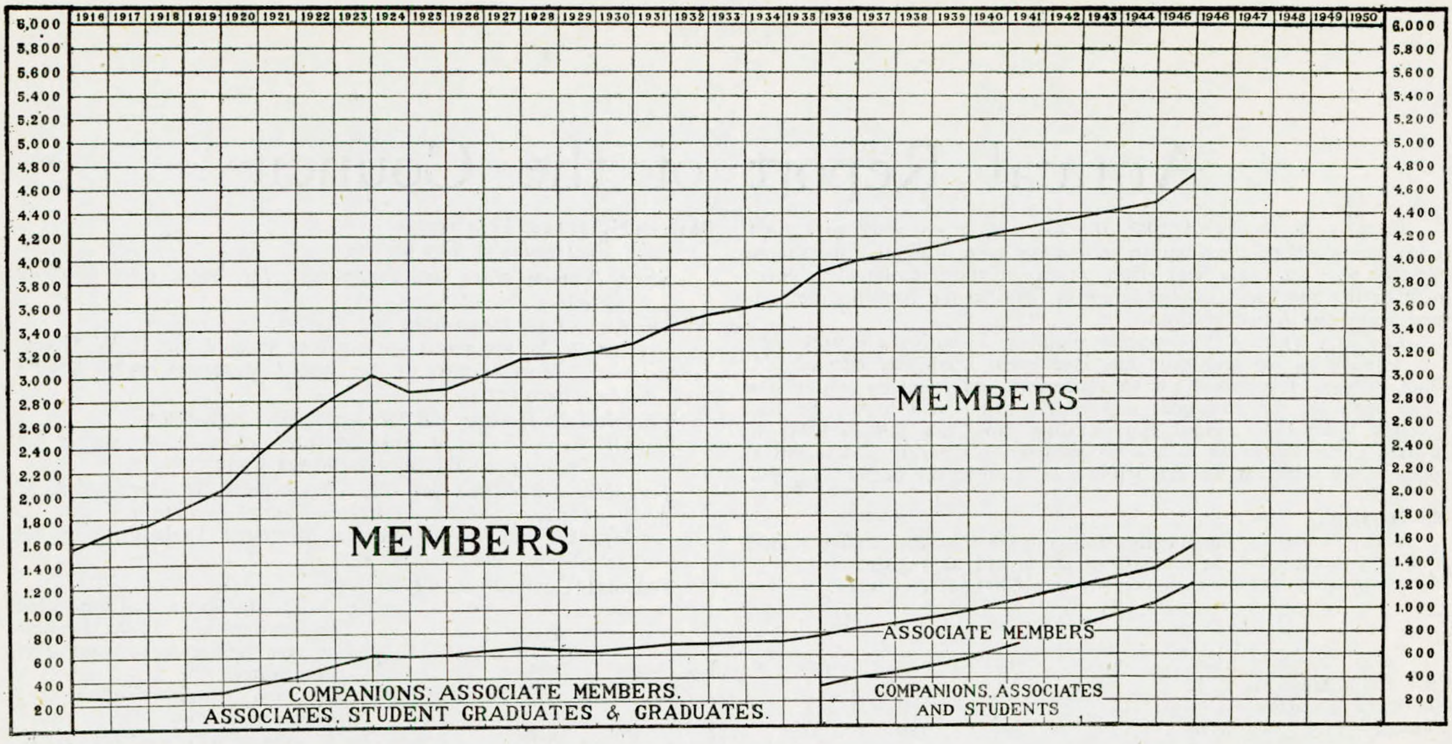

Chart of Membership.

The Institute Silver Medal, for the best paper contributed by a non-member during 1945, has been awarded to Mr. J. H. G. Monypenny, F.Inst.P. for his paper entitled "Stainless Steels for Turbine Blading", published in the December TRANSACTIONS.

The Junior Silver Medal and Premium. No paper was contributed by a junior member during 1945.

The Herbert Akroyd Stuart Award, value £50, for the best paper on the history and development of heavy oil engines contributed by a member or a non-member during the two years ending on the 30th April, 1945. This Award has been conferred jointly upon Professor S. J. Davies, D.Sc., Ph.D., and Dr. M. I. Fawzi, for their paper entitled "Development, Principles and Application of the Combustion Turbine", published in the January, 1945 TRANSACTIONS.

An additional award of £25 from this Fund was granted to Mr. J. W. Armstrong for his paper entitled "Heavy Oil Engine Progress", published in the October, 1944, TRANSACTIONS.

The W. W. Marriner Memorial Prize, value £5, for the best Engineering Knowledge script written by a candidate in the Ministry of War Transport's 1945 Examinations for the Second Class Engineer's Certificate of Competency, has been awarded, on the recommendation of the Ministry's Chief Examiner of Engineers, to Mr. Michael Wyndham Sydenham (Associate).

Thames Nautical Training College, H.M.S. "Worcester".

The Institute's Prize, value £2 2s., for excellence in Marine Engineering, was won by Cadet J. E. Robinson.

Awards for Essays.

With a view to stimulating competition for the prizes available from the various legacies, the Council decided to merge the accrued interest on these funds and to offer two Awards of £20 each, namely:

(a) for the best essay on any subject of marine engineering interest submitted by a Student or a Graduate; this prize to be provided out of the John I. Jacobs, W. Murdoch and D. F. Robertson funds;

(b) for the best essay on any subject of marine engineering interest submitted by a member of any grade (including Students and Graduates); this prize to be provided out of the Sir Archibald Denny, J. Stephen, and Lord Inverforth funds. Six entries were received, of which none was from a Student or a Graduate. On the recommendation of the Awards Committee the Council awarded a prize of £15 to Mr. David Bruce (Associate) for his essay entitled "The Future Training and Status of the Marine Engineer", and a prize of £5 to Mr. Peter L. Gaches (Associate) for his essay entitled "Some Points on the Layout and Installation of Marine Machinery".

Institute Prizes for Students of Technical Colleges in Marine Centres.

The Institute's Annual prizes, increased to £2 2s. each, for students accomplishing the best year's work in Heat Engines at technical colleges and schools in marine centres were awarded as follows:—

Leslie Reid Forrest, Dundee Technical College.
George William Parsons, Cardiff Technical College.
Leslie Albert Darby, West Ham Municipal College.
Mark Alan Stephenson, Plymouth and Devonport Technical College.
John Steenson, Belfast College of Technology.
John Hutton Neilson, Royal Technical College, Glasgow.
Kenneth Maurice Batley, Hull Municipal Technical College.
Allan Robinson, Liverpool Technical College.
William High Schofield, Constantine Technical College, Middlesbrough.
Walter Alan Rowley, West Hartlepool Technical College.
Brian Fenwick, Sunderland Technical College.
Henry Watson, Rutherford College of Technology, Newcastle-upon-Tyne.
David Newman Jones Cole, Portsmouth Municipal College.
Stanley Henderson, Senior Technical Institute, Gateshead.
John Noble Strachan, Robert Gordon's Technical College, Aberdeen.
James L. Cheyne, Leith Technical College.
Brian Fenwick, Sunderland Technical College.
John Richard Harrison, The Polytechnic, Regent Street, W.1.
Kenneth Albert Setterfield, The Woolwich Polytechnic.
Derek Richard Field, University College, Southampton.
Andrew Beattie Scrimgeour, Greenock Technical College.
William George Collins, Birkenhead Technical College.
John Harrison, Marine School of South Shields.
Edward Francis Pimlott, Falmouth Technical School.
William George Munday, Swansea Technical College.

Lloyd's Register Scholarships.

The tenure of the three Scholarships awarded in 1940, 1941 and 1942 remains in abeyance pending the release of the holders from their respective war service.

National Certificates in Mechanical Engineering, with Special Reference to Marine Engineering.

243 Ordinary Certificates, 34 Higher Certificates and 3 Higher Diplomas were endorsed by our President during 1945.

Education Group.

On a recommendation passed at the first post-war Annual Meeting of the Group in June, the Council agreed to resume the Institute lectures at Universities and technical colleges during the winter session. With the concurrence of the Chairman of the Junior Section Committee, the following programme was arranged by the Executive Committee of the Education Group:—

Tuesday, November 20th, 1945, at Wimbledon Technical College: "The Value of Research to the Young Engineer", by R. A. Collacott, B.Sc., Ph.D. (Associate Member of Council).

Wednesday, December 5th, 1945, at the Polytechnic, Regent Street, W.1: "Precision Measurement", by H. Barrell.

Tuesday, January 29th, 1946, at South East London Technical Institute: "Applications of Welding to Marine Engineering", by H. N. Pemberton.

Friday, February 15th, 1946, at West Ham Municipal College: "Modern Trends in Water Tube Boiler Installations", by S. D. Scorer (Member).

The Council's prize, value 2 2s., for the best report on Dr. Collacott's lecture submitted by a Student under 25 years of age, was won by E. N. Grantham, and a consolation prize, value £1 1s., was awarded to S. W. White. Adjudication of entries received in respect of Mr. Barrell's lecture is pending.

The Group also held a meeting at the Institute on Friday, November 9th, 1945, at which Mr. F. H. Reid, B.Sc., Wh.Ex. (Member), Principal of South East London Technical College, gave an address on "The Education Act in relation to Technical Education". The address and discussion have been published in the January, 1946, TRANSACTIONS.

Junior Section.

Whilst the activities of this Section have remained in abeyance, Mr. E. W. Cranston, as a member of the Junior Section Committee, was co-opted by the Education Group Executive Committee to assist in arranging the above mentioned lectures at technical colleges.

Transactions.

The monthly publication of the TRANSACTIONS, including the marine engineering and shipbuilding abstracts, has been maintained during the year. An increase in the paper supply is eagerly awaited.

The Council wish to record their thanks to the authors of the papers and contributors to the discussions published in the TRANSACTIONS during 1945.

Publication of Books.

The three books published by the Institute—"The Running and Maintenance of Marine Machinery", Laws's "Electricity Applied to Marine Engineering", and Hogg's "Naval Architecture and Ship Construction"—have continued in steady demand. The second reprint of the last named book was received from the printers early in the year.

Premises.

The de-requisition of the City Premises by the War Office and their re-occupation by the Institute Staff took place in May. The lease of 73, Amersham Road, High Wycombe, was terminated at the end of July. The Lecture Hall was partially reconditioned and used for the first time post-war on the occasion of the Presidential Address on October 9th.

The hire of the Library has been permitted to the Engineer Surveyors' Association and the Omnibus Society for their meetings as before the war.

New Premises.

At their February meeting the Council decided to form a New Premises Committee, under the chairmanship of the Honorary Treasurer, Mr. A. Robertson, and that Mr. Robertson should nominate the members of this Committee. The Committee was duly constituted and appointed at the March meeting of the Council, the members being Messrs. J. D. Farmer, R. M. Gillies, W. D. Heck, J. C. Lowrie, W. L. Nelson, A. Pollitt, H. A. J. Silley, S. A. Smith, A. F. C. Timpson, H. J. Wheadon and F. W. Youldon.

At the October Council meeting, Mr. Robertson reported the results of the Committee's deliberations, and of subsequent consultation with the President.

The Council unanimously agreed:—

(i) that the new building should form a national memorial to the engineers of the Merchant Navy who had lost their lives during the war.

(ii) that the appeal should also make reference to the Diamond Jubilee of the Institute in 1949, by which date it was hoped that preparations for the erection of the new building would have been completed.

(iii) that the names of prominent men who agreed to support the appeal should be added to those of the President and other signatories to the appeal.

(iv) that Sir William Currie should launch the appeal on the occasion of his Presidential Address on October 9th.

The last-named decision was duly carried out; the other three proposals are now being implemented, with the kind assistance of the President.

Donations have already been received from Mr. Alfred Robertson, Mr. A. H. Mather, Mr. H. Y. Mosey, Mr. J. Y. Mosey, Mr. A. C. Hardy and the Todd Shipyards Corporation, New York.

Staff.

Messrs. G. Lambert (Royal Army Service Corps) and R. Cane (Royal Army Pay Corps) were still on active service at the end of December. Mr. Lambert has since been released under Class B arrangements and resumed his duties as assistant to the Secretary on February 14th, 1946.

J. Willis was temporarily released from the Merchant Navy Pool and resumed duty as assistant to the Caretaker in August, being finally released by the Pool in November.

Miss K. B. Holman was engaged as librarian vice Mr. F. D. Clark (resigned).

Miss D. E. Gillmar (shorthand typist) and Miss J. E. Daykin (junior book-keeper) were engaged vice Mrs. J. C. Isbester and Mrs. N. Trendall, who were unable to accept transfer from High Wycombe. Miss M. Strathdee was engaged as junior shorthand typist (additional).

Guild of Benevolence.

The Council, as Trustees of the Guild of Benevolence, are pleased to record that donations to the Guild received during 1945 amounted to £643, in addition to the third annual donations of £1,000 and £500 to the John Silley Memorial Fund received under covenant from Mr. H. A. J. Silley and Mr. B. L. Silley respectively.

Revision of the By-Laws.

The Special Committee under the chairmanship of Dr. S. F. Dorey concluded their work on the revision of the By-Laws in October. Their recommendations as adopted by the Council are being submitted for approval by the Members at an Extraordinary General Meeting on March 19th, 1946 (postponed from February 1st).

Merchant Navy Training Board.

The Merchant Navy Training Board published in November their Report on the training of engineer officers for the Merchant Navy. The Report was reprinted in the December TRANSACTIONS.

The Council, having in mind the anomaly by which the Institute, holding its Royal Charter as the representative of the marine engineering profession, was not represented on the National Maritime Board, obtained the agreement of the Ministry of War Transport to accept the Institute's comments on the above mentioned Report.

The Council accordingly held two special meetings in December, 1945, and a third in January, 1946, to consider the proposals contained in the Report.

A number of amendments were agreed upon and have since been submitted to the Ministry of War Transport and the Merchant Navy Training Board.

Scottish Engineering Students' Association.

The Council gave their support to the newly formed Scottish Engineering Students' Association, and appointed Mr. J. Adam (Student) to represent the Institute on the Council of the Association.

Visit to Messrs. Davey, Paxman & Company's Works.

By the kind invitation of Messrs. Davey, Paxman & Co., Ltd., a party of members of the Institute, with members of the Diesel Engine Users' Association, visited the Company's Works at Colchester on Saturday, July 7th, 1945. A detailed report of this event was published in the July TRANSACTIONS.

Library.

The Institute's library service was increasingly in demand, both as regards the loan of books and replies to enquiries for technical information.

The Council are greatly indebted to members and others who have reviewed the new books added to the Library during the year.

Social Events.

Notwithstanding the difficulties imposed by the continuing wartime austerity, two of the Institute's customary social events were successfully arranged. An autumn Golf Meeting was held at Hadley Wood Golf Club on Wednesday, September 19th, 1945, and the Allied Victory was celebrated by a Conversazione at the Connaught Rooms on Friday, December 7th, 1945.

Following the Presidential Address, a Council dinner was held at the Great Eastern Hotel on Tuesday, October 9th, 1945, the guest of honour being the Rt. Hon. A. V. Alexander, P.C., C.H., M.P., First Lord of the Admiralty, Honorary Member of the Institute.

The above mentioned events were reported in the succeeding issues of the TRANSACTIONS.

Armistice Day, 1945.

The Institute was represented by Mr. W. Lynn Nelson, Chairman of Council, at the Commemoration Service at Westminster Abbey on November 11th, 1945, and by Mr. J. A. Rhynas, Vice-Chairman of Council, at the service and laying of wreaths at the Mercantile Marine Memorial, Tower Hill.

President-designate.

The Council were highly gratified by Sir Amos Ayre's acceptance of nomination for election as President for 1946-7. He has always shown keen interest in the Institute's activities, and as Chairman of the Shipbuilding Conference his accession to the Presidential office at the present time is particularly opportune.

Representatives' Reports.

Owing to prevailing conditions a number of outside organizations on which the Institute is represented have remained inactive during 1945. Brief reports on the others are given below.

The Engineering Joint Examination Board. Representatives: Mr. F. H. Reid, B.Sc., Wh.Ex.; Mr. R. F. Thompson, B.Sc.

Meetings of the Board were held on 9th March, 22nd June, and 23rd November, 1945.

At the meeting on the first date, the Report for 1943/44 and a statement of accounts for the year to December, 1944, were adopted. At the second meeting, the 1946 examinations were arranged to be held on the 2nd-5th April and on the 1st-4th October. At the third meeting, further consideration was given to the future administrative work of the Board and to applications from other professional institutions to join the Board.

At the June and November meetings the reports of the Moderators were considered and adopted.

The following qualifications have been added to those already recognised for exemption from the Common Preliminary Examination:—

The Forces Preliminary Examination Certificate.

The Royal Naval Higher Education Test (First and Second Class Certificates).

The Royal Marine First Class Certificate.

The total number of exemption certificates received from the Constituent Institutions from 1st June, 1941, to 30th June, 1945, were:

The Institution of Civil Engineers	1,980
„ „ „ Mechanical Engineers	1,741
„ „ „ Municipal and County Engineers	94
„ „ „ Naval Architects	3
„ „ „ Structural Engineers	66
The Institute of Marine Engineers	101
The Royal Aeronautical Society	288
Total ...	4,273

For the April, 1945, examination there were 242 home candidates, of whom 230 presented themselves, and arrangements were made to examine 17 candidates at eight centres overseas and in four Prisoners of War Camps.

For the October, 1945, examination there were 129 home candidates, of whom 119 presented themselves, and arrangements were made to examine 48 candidates at 11 overseas centres.

The results of the home examinations were:—

	Sat.	*Passed.*	*Referred.*	*Failed.*
Whole examination:				
April, 1945 ...	111	46	37	28
October, 1945 ...	42	15	20	7
One or two subjects:				
April, 1945 ...	119	82	26	11
October, 1945 ...	77	39	30	8

The British Shipbuilding Research Association. Representative: Mr. S. A. Smith, M.Sc.

During the year there have been a number of meetings of the Association and of the various sub-committees formed by the parent body. Priorities have been assigned to the items of research work and co-ordination has been arranged. The Institute's representative has been appointed to a number of sub-committees and a very comprehensive and interesting research programme is envisaged. Work of a confidential nature has already been carried out.

Lloyd's Register of Shipping, Technical Committee. Representative: Mr. S. B. Freeman, C.B.E., M.Eng., who resigned during 1945 and whose place was taken by Mr. H. S. Humphreys.

A preliminary meeting of the Technical Members was held on Wednesday, 14th February, 1945, the full meeting being held on Thursday, 15th February.

The following matters were brought forward, and after discussion were dealt with generally on the lines desired by the technical staff.

Revised Rules for Electric Arc Welding in Ship Construction. Modification to the Rules for Riveting of Steel Ships. Amendments to the General Regulations relating to the Classification of Steel Vessels. Amendments and additions to the Rules for periodical surveys of main and auxiliary engines and boilers, electrical equipment and exhaust steam turbines connected to the main shafting of steam reciprocating engines. Amendments to Section 20D and Section 34 of the Rules for Steel Ships. Amendment to Section 21 clause 4(d) of the Rules for vessels intended to carry petroleum in bulk. Amendments and additions to the Rules for the Construction and Survey of Engines and Boilers of Steam Vessels. Modifications of the Rules for Welded Pressure Vessels. Requirements for the supply of spare gear added to the Rules for the construction and survey of petrol and paraffin engines. Additions and amendments to Rules for the construction and survey of heavy oil engines and their auxiliaries.

Amendments to Section 1-4 (Requirements for new Refrigerating Installations) and Section 5 (Periodical Surveys) of the Rules for Refrigerating Machinery and Appliances.

Amendments to Section 4, para. 2 (Critical Speed) of the Rules for Electric Propelling Machinery. Alterations to the Rules for Electrical Equipment. Amendment to Section 10 (Quality and Testing of Ingot Steel Forgings) of the Rules for Quality and Testing of Materials.

The subject of gauging finished gears and the measurement of errors in gear hobbing machines was discussed at length, and it was agreed that a technical sub-committee should pursue the matter with the Chief Engineer Surveyor.

MR. HUMPHREYS attended his first meeting of this Committee on 27th November, 1945, when various matters regarding Lloyd's Rules, etc. were fully discussed in the forenoon by the Technical Committee and the recommendations were put to the main Committee at the afternoon session.

There is a wide representation of various sections of the Industry on this Committee and it is felt that all Lloyd's requirements are most thoroughly investigated before they are put into practice.

Corrosion Research Committee of the British Non-Ferrous Metals Research Association. Representative: Mr. J. A. Rhynas.

This Association has completed 26 years of service to the non-ferrous metals industry.

The Association has modern Research Laboratories and Headquarters at Euston Street, London, N.W., which are well and specially equipped with apparatus for different kinds of research work such as melting and casting, mechanical testing, pyrometry laboratory, metallography, corrosion laboratory, chemical laboratory, physics laboratory, and workshop.

The Admiralty have now removed the secrecy restrictions on reports on copper nickel iron alloys. The reports have been released to members generally by announcement in the Bulletin in the usual way, but the Association request members to treat many interesting research results as confidential.

The subjects of research carried out during its existence are as follows: impurities in copper, casting of brass ingots, properties of lead and lead alloys, atmospheric corrosion, condenser tube corrosion, gases in metals, shrinkage and gas porosity in castings and solders, etc.

This brief reference to some of the Association's interests and work at present in progress will serve to illustrate its usefulness.

Association of Special Libraries and Information Bureaux. Representative: Mr. B. C. Curling.

In July, 1945, the Association published the first issue of the *Journal of Documentation.* The contents of this and the two further parts issued by the end of the year indicate the importance of this publication to library users.

A Manual on the Technique of Special Librarianship, by J. E. Wright, published by the Association in June, 1945, has met an immediate and continuing demand.

A new edition of the *Select List of Standard British Scientific and Technical Books* is in active preparation.

The programme of the Annual Conference in September contained a number of valuable papers on information services and research libraries, including Professor J. D. Bernal's opening address on "Information Service as an Essential in the Progress of Science".

British Society for International Bibliography. Representative: Mr. B. C. Curling.

A further programme of informative papers and discussions has been carried out during 1945, including a discussion on the technique of making abstracts of scientific and technical papers, which was opened by Engineer Commander D. Hastie Smith, R.N.(ret.), M.I.Mar.E., at the October meeting. The Council is prominently associated with the post-war revival of the activities of the International Federation for Documentation, including the arrangement of a conference in Paris early in the coming year.

World Power Conference, British National Committee. Representative: Mr. E. W. Green, O.B.E.

A meeting of the Committee was held on 30th August, 1945, the first for over six years. The business transacted was of a purely formal nature.

British Corporation Register of Shipping and Aircraft, Technical Committee. Representative: Mr. W. F. Brown, B.Sc., Wh.Ex.

The matters dealt with by the Technical Committee in the course of the past year have been mainly concerned with reversion from war-time to peace-time practice.

It has been agreed that certain emergency measures affecting ships' pumping, valves and fittings in machinery space, etc. should be permanently adopted and included in the Society's Rules. It has also been agreed that certain provisions for hull structure and fittings (such as the provision of horizontal stiffeners at the end of weather deck hatchways, the protection of the ends of wood hatch covers by steel bands, the provision of locking bars on exposed hatchways, the standardisation of cleats and wedges and the non-acceptance of cast iron for valves and discharges below the freeboard deck) all of which are already incorporated in the Rules either as requirements or recommendations, should in future form a part of the conditions of assignment of loadlines. During the war a reduction in anchor and cable equipment has been permitted, but it is not intended that this relaxation of Rule standards be made permanent.

The materials used in construction of ships and machinery have been the subject of investigation. Ships constructed at Continental ports, in which Thomas steel has been used, must be kept under observation for a sufficient period to show whether or not classification is justified, and even in the case of ships built from open hearth steel there have been instances of the cracking of plates which have emphasised the need for research.

The question of the best sizes and shapes of rolled sections for welded work has also been examined, but although a considerable amount of data has been collected, the Committee do not regard the production of an extensive series of new sections as justifiable, although certain large sections might well be developed where at present there is no suitable rolling available.

The Parliamentary and Scientific Committee. Representative: Mr. H. S. Humphreys.

This Committee has been very active and deserves the utmost support. The usual monthly Committee Meetings were held, at which there was always a short talk by an eminent politician or professional man. At a meeting held late in 1945 three of the scientists who visited Russia gave most interesting talks on their experiences. There are a number of members of both Houses of Parliament on the Committee, and practically all the scientific bodies are well represented. The prestige and work of the scientist and engineer were kept well to the fore, and often a Cabinet Minister attended the meetings to answer questions on scientific subjects.

As regards the Officers of the Committee, the three-year rule is adopted, as with this Institute; accordingly Lord Samuel retired from office for at least one year at the Annual General Meeting and Sir John Anderson has succeeded him as President.

The British Electrical and Allied Industries Research Association: Joint Committee on Steels for High Temperatures. Representative: Dr. S. F. Dorey, C.B.E., Wh.Ex.

Investigations undertaken in order to determine the equations for plastic flow (on loading) and creep under general stress systems for a 0·17 per cent. carbon steel have recently been completed and reports are being prepared. Experiments to determine how relaxation behaviour is related to creep behaviour under constant stress, using the same 0·17 per cent. carbon steel, have nearly been completed and two chromium molybdenum bolt steels have been obtained from different sources for examination of their relaxation behaviour. The final stage in the comparison of various short-time creep limits and long-time creep properties of molybdenum steel has been reached.

Two carbon steel ingots, one good and one poor on creep resistance when forged into bar have been chosen to produce tubes in the various final states met in industry. Samples of these tubes have been undergoing test to examine the differences in creep behaviour produced by the commercial processes and heat treatments, full details of which have been supplied.

A series of tests have been carried out on steels to determine whether failure in high temperature creep tests occurs at an earlier period in steam than in tests in air, at atmospheric pressure, or in vacuum. The tests have shown a great degree of variability in life tests to rupture. It appears that steam somewhat accelerates failure in these high stress tests. Some additional tests in hydrogen showed a more active attack.

Apparatus has been constructed to study the creep behaviour of superheater tubes under internal high pressure high temperature steam (1,000lb./in.^{2}, 950° F.). Comparative tests will subsequently be made using air under pressure instead of steam.

Further work has been carried out to determine whether abnormality as known to exist in carbon steels occurs in molybdenum steels. The effect of other alloying elements in molybdenum steel has been further studied in regard to intercrystalline cracking, spheroidisation and graphitisation. A separate study has been made of the latter in view of the reported failure of steampipe by this action.

Scottish Engineering Students' Association. Representative: Mr. J. Adam.

The Scottish Engineering Students' Association was formed in 1945 and to date has been officially recognised by more than 20 institutions and societies. Some of these have only very few Scottish members under the age of thirty, others have a much larger younger membership. Altogether there is a potential membership of approximately 800 and of this number about 550 have applied for membership. Numerous letters received from young Scottish engineers in every branch of the profession seem to indicate a wholehearted welcome for the Association. The active support received and the interest shown appear fully to justify the formation of such an organization.

Three evening meetings have been held. The first of these was on 11th October when Sir Harold E. Yarrow, Bt., C.B.E., Honorary President of the Association, delivered his Presidential Address. After paying tribute to the energy and foresight of Mr. J. L. Adam, C.B.E., who had originally conceived the idea of such an Association, Sir Harold stated that the Association could fulfil a very useful function by bringing young men in all branches of engineering together from time to time and by removing the objection that engineers keep all too often within their own "watertight compartments". Sir Harold went on to discuss certain research work and experiments which had been undertaken in shipbuilding and marine engineering, with special reference to fast torpedo boat destroyers. He ranged over the effect of depth of water on speed of ships, the work of the ship experiment tank, vibrations of ships, ships' machinery and boilers. About 100 persons attended the meeting.

The second meeting was held on 7th November when Mr. A. A. Wells, B.Sc., Stud.Inst.C.E., member of the Association, read a paper entitled "Photoelasticity: Modern Methods and their Application to Engineering Problems". In this the Author gave a brief history of the development of photoelasticity and mentioned the outstanding personalities responsible for this development. The paper dealt mainly with modern methods and the Author explained both the practical and theoretical aspects. About 50 persons attended the meeting.

The third meeting was held on 3rd December when Major E. F. J. Plowden, R.E., G.I.Mech.E., A.I.Mar.E., A.Inst.N.A., member of the Association read a paper entitled "Some Notes on R.E. Work in Italy". Illustrating the different aspects of R.E. work, Major Plowden, who had recently returned from service in Italy, discussed road construction and maintenance, bridge-building and the use and maintenance of mechanical equipment, and closed his address by referring to the ship salvage work undertaken by the R.E.'s in North Africa. About 50 persons attended the meeting.

An interesting programme has been arranged for the second half of the Session.

British Standards Institution.

Petroleum Industry Section: Technical Committees PTC/2 Fuel Oils; PTC/3/1 Lubricating Oils; PTC/3/2 Turbine Oils. Representative: Mr. J. L. Chaloner. [The identification Code of these Committees has been changed from PT/- to PTC/-.].

PTC/2 Fuel Oils. On the instructions of the Petroleum Industry Committee, this Committee has been reconstituted and now includes a representative of the Ministry of War Transport. Instructions have been issued to re-draft B.S. 209 and 742, for which purpose a new drafting Committee PTC/2/1 has been set up.

PTC/3/1 Lubricating Oils. B.S. 210 is under review for the purpose of decision whether the present specification of classification is to be replaced by a set of actual oil specifications.

PTC/3/2 Turbine Oils. B.S. 489 remains as amended in February, 1944, and no further changes are proposed at present.

Technical Committee ME/17, Gears. Representative: Mr. G. H. Forsyth, M.Sc.

The Committee has met at intervals, preparing a revision of B.S. 545, Machine Cut Gears, B. Bevel (with helical, curved and straight teeth).

In addition, the question of Traction Gears has been raised and was referred to the British Gear Manufacturers' Association, who recommended that the existing standard required reconsideration and that any revision should be effected by incorporating the requirements of B.S. No. 436.

Air Receivers. Representatives: Messrs. J. Carnaghan and R. S. Kennedy.

B.S. 429, Riveted Air Receivers, is under revision.

Mechanical Industry Committee. Representatives: Messrs. J. Carnaghan and R. S. Kennedy.

The following specifications, amendments and authorisations have been approved:—

New specifications.

- Drawing boards and tee squares.
- Methods of sampling boiler feed water.
- Reinforced diamond dies for wire pulling.
- Shapes of butt-welded lathe and planer tools.
- Wire rope slings and sling legs.

Amendments.

- B.S. 466, Electric overhead travelling cranes.
- B.S. 431, Manila ropes for general purposes.
- B.S. 908, Sisal ropes for general purposes.
- B.S. 863, Steel straight edges.
- B.S. 1127, Circular screwing dies.
- B.S. 907, Dial gauges for linear measurements.

Authorisation was given to set up Technical Committees for:—

- Revolution counters.
- Standard thread rolling dies.
- Cast iron and pressed steel sectional tanks.
- Lubrication nipples for machinery and vehicles.
- Filters for air, oil, fuel and other gases, and liquids.
- Component parts for locomotives.
- Pressure gauges.

Protective Lenses for Welding Operators. Representative Mr. R .S. Kennedy.

A Sub-Committee on Personal Safety Equipment has been busily engaged in a revision of B.S. 679. In this work consideration is being given to the American Specification and to a draft Australian Specification. A programme of experimental work is also in hand.

Solid Fuel Industry Committee, SF/-. Representative: Mr. W. Dowling (in place of Mr. E. W. Green, O.B.E., who resigned during the year).

Since August, 1945, the following have been dealt with:—

(*a*) Proposed British Standard Log Sheet(s) for Small Steam Boiler Plants. These applied only to small or medium Land Boiler Plants.

(*b*) The 7th Draft British Standard Specification for "ready to fit" thermal insulating materials for hot and cold water supply and heating installations for dwellings with a water heater power of not greater than 40,000 B.T.U.'s/hour. Brickwork setting for cylindrical boilers. Open fires and domestic cookers and combination grates, canteen equipment, etc.

(*c*) Methods of test for transport gas producer fuels.

(*d*) Small domestic hot water supply boilers for solid fuel.

(*e*) 4th Draft British Standard for pre-formed insulating materials for central heating and hot and cold water supply installations.

(*f*) Memorandum re methods for testing atmospheric pollutions and the standardisation of the instruments required for such tests.

(*g*) Report of meeting of the United Nations Standards Co-Ordinating Committee, held in New York in October, 1945.

Iron and Steel Industry Committee, IS/-. Representative: Mr. James Turnbull, O.B.E.

The war-time practice of dealing with the business of this Committee by correspondence has been continued. During the past year the three following specifications have been published:—

(1) B.S. 1271, Proof Test for Creep Quality of Carbon Steel Plate of Boiler Plate Quality.

This specification is intended to be applied when agreed, to ascertain the creep qualities of the plate material in the temperature range 700° F.-950° F. It is not intended to describe a method for investigating the creep qualities for the purpose of determining suitable design stresses.

(2) B.S./STA. 25, Services Specification for High Silicon Iron Castings—which has been specially prepared for the Ministry of Supply.

(3) B.S.405, Expanded Metal (Steel) for General Purposes.

In addition, a draft has been prepared giving recommendations to manufacturers on the protection by painting, spraying, etc., of light iron and steel items such as window frames.

Technical Committee on Land Boilers. Representative: Mr. J. Carnaghan.

The whole series of land boiler specifications are under revision. A new specification for non-ferrous pipes for and in connection with land boilers has been prepared and will have been published before this report appears in print.

Technical Committee on Fans. Representative: Mr. T. A. Bennett, B.Sc.

One meeting was held during the year to discuss proposals for the modifications of B.S. 848 Testing of Fans for General Purposes, and B.S. 707 Testing of Mine Fans and to amalgamate these into one specification.

Technical Committee on Documentation. Representative: Mr. B. C. Curling.

No meeting was held during 1945 but it was arranged that one should be held as soon as possible to consider a letter from the *Féderation Internationale de Documentation* suggesting the resumption of international standardisation in the field of Documentation.

Since the cessation of hostilities a large mass of material relating to extensions of the Universal Decimal Classification which have been proposed on the Continent during the war years are now becoming available. It is necessary to consult these documents in the preparation of the English edition, and this has considerably slowed up the rate of progress both as regards the Abridged Edition and the full tables.

Ships' Side Scuttles and Frames (Type A). Representative: Mr. F. M. Burgis.

A meeting of this Committee was held on 28th November, 1945, to consider the revised draft British Standard Specification on ships' side scuttles. This draft was very carefully scrutinized and certain minor alterations were made to the wording. The one representative of the sidelight manufacturers present was called upon to settle certain minor points regarding design and phraseology, and the draft was then finally approved. It was decided to proceed with the publication of the specification in pamphlet form of similar type to No. 3024-1926 Ships' Side Scuttles British Standards Specification.

Technical Committee on Hand Hammers. Representatives: Messrs. J. Carnaghan and R. S. Kennedy.

B.S. 876, Hand Hammers, is under revision and a new specification for picks, beater picks and mattocks is in course of preparation.

Committee on Coupling Guards for Machinery. Representative: Mr. T. A. Crompton.

A meeting to consider various comments on the second draft British Standard for guards for couplings was held on the 13th November, 1945. It was decided to circulate, in the near future, a further draft to manufacturers and others interested, and a suggestion was made that another meeting should be called sometime in April, 1946.

Technical Committee ME/12 Chains and Fittings. Representative: Mr. J. Carnaghan.

B.S. 394, short link wrought iron chains, and B.S. 590, steel chains, are under revision.

Sub-Committee ME/12/6, Anchor Chains. Representative: Mr. J. Carnaghan.

B.S. 3006, stud link cables (anchor cables) is under revision.

Committee ME/72, Boiler Water Tests. Representative: Mr. H. J. Wheadon.

During the latter part of 1944 the Sub-Committee ME/72/3 (Methods of Boiler Water Treatment) elected a small panel to revise the draft code entitled "Treatment of Feed and Boiler Water for Marine Boilers", of which some 1,000 copies were circulated to various interested persons and organisations, both in this country and abroad, for comment. During the past year the panel has met on eleven occasions to review the considerable number of comments received. The revision of the draft code is now nearing completion for the approval of the Committee.

Until the final publication is available, copies of the draft can be obtained from the British Standards Institution, Publishing Department.

Technical Committee ME/94, Revolution Indicators. Representative: Mr. R. A. Collacott, B.Sc., Ph.D.

The first meeting of this Committee was held on 20th September, 1945, Mr. Sterry B. Freeman, C.B.E., M.Eng., being elected Chairman. Three Sub-Committees were then set up to consider the standardisation of revolution indicators for (*a*) aircraft; (*b*) road transport vehicles; and (*c*) industrial and marine applications. The work of these Sub-Committees is proceeding.

Obituary.

RONALD ALLAN (Member 7660) died at his home in Edinburgh on December 26th, 1945, aged 59 years. He was the youngest son of the late Sir William Allan, M.P., of Sunderland, and was educated at Sunderland High School and at Durham School. His technical training was obtained at Armstrong College and he served his apprenticeship with Messrs. S. P. Austin's Shipbuilding Yard, Sunderland. During the 1914/18 war he was in the Royal Garrison Artillery, leaving with the rank of Captain. He spent two years as improver with Messrs. McKenzie & Torrance, Edinburgh, and four years as engineer (Factory Manager) at Castlefield Estate, Federated Malay States. For over 20 years he was London Representative (Marine Department) of Messrs. Richardsons, Westgarth. In February, 1942, he joined the Ministry of Supply but retired owing to ill-health in 1944. Mr. Allan was a Freeman of the City of London. In October, 1924, he designed and patented a reciprocating cylinder engine. The drawings and description are in "Motor Ship" of October of that year. He was an Associate Member of the Institution of Naval Architects.

WILLIAM HENRY H. BEVAN (Member 9298) was born in Sunderand on July 12th, 1891, and was the second and only surviving son of the late Captain Samuel Bevan and Mrs. Bevan. He served his apprenticeship at the Central Marine Engineering Works, West Hartlepool, and on leaving went to sea as 4th engineer with the London and Northern Steamship Company. In August, 1915, he joined Messrs. Coombes & Marshall as 2nd engineer and in September of the next year was appointed Chief Engineer of the s.s. "Grasmere". He joined the Union Castle Mail Steamship Co. in October, 1916, his first ship being the "Gloucester Castle" which was then a hospital ship and Mr. Bevan was on board when she was torpedoed in the Channel. He served in many ships of the Union Castle Line and in August, 1938, was Chief Engineer of the s.s. "Dromore Castle". During the course of his time at sea Mr. Bevan obtained his First Class Board of Trade Certificate. Taken ill during a voyage to South Africa in 1941 he underwent an operation in Durban and did not regain his health. In 1942 he left the Union Castle Company and became Engineer Surveyor for the Gresham Insurance Company. He died on March 30th, 1945 after an operation at the Seamen's Hospital, Tilbury.

JAMES H. BLIGHT (Member 3730) was born on January 10th, 1884. He served his apprenticeship with the Thames Ironworks, Greenwich, from 1898 to 1905, continuing there as draughtsman until 1910. Mr. Blight went to Singapore, where he worked on a rubber plantation for about 18 months. He returned to England, and in 1912 joined the firm of Messrs. R. & H. Green and Silley Weir, Ltd., as draughtsman. From 1914 to 1919 he was draughtsman and assistant works manager, and in 1919 was appointed works manager, Royal Albert Dock, which post he held until 1943, when he resigned owing to the weak condition of his heart. In 1943 Mr. Blight was appointed managing director of the British Arc Welding Company, Ltd., and was with this firm until the time of his death, which occurred on July 5th, 1945.

THOMAS BROWN (Member 6675) was born at Polmont, Stirlingshire, on January 6th, 1885. He was educated at Falkirk High School, Falkirk S. and A. School, and received his technical education at the Glasgow and West of Scotland Technical College. His apprenticeship was served with Nobel's Explosive Company, Glasgow, and Messrs. Napier Bros., Ltd. of Glasgow. Mr. Brown joined the Greenock Steamship Company as 4th engineer in 1907, sailing in the "Gulf of Venice", and from 1909 was with the Australian United S.N. Company of Sydney, commencing as 7th engineer and attaining the rank of chief engineer. In 1926 he was appointed assistant superintendent engineer with the latter company. He obtained his First-Class Certificate in May, 1941. Mr. Brown was chief engineer of s.s. "Nankin" (The Eastern and Australian Steamship Company Limited) when she was taken as prize by a German raider on May 10th, 1942. He was taken to a prisoner-of-war camp in Japan, and it was later learned that he died from pneumonia there on December 13th, 1943. Mr. Brown had been sailing to the East for about nine years. The Eastern and Australian Steamship Company Limited have written of his sterling qualities, and said that he would be sadly missed.

JOHN F. CAMPBELL (Member 3488) was born on September 28th, 1897, at Southampton. He was educated at Swansea Grammar School and Manchester Grammar School, and served his apprenticeship as engineer with the Manchester Dry Dock Company and D. & W. Henderson of Glasgow. Mr. Campbell commenced his sea-going career in 1918 in vessels belonging to the Manchester Liners Ltd, and the Donaldson Line Ltd. On obtaining his 2nd class Certificate he went to sea in a Beardmore-Tosi diesel driven vessel and subsequently in a Sulzer diesel driven oil tanker. He obtained his First Class Certificate and was for a time in the Drawing Office of the British Westinghouse Electrical Company, Manchester. In 1924 he was appointed Engineer Surveyor to Lloyd's Register of Shipping, and served at Liverpool, Manchester, Cardiff and Leith. Mr. Campbell died at his home in Edinburgh on January 25th, 1946.

ROBERT A. CATTERALL (Associate 8979) was born on 2nd October, 1913. He served his apprenticeship with Messrs. Dunlop Bell & Co., and Messrs. J. W. Pickering & Sons, Ltd. of Liverpool. In November, 1934, he went to sea as 5th engineer in the service of Messrs. T. & J. Harrison of Liverpool, and obtained his First-Class Board of Trade Certificate. From April, 1939, until his election as an Associate of the Institute he was on the shore staff of the same firm, but later returned to sea. He was a survivor from the "Auditor" when she was torpedoed in the Atlantic in June, 1941—on that occasion he was in a boat for ten days. Mr. Catterall was 2nd engineer of the "Novelist" and was posted as missing when the ship was lost by enemy action off Madagascar in 1944.

HAROLD THOMAS BELIEU DIXCEE (Member 10102) was born on 26th October, 1891. He served an apprenticeship with Messrs. Rait and Gardner from 1905 until 1910. He was employed as a seagoing engineer from 1910 until 1926 (finally as chief engineer). From 1926 to 1927 he was Head Foreman and Assistant Manager with Messrs. Fletcher, Son & Fearnall, of Tilbury Docks. For two years after that date he held an appointment in Singapore and on returning to this country joined the firm of Silley, Cox & Co., Ltd., in Falmouth, in the capacity of Assistant Engineer Manager. In 1943 he was for a short time at the Royal Albert Dock, after which he went to Millwall and Surrey Docks as Branch Manager for Messrs. R. H. Green & Silley Weir, Ltd. Mr. Dixcee died on 6th April, 1945.

JAMES CAMPBELL ERSKINE (Member 4986) was born in Scotland in 1884. He served his apprenticeship with Messrs. Muir and Houston, Ltd., of Glasgow, afterwards going to sea and obtaining his First-Class Board of Trade Certificate. For six years he was chief engineer of vessels owned by Messrs. Burrell & Son, Glasgow. Mr. Erskine settled in Australia in 1917, and was for two years Inspector of Machinery, Commonwealth Ship Construction and for three years manager of the Williamstown Works of Messrs. Thompson & Co. Pty. Ltd., Victoria. He then became a partner in the firm of Messrs. Greenlees & Co., Naval Architects and Engineers, Sydney, and in 1924 joined Lloyd's Register as ship and engineer surveyor at the latter port. At the time of his death on the 16th

December, 1945, he was senior ship and engineer surveyor at Sydney. He is survived by a widow and two sons. His loss will be keenly felt by his many friends and associates in the shipping and engineering professions.

James Fairgrieve (Member 4033) was born on the 21st of April, 1884. After serving his apprenticeship with Messrs Morrison & Sons, of Leith, and with Messrs. Hawthorn & Co., also of Leith, he spent six years at sea, and obtained his First Class Board of Trade Certificate. He worked for some time with the Standard Oil Company of New York on their installations in North China. When in 1919 this company decided to replace all British staff by American, Mr. Fairgrieve joined the Asiatic Petroleum Company as Installation Manager in North China, spending practically the whole of his time at different points on the Yangtse River, for some years at Chinkiang, later at Chungking, and for the last eight years of his service he was in charge of Hankow Installation which is the largest in that area. While at Chinkiang he acted as Lloyd's Surveyor. In 1934 Mr. Fairgrieve joined a family business, Robert N. Fairgrieve, Ltd., distributors of Frigidaire Refrigerators for Scotland. Soon after the outbreak of war he joined the Admiralty and was stationed in London, supervising generally the Admiralty fuel oil installations in the U.K. from an engineering standpoint. This position he held until shortly before his death, which occurred on May 20th, 1945.

Henry Ford (Associate 9276) was born on December 13th, 1918. He obtained his technical education at the Hull Municipal Technical College, and served his apprenticeship with Messrs. Charles D. Holmes Company, Limited, of Hull. In 1939 he went to sea as 5th engineer with the Anglo-Saxon Petroleum Company. He obtained his First Class Motor Certificate in December, 1943. Mr. Ford died on July 23rd, 1945.

Harry Charles Gearing (Member 7850) was born on 19th October, 1877. He was the eldest son of the late Mr. Sydney Charles Gearing, who, with Mr. Andrew Cunningham, founded the firm of Cunningham and Gearing in Cape Town in 1878. This firm became registered as a limited liability company in May, 1919, and was known as Gearing's, Ltd. Mr. H. C. Gearing became its managing director and chairman on the death of his father in December, 1923. He was a leading authority in the Union on marine engineering. Educated at the Sea Point Boys' High School, he served his apprenticeship in mechanical engineering in his father's firm. After completing his education and training oversea, he worked for the engineering firm of Richardsons, Westgarth & Co., Ltd., West Hartlepool. He was a member of the Institution of Mechanical Engineers, a member of the Institution of Naval Architects, a Fellow of the Royal Society of Arts and a Fellow of the American Geographical Society. He held many important positions in Cape and South African industry. He was president of the South African Federated Chamber of Industries in 1926, 1927, 1935 and 1936. From 1929 to 1932 he was president of the Cape Chamber of Industries, and from 1920 until the time of his death he was chairman of the Cape Engineers' and Founders' Association. From 1929 to 1934 he was chairman of the Cape Industrial Council for the Engineering Industry, and was a foundation member of the Cape Apprenticeship Committee for this industry from July, 1932, becoming its chairman in 1934 and holding this position until he died. During the last war he became the first president of the South African Federation of Engineering and Metallurgical Associations. He was also a member of the Table Bay Harbour Advisory Board and was on the council of the Cape Technical College. Tennis was his chief sporting interest, and it was his custom to invite prominent tennis players to play on his private court at Rondebosch at week-ends. Mr. Gearing died at his home in Rondebosch on 31st October, 1945, after a long illness. He leaves five daughters. His wife died in December, 1944.

Thomas Gerard (Member 1416) was born at Montrose, Scotland, and served his apprenticeship with Messrs. Shanks & Co., Ltd., Arbroath, and with Messrs. Armstrong's, Newcastle, continuing for two or three years as foreman millwright in the gun shops of the latter firm. In 1885 he went to sea in tramp steamers, including the "City of Lincoln" and "Nesmore", during which time he obtained his First-Class Board of Trade Certificate. Mr. Gerard spent some years with the Corries Star Line, sailing as 2nd engineer and chief refrigerating engineer in the "Star of England" and "Star of New Zealand". He joined the Federal Steam Navigation Company, Ltd., as a 2nd engineer, serving in this capacity in the "Cornwall" and "Dorset" and as chief engineer in the "Suffolk" and "Essex". In 1911 he was appointed to superintend the construction of this company's two large refrigerated cargo and passenger ships "Wiltshire" and "Shropshire" at the works of Messrs. John Brown & Company, Ltd., Clydebank. The work was completed in 1913 and Mr. Gerard sailed as chief engineer of the "Wiltshire" until his retirement from sea service in 1921. During the 1914-18 war this ship became a troopship and was in service at Gallipoli. In 1921 he transferred to Falmouth where he supervised repair and conversion work on a number of ex-German steamers. Two years later Mr. Gerard lost his wife. Upon completion of the work in the same year he retired from further active service and lived quietly at his home at Forest Gate. Owing to the explosion of a land mine during an air raid he lost his home and afterwards took a house at Wanstead. He died on November 25th, 1944, after a short illness, at the age of 85 years.

Albert Higgins (Member 1193) was born in 1869. He was apprenticed with Strode & Co., Engineers, London, and received his technical education at Finsbury Technical College and the Regent Street Polytechnic. He gained many certificates and was a Silver Medallist for his skill in metalwork. For a number of years he was the electrical engineer for Strode & Co., and carried out several large contracts both in town and country. In 1902 he formed the firm of Higgins & Griffiths Ltd., and in 1934 joined the firm of Higgins and Cattle Ltd., remaining a director until his death. He was as keen on the smallest mechanical or electrical detail (such as in the Queen's Doll's House) as in the larger contracts for works, docks, ships, factories, etc. He saw through his long life the evolution of the application of electricity from the gutta percha insulated cable and the Book carbon lamp to the polyvinal cable and the fluorescent lamp. His sport in his early days was boxing and later golf. He was a great traveller and knew the seven seas. There were not many ports in the world at which he had not called or lands he had not visited during the past 30 years. He took a lively interest in farming and country life. He was an officer of the Grand Lodge of Freemasons and was associated over many years with hospitals and children's homes. To those who enjoyed his friendship, and there were many, he was a man of exceptional heart and mind, who never forgot old friends. In his passing we have lost one of the pioneers of the modern electrical installation, who gave his knowledge to many over 60 years of engineering. He died at the age of 76 at a nursing home in Cape Town.

Francis M. Hunter (Associate 10155) was born in Lerwick, Shetland, on May 31st, 1913. He was educated at the Central Public School there and served his apprenticeship with Mr. P. T. Johnson, engineer, and in Gray's Garage. He was then employed as a journeyman until August, 1936, when he left Shetland and went to sea with the Anglo-Saxon Petroleum Co. After completing the necessary time at sea he studied at Leith Engineering School and obtained his Second Class Board of Trade Certificate. From December, 1939 to May, 1940, he was 2nd engineer with the North of Scotland S.N. Company and in July, 1940, returned to the Anglo-Saxon Petroleum Company as 2nd engineer. He obtained his First Class Motor Certificate in May, 1943. Mr. Hunter died at sea, owing to enemy action, on April 17th, 1945. He leaves a widow.

Frederick Hurst (Member 9348) was born on 1st May, 1881. He served his apprenticeship with the Lancashire and Yorkshire Railway Company. He went to sea in 1902 and obtained his First Class Board of Trade Certificate. In 1906 he was appointed Assistant Engineer, Royal Indian Marine, remaining in this service until 1909, when he became Second Engineer in the s.s. "Labuan". From 1910 until 1914 he was employed at Power Stations at Blackpool, Runcorn, and Stoke-on-Trent. During the whole of the 1914-1918 war he was E.R.A. and Chief E.R.A., R.N.R., and from 1919 to 1922 was Third Engineer in Belfast steamers of the L.M.S. Company. For the following six years he was in business on his own account. He went to sea again in 1928, serving with Bibby Line and Houlder Bros., and afterwards with the Glen Line. From 1933 to 1939 he was ashore as a representative of Compton Bros. & Russell Edwards. He became Temporary Boom Engineer, R.N.R., in 1939, in which position he remained until February, 1943, when he retired owing to the ill-health of his wife. Mr. Hurst died on 5th June, 1945, after a very short illness.

William Middleton Japp (Associate 8903) was born on 3rd April, 1898, and served his apprenticeship with Barclay Curle & Company, with the Sunbeam Motor Company, Ltd., of Wolverhampton, and Fraser and Bothwick. He volunteered for war service in 1915, and was an artificer in R.E. Signals, serving in France, and was wounded in the first battle of the Somme. Later he served in Mesopotamia and India until 1919, and attained the rank of Captain. On coming back to England he returned to the Sunbeam Motor Company in the Experimental Department, where he remained until

1923. Mr. Japp then became Chief Assistant to Mr. William Alexander, the well-known Consulting Engineer, of Glasgow, to whom he always said he owed a great deal. Upon the decease of Mr. Alexander, Mr. Japp took over his agencies, and represented The Standard Piston Ring Company of Sheffield, The Eyre Smelting Company, and Prodorite Ltd. of Wednesbury. He was very well known to all marine engine builders in Glasgow. His recreation was trout fishing. During the last war Mr. Japp took an active interest in the cadet movement, being second in command of the 7th Cameronian Cadet Force at the time of his death on 26th August, 1945. He leaves a widow and one daughter.

William Kerr (Member 4974) was born at Lochwinnoch, Scotland, on 5th March, 1872. He was the eldest son of James Kerr, Parish Clerk of Lochwinnoch. He was educated at John Neilson School, Paisley, was a Queen's Prize Scholar at Paisley Technical School, and served his apprenticeship with Bow and McLachlan of that town and with Lobnitz & Co., Renfrew. For some time he was in Cape Town Power Station. He went to sea and obtained his First Class Board of Trade Certificate. He spent eleven years with the Nippon Yusen Kaisha and China Navigation Co. and acquired a Japanese Chief Engineer's certificate. Afterwards he joined the China Merchants Company and sailed on the China Coast. Then he went to the Taikoo Dockyard and Engineering Company, Hong Kong as engine shop foreman. While there he invented and patented a steam drier, which was fitted in all China merchant ships, with gratifying results. He retired through ill health in 1930. Mr. Kerr was much esteemed by all who knew him and was a Life Member of the Marine Engineers' Association. He died on 23rd June, 1945; he leaves a widow and one daughter.

Edgar James Kyte (Associate 9774) was born on August 20th, 1890. He served his apprenticeship from 1906 to 1911 in one of H.M. Dockyards. From 1911 he was at sea with the Royal Navy and served in submarines from 1917 to 1920, in the latter year as Senior Engineer. He was Assistant (later Chief) Engineer, Oilfields of Egypt from 1921/22, then for a year worked with the Anglo-Persian Oil Company as Assistant Engineer. During the years 1923/26 he was Instructor in Aero. Engines with the R.A.F., and from 1926 to 1929 was Assistant (later Chief) Engineer for nine factories, Bombay Company in India. For a year he was Mechanical Engineer to the Greek Government engaged on the erection and maintenance of large modern machine shops, etc., then the year 1931/2 he spent teaching and studying. For two years Mr. Kyte was marketing engineering products. From 1936 to 1940 he was Examiner in Marine Engineering and Technology and advanced engineering subjects and editor of various engineering instruction manuals for the I.C.S. London. In 1940 he was Boom Engineer Officer, R.N.R. He died on January 20th, 1945, at which time he was Chief Engineer Officer of H.M.S. "Bartizan".

Engineer Rear-Admiral Harry Lashmore, C.B., D.S.O. (Member 9979) was born on November 16th, 1868. He entered the Royal Navy in July, 1889, and served in H.M.S. "Marlborough" at Portsmouth, and at the Royal Naval Engineering College, Keyham, the first training establishment for naval engineer officers. From 1890 to 1893 he was in H.M.S. "Mercury" on the China Station, and from 1894 to 1898 in the East Indies in H.M.S. "Brisk". He then went to South Wales, where he was Assistant, Admiralty Coal Inspection. From 1902 he was in H.M.S. "Orwell", and was one of the few survivors when, in 1903, she was sunk in collision with H.M.S. "Pioneer", receiving special promotion for his services in the incident. Later he was in H.M.S. "Foresight", and afterwards was concerned in the building of H.M.S. "Ness". In later years he served in destroyers, including H.M.S. "Swift", and then served for a time with the Home Fleet. From 1908 he was in charge of various ships, and was engineer commander in H.M.S. "Inflexible" when she left Invergordon in 1915 for an unknown destination, arriving with Admiral Sir Doveton Sturdee's squadron at the Falkland Isles to engage and destroy the "Scharnhorst" and "Gneisenau". He later went to the Dardanelles in the "Inflexible", and was awarded the C.B. and D.S.O. Admiral Lashmore was promoted to engineer captain in 1917, and in 1918 served in H.M.S. "Euryalus" in Egypt, and was awarded the Order of the Nile. He was in command at the Royal Naval Engineering College, Keyham, from 1919 until 1922, when he was promoted and appointed to the Staff of the Commander-in-Chief, Portsmouth, retiring in 1925. Admiral Lashmore was a Member of the United Services Institution and of the Royal Empire Society. His death occurred suddenly in November, 1945.

John Goodwin McKay (Member 2342) was born on 7th November, 1865, at Seacombe, Cheshire. He served his apprenticeship with Messrs. Cochran & Co., Birkenhead, and Messrs. D. Rollo & Sons, Liverpool. His first trip to sea was made in the s.s. "Kansas" in 1886. He obtained his First Class Board of Trade Certificate in 1890 at the age of 24, and had an adventurous career, being shipwrecked in the s.s. "Brunswick" in 1888 and in the s.s. "Kildona" in 1896. He joined the s.s. "Knight Commander" in 1901. This vessel was sunk by the Russians off Yokohama on 24th July, 1904, for carrying contraband of war. Mr. McKay was taken prisoner on the Russian first class cruiser "Russia", released at Vladivostok and travelled across Siberia by train to St. Petersburg, en route for home, and was remunerated by Russia eight years afterwards for the loss of all his effects. In 1909 he was appointed Chief Engineer. After serving for three years in the s.s. "Trentham Hall" he retired from the sea in 1917. Having spent 31 years at sea he was again employed by Messrs. D. Rollo & Sons as assistant foreman until 1929, when he became assistant secretary to The Marine Engineers' Association, Liverpool Branch, until his final retirement in 1940. Mr. McKay held authority to wear the British War Medal Ribbon and the Mercantile Marine Medal Ribbon, 1919. He died on 4th August, 1945, in his 80th year.

William MacFarlane (Member 2876) was born in January, 1874. He served his apprenticeship with Messrs. Denny & Company of Dumbarton from 1890 to 1895. Mr. MacFarlane spent many years at sea and obtained his First Class Board of Trade Certificate. In 1914 he was Chief Seagoing Engineer and in 1940 retired from the Indo-China S.N. Company, with whom he had been since 1924. He died on January 30th, 1945, following a short illness.

James H. Mancor (Member 2297) died on 12th September, 1945, at Southsea. A native of Ayr, he served his apprenticeship with J. & T. Young & Co. of that town and went to sea as a junior engineer in the service of the Pacific Steam Navigation Co. His next service afloat was with the British and African Steam Navigation Co., and, lastly, with the Blue Funnel Line (Alfred Holt & Co.). In 1883 he obtained his First Class Board of Trade Certificate and after a short spell ashore entered the service of the old Underwriters' Register for Iron Vessels, of Liverpool, in the capacity of a surveyor. In September, 1885, the Underwriters' Register was amalgamated with Lloyd's Register of Shipping and Mr. Mancor thus became a Lloyd's Surveyor. His new duties kept him at Liverpool, from which port he was transferred to London, then to Cardiff, and finally to Leith, and the best evidence of the esteem in which he was held by his chiefs was his appointment, early in 1894, to go to New York as the first exclusive Lloyd's Engineer Surveyor in the United States. In 1901, the activities of Lloyd's Register had so far extended in America that Mr. Mancor was raised to Principal Engineer Surveyor, and when the post of Principal Surveyor for the United States was vacant Mr. Mancor was appointed to fill the berth in recognition of his faithful services and with the universal approval of all shipping interests concerned with the efficiency of the Society's work in the matter of ship repairs, alterations, improvements and new construction. Mr. Mancor's retirement in May, 1916, may be said to mark the closing of an era in the history of Lloyd's Register in the United States. When he first arrived in America the activities of Lloyd's Register were chiefly concerned with the surveying of foreign vessels going to those shores, while little by little the scope of the Society's operations was made to include American vessels, so that it became foremost in the esteem of American underwriters, shipowners and shipbuilders. It is in connection with this uphill work in winning American shipping interests over to the strict requirements of Lloyd's Register that Mr. Mancor's success was most marked. This was done without in any way departing from the high standard imposed by the Society, but solely by dint of patience, geniality and eagerness to serve all that went to him for assistance. It was again a case of the human element proving itself indispensable in making the system a success, and the commanding rank which the society has achieved in all countries, including America, is due largely to the loyal effort of its servants, among whom the name of Mr. Mancor will occupy a leading place. After his retirement he was attached to the staff of the British Consul-General in New York, where his long experience and knowledge of shipping affairs was of the utmost value. Mr. Mancor was very active in church affairs in New York, being a Vestryman of the old Parish of Christ Church, Clinton Street. He was the Institute's Vice-President for New York from 1912/13. Mr. Mancor leaves a widow.

James D. Mauchline (Associate 6859) was born on 8th October, 1883. He served his apprenticeship with Messrs. Watson, Laidlaw & Co., of Glasgow, and Messrs. Lees, Anderson & Co., also of Glasgow. For four years he was in the high speed engine and turbine department of Messrs. J. Howden & Co., Ltd., Glasgow. For a time he was engaged on the construction of naval guns at the Coventry Ordnance Works, Glasgow, and then joined Messrs. Mirrlees, Watson & Co. of that city, being engaged on the erection of sugar plant. During the 1914-18 war he was in the Royal Engineers, and for two years prior to this was commercial and technical representative of the Universal Metallic Packing Company, a post which he resumed on leaving the Army. He came from a family of engineers —his father was responsible for the change over from the three-bladed to the four-bladed propeller. Mr. Mauchline could not be persuaded to take a much needed rest and died on 30th September, 1945.

Sidney Owen (Associate Member 3942) died suddenly on 22nd June, 1945. He served his apprenticeship with the Barry Graving Dock and Engineering Co., Ltd., Barry Dock. He was a lecturer in mechanical and marine engineering and was an Associate Member of the Institution of Mechanical Engineers, and Honours Medallist in Marine Engineering. During the war he had entered fully into several services, being a Zone Officer in the A.R.P. and a Flight Lieut. in charge of a unit in Bideford. For the past ten years or so he had been an examiner in engineering subjects for the Union of Lancashire and Cheshire Institutes, and had made quite a name in North Devon as a sound engineer and one always ready to help in any problem. He was in the way of building up for himself quite a large consulting practice. His interest in youths was shown by his membership of the Juvenile Employment Committee for Ilfracombe, and he was very active in many other directions in Barnstaple and the surrounding area. At the time of his death he was a member of the staff of the Barnstaple School of Science and Art.

Hugh Lewis Pirie (Member 8132) was born on 29th November, 1888, and served his apprenticeship with James Abernethy & Co., Aberdeen. In 1909 he became Assistant to the Mechanical Superintendent, Algoma Steel Company of Canada. In 1911 he went to America and continued his studies at Puerdue University. Later he joined the Illinois Steel Company. In 1915 he returned to England and joined the Army. He saw service in France and gained the Military Cross. In 1919 he joined the staff of Stein and Atkinson, Ltd., and later on the Stanton Ironworks Company, Ltd. About that time he initiated the movement from which the Institution of Fuel Economy Engineers originated. He became honorary secretary of that body, which was later merged into the Institute of Fuel, of which Mr. Pirie became a joint honorary secretary and a Member of Council. After a period as chief engineer to Messrs. Caswell and Shearing, Mr. Pirie took up the appointment of chief combustion engineer and adviser to Amalgamated Anthracite Collieries, Ltd., which he held for four or five years before becoming chief engineer to the Coal Utilisation Joint Council. He did excellent work in building up a technical advisory department. In 1939 Mr. Pirie was recalled to active service, and with the rank of Major he served in France with the British Expeditionary Force. In 1940 he was released from the Army on the ground of health and returned to the Coal Utilisation Joint Council. Later on he was seconded by the Council with the complete technical department to the then Mines Department, which became the Ministry of Fuel and Power. Mr. Pirie did much to organise a nation-wide fuel advisory service, which was most helpful to the Government's fuel efficiency campaign and to industry in general. His many friends will mourn his loss. He died in Leeds on 19th September, 1945.

David Wood Paterson (Member 8561) was born on 29th December, 1905, and was a native of Macduff, Banffshire. He served his apprenticeship with the Macduff Engineering Company. Mr. Paterson spent the whole of his time at sea in the service of the British India Steam Navigation Company commencing in September 1928 as 5th engineer. He obtained his First-Class Board of Trade certificate in 1937. During the late war he served in various ships and in March, 1943, when homeward bound in the s.s. "Umaria", the ship was torpedoed and sunk. Mr. Paterson was picked up and arrived in Britain in borrowed clothes, having lost all his possessions. After recovering from injuries received he returned to India, where his death occurred in the Military Hospital at Chittagong on February 2nd, 1946, so far as is known through an explosion in the refrigerating engine room. He leaves a widow and a small daughter who was born five months after her father's return to India.

Isaac L. Pullen (Member 8606) was born on August 25th, 1903. He served his apprenticeship with The Avonside Engine Company of Bristol, went to sea in 1925, and obtained his First-Class Board of Trade Certificate. After spending most of his sea service with the Anglo-Saxon Petroleum Company, Mr. Pullen, in 1936, took up a position as assistant maintenance engineer with Messrs. Sprostons, Limited, and with their affiliated company, The Demerara Bauxite Company, Limited, in Georgetown, British Guiana. He died at Mackenzie, B.G., on November 22nd, 1941.

Vincent B. Pybus (Member 7291) was born in June, 1887. He was educated at Bridlington Grammar School, and obtained his technical training at the Hull Municipal Technical School. His apprenticeship was served with Messrs. Earle's Shipbuilding and Engineering Works, Hull, from 1906 to 1910. Mr. Pybus spent many years at sea with various companies, and obtained his Extra-First Class Board of Trade Certificate. For eight and a half years he was employed by The Silver Line Limited, of London, three years being spent as chief engineer in their vessels and five and a half years as superintendent engineer in Calcutta and the Pacific Coast of North America. In 1933 he set up in business at San Pedro, California, as a consulting engineer. Later Mr. Pybus became wharf engineer of the Singapore Harbour Board, which post he was occupying when taken prisoner by the Japanese and interned in a camp at Sumatra. He died there on November 11th, 1944.

Venkatarama Radhakrishnan (Associate 10398) was born on 22nd September, 1908. He studied at the Engineering College, Benares Hindu University. From 1931 to 1934 he was Special Assistant with Messrs. Shalimar Works, Shipbuilders, Calcutta (Turner, Morrison & Co., Ltd.). He then joined the Mysore Iron Works, Ltd., Bhadravati, Mysore, in the blast furnace department. Later he was engineer in charge of the making and laying of sewerage spun concrete at Messrs. the Hume Pipe (Far East) Ltd., Singapore and supervisor of the ground work for the Singapore Civil Air Port. From 1936 onwards he was Lecturer in Engineering at the Government Technical School, Singapore and Lecturer in Engineering at evening classes at the Government (Electrical) Raffles Institute, Singapore. Mr. Radhakrishnan served in the Singapore Volunteers, being lieutenant and second in command of the Government Technical School Cadet Corps, Singapore. During the war he obtained a commission as a Sapper Officer (Lieut.) in the Indian Army, being later promoted Captain and working as an Intelligence Officer. Captain Radhakrishnan was awarded the M.C. in recognition of a very fine exploit. He was a prisoner of war under the Japanese in Singapore from February to May, 1942, when he escaped, reaching India at the end of August. Captain Radhakrishnan suffered a breakdown in health owing to malnutrition and his long trek and was for some time a patient in the British Military Hospital, Bangalore; it is presumed that he died there as no further details have been received.

Robert Ramsay (Member 9752) was born at Perth on December 23rd, 1888. He served his apprenticeship with the Caledonian Railway Company, Glasgow from 1904/06, and then went to Messrs. Rennie and Prosser, motor engineers, until 1910, after which he took a short engineering course with Messrs. John Brown & Co., Ltd., of Glasgow. In October, 1910, he went to sea as assistant engineer with the P. & O. Company, remaining with them until April, 1915, when he joined the Army and served with the R.A.S.C. until May, 1919. In June of that year he joined the staff of Messrs. Andrew Weir & Co., and served as second engineer on s.s. "Comeric", and two years later became chief engineer on the "Monaduock". Mr. Ramsay subsequently held this position on various vessels belonging to this company. During the course of his sea-going career he obtained his First-Class Board of Trade Certificate. In October, 1938, he was appointed to the staff of United Baltic Corporation as marine superintendent, and continued to hold that position until the time of his death, which occurred suddenly in Liverpool on February 12th, 1945.

Harry L. Rees (Associate Member) died on December 17th, 1945. He served his apprenticeship with Messrs. Fawcett Preston of Liverpool, and the Vulcan Foundry Company, of Earlstown, Lancs. Mr. Rees went to sea and obtained his Second-Class Board of Trade Certificate, but details of his subsequent activities are not known at present.

W. A. Reynolds (Member 2867) served his apprenticeship with London & India Docks (now the P.L.A.) He spent eight years at sea, during which time he obtained his First-Class Board of Trade Certificate. In 1914 Mr. Reynolds was on the staff of Messrs. Babcock & Wilcox, Limited. He was later in charge of the erection of large land plants in various countries, working from the London office. At the time of his death, which occurred on April 23rd, 1945, Mr. Reynolds was manager of the Melbourne office of Messrs. Babcock and Wilcox, Limited.

John Lyth Richardson (Member 2975) of Messrs. J. L. Richardson & Sons, Ltd., Consulting Marine Engineers and Ship Surveyors, Hull, was born in 1865 and served his apprenticeship with Earle's Shipbuilding & Engineering Co., Ltd., Hull. He later went to sea as a marine engineer, obtained his certificates, and afterwards came ashore and started as a consulting marine engineer and ship surveyor in Hull. He was very well known throughout the country, as during his early days he did considerable salvage work in the Humber district and had during this time considerable experience of Admiralty court work. During the last war and afterwards, Mr. Richardson acted for the Ministry of Shipping as District Superintendent for the area from Whitby to King's Lynn. He was a founder member, and President in 1930, of the Society of Consulting Marine Engineers and Ship Surveyors and was, for many years, Chairman of the Humber District and Member of the Council.

WILLIAM A. RICHMOND (Member 8144) was born on 18th February, 1885. He served his apprenticehip with Messrs. C. D. Holmes and Company of Hull. In 1909 he went to sea in the service of W. H. Cockerline & Company and obtained his First Class Board of Trade Certificate. Mr. Richmond was Chief Engineer when he resigned and took up the position as Secretary to the Hull Branch of the Marine Engineers Association, which post he held from September, 1933, to September, 1942. Afterwards he became Joint Secretary at the Hull Branch of the Navigators and Engineer Officers' Union. For some time he was the Honorary Treasurer, Hull Association of Engineers. Mr. Richmond died on December 1st, 1945, at the age of 61.

LEWIS RAPHAEL RICKINSON, Engineer-Commander, R.N. (Member 8529) was born on 21st April, 1883. He served his apprenticeship with A. Harker & Co., of Stockton-on-Tees. Commander Rickinson was chief engineer with Sir Ernest Shackleton's Antarctic Expedition, 1914-16. In later years he became partner of Wells and Kemp, consulting naval architects, London. Mr. Kemp died in 1927 and the firm was later conducted under the style of Wells and Rickinson. They had a considerable consulting practice with the Crown Agents for the Colonies. Commander Rickinson went to sea at the age of 20 as fourth engineer in a tramp steamer and subsequently was with Scrutton's Direct Line to the West Indies and with C. T. Bowring & Co., Ltd. He was consulting engineer to Jacobs & Barringer when he joined the Antarctic Expedition as chief engineer of the "Endurance". Commander Rickinson died at Newbury, Berks., on 16th April, 1945.

JAMES RIGBY (Member 8645) was born at West Hartlepool on 4th March, 1902. He served his apprenticeship there at the Central Marine Engine Works. On leaving the Engine Works he went to sea with the British India Steam Navigation Co., and obtained his First Class Board of Trade Certificate. In 1937 he joined the Takuapa Tin Dredging Company, South Siam, as engineer. When that country became involved in the war he escaped to Penang, then to Singapore and later to India. There he became attached as a Captain to a special service branch of the Army, and his knowledge of native dialects was such that he was entrusted with many important and dangerous missions. From April, 1944, to January, 1945, he was Engineer in Charge of Force 136, Bombay. Mrs. Rigby returned to this country before the war began and Captain Rigby joined his family when he came home on leave in January, 1945. He took up a post in Malaya in August of that year and met with a fatal accident within two or three months of his arrival. He leaves a widow and two children. Captain Rigby was an Associate Member of the Malayan Dredging Association and a Member of the Diesel Engine Users Association.

THOMAS E. ROBSON (Member 6087) was born at Seaham Harbour, Co. Durham in 1883. He was educated at the Church School there and at Rutherford College, Newcastle-on-Tyne, and served his apprenticeship at the Central Marine Engine Works, West Hartlepool, from 1899 to 1904. From 1904 to 1908 he was a junior engineer with J. F. Wilson & Co., of West Hartlepool, afterwards going to sea and obtaining his First Class Board of Trade Certificate. In 1908 he was second engineer in the s.s. "Balaclava", owned by the Agincourt Steamship Company, and in the early part of 1914 was Chief Engineer in the s.s. "Northwestern Miller". From 1914 to 1930 he was Chief Engineer with the Furness Withy Line, chiefly on the Western U.S.A. trade route. He also supervised the building of ships for this Company in Copenhagen and Glasgow. He afterwards joined the Prince Line as Superintendent Engineer, first in Singapore and later in Hong Kong. In 1940 he left Hong Kong and returned to Singapore, leaving here for the United States in 1941. From 1941-45 he was Superintendent Engineer in New York and Baltimore, leaving in April, 1945, to serve in the same capacity in Montreal, where he met his death in a street accident in October of this year.

GEORGE RICHARD RUSSELL (Member 8449) was born on 25th April, 1885. He served his apprenticeship in Sunderland, first with Messrs. Wigham, and then at Scotia Works. He obtained his First Class Board of Trade Certificate and was at sea from 1904 until January, 1945. In 1937 he was appointed Chief Engineer with the British Tanker Company. His death occurred on the 7th July, 1945.

THOMAS D. SCORER, Sub. Lieut. (E.), R.N.R. (Associate 9306), was born on June 9th, 1913, and served his apprenticeship with the Wallsend Slipway and Engineering Company from 1930/35 when he entered the Drawing Office of this Company. During 1937/9 he was a seagoing engineer with the Shaw, Savill & Albion Company, obtaining his Second Class Board of Trade Certificate. In 1939 he was Acting Sub. Lieut.(E.), R.N.V.R. in H.M.S. "Mersey", being promoted to Sub. Lieut.(E.), R.N.R., in October, 1941. He was a Graduate of the Institution of Mechanical Engineers. In 1943 it was reported that Sub. Lieut. Scorer was missing and his death must now be presumed.

JAMES SHEPHERD (Member 4534) was born on 16th November, 1882. Having served an apprenticeship at Messrs. Earle's Shipbuilding and Engineering Company, Ltd., Hull, he went to sea and in record time obtained his Extra Chief's Board of Trade Certificate. Then followed his acceptance of the position of Secretary of the Hull Branch of the Marine Engineers' Association, which post he held until he joined the Inland Water Transport Section, Royal Engineers during the first world war. After demobilization, Mr. Shepherd assisted the late Mr. A. N. Somerscales in the coaching of marine engineer officers for their Board of Trade Certificates, and also teaching evening classes at the Technical College, Hull. In 1922 he was appointed Consulting Engineer with J. Watt Peterson & Co., Hull, and in 1936 became Branch Manager for the Beldam Packing and Rubber Co., Hull. From 1940 until his death he was Manager for the Humber District of this Company. He died on 25th August, 1945.

A. K. SOWTER (Member 10478) was born at Greenock in 1880 and was educated there at Kiblains Academy, and subsequently at St. Dunstan's College. Most of his apprenticeship was served with The General Steam Navigation Co., Ltd., at Deptford, but the last six month's of his training he received at the Belfast works of Messrs. Harland & Wolff, Ltd., with whom he subsequently remained for about four years as a draughtsman. He commenced his sea career in 1905 with the Royal Mail Steam Packet Co., in whose service he remained for the next 11 years. During the latter part of this time he served as Eng. Lt.-Com., R.N.R. on the armed merchant cruiser "Alcantara". From 1916 to 1924 he was employed as manager at several yards of Messrs. R. & H. Green & Silley Weir, Ltd., and then he became general manager of Messrs. S. Hodge & Sons, Ltd., of Millwall. In 1926 he established himself as a consulting engineer and surveyor, a business in which he remained engaged until the time of his death, which occurred on the 16th April, 1946.

WILLIAM BROWN STEVENSON (Member 8426) was born on February 15th, 1892. He served his apprenticeship with Messrs. T. & J. Stevenson, Kilmarnock. Mr. Stevenson went to sea in 1914, and obtained his First-Class Board of Trade Certificate. From 1916 to 1919 he was a Sub. Lieut. (E), R.N.R. In August, 1919, he joined the Bank Line as 2nd engineer, being promoted to chief engineer in 1922. In the autumn of 1924 he spent a few months in Messrs. Harland and Wolff's Diesel shops, and in January, 1925, returned to the Bank Line, serving as chief engineer in various ships until January, 1943. In June, 1943, he was appointed chief engineer with The Hain Steamship Company, and went out to Vancouver to take over the "Fort Bellingham" from the builders. The vessel loaded on U.S.A. West Coast ports and discharged in London late in that year. On completion of discharge the "Fort Bellingham" was fitted out for the North Russian trade, on which voyage she was lost owing to enemy action off Cape North on January 26th, 1944. Mr. Stevenson was not amongst the survivors, and his death was therefore presumed on that date. He left a widow, who passed away just a year afterwards.

JOHN J. TAIT (Member 9050) was born on September 10th, 1886. He served his apprenticeship with Messrs. Davidson & Company of Belfast, and following this went to the Belfast Engine Works of Messrs. Harland & Wolff to gain experience in marine engine work prior to going to sea. From 1912 to 1917 he was at sea in the service of the Shaw Savill & Albion Company and during that time obtained his First Class Board of Trade Certificate. In 1917 he joined the Atlantic Transport Company and later the Eagle Oil Transport Company, remaining until 1919 when he entered the service of Coast Lines Ltd., attaining the rank of Chief Engineer. Mr. Tait was a member of the Marine Engineers Association. He died in November, 1943.

ROBERT RICHARDSON TURNBULL (Member 5065) was born on 12th July, 1884, and served his apprenticeship with Robert Shiel & Son, Berwick-on-Tweed, and Fawcett, Preston and Company, of Liverpool. He then spent four years at sea with T. & J. Harrison, Ltd., Liverpool, obtaining his First Class Board of Trade Certificate. Joining the firm of H. & C. Grayson Ltd. (later Grayson, Rollo & Clover Docks, Ltd.) in 1909 as a draughtsman and assistant repair manager, he became manager of their repair works at Liverpool two years later, and at various times acted as manager of other branches of the firm's activities until his appointment as general manager, a position he held for 16 years. In August, 1938, he severed his connection with the firm and for a short time represented Harland & Wolff, Ltd., in their repair work branch until he was appointed managing director of the "J.D." Insulating Co., Ltd., in 1939. For some years Mr. Turnbull was the Mersey representative in London on the executive committee of the Shipbuilding Employers' Federation. He was a member of the Institution of Naval Architects, and a past-president of the Liverpool Marine Engineers' and Naval Architects Guild. Mr. Turnbull was attending a Masonic consecration of a new Chapter, Perseverance, of which he had just been installed the first head, and was rising to reply to a toast when he collapsed and died almost immediately. He had not been in good health for some years.

JOHN S. WILKIE (Associate Member 5761) was born on 4th February, 1897. and served his apprenticeship with Smith's Dock Co., Ltd., North Shields. He commenced his sea career in November, 1917, and served in the Mercantile Marine during both world wars, obtaining his Second Class Board of Trade Certificate. In 1927 he was appointed second engineer with Messrs. Capper Alexander & Co. His death occurred on 10th December, 1945, and he was the last seafaring member of a family that had been connected with the sea for many generations.

WILLIAM F. WELCH (Associate 9375) was born on February 2nd, 1913. He received his technical education at the Rutherford Technical College, Newcastle, and served his apprenticeship with Sir W. G. Armstrong Whitworth & Company, Limited, Scotswood. In 1934 he went to sea as Assistant to Senior 4th engineer with the Anglo-American Oil Co. He joined Messrs. Alfred Holt & Company as Assistant to 3rd engineer in 1936, remaining with them until his resignation in 1942, when he was 3rd engineer. During the course of his sea-going career Mr. Welch obtained his First Class Board of Trade Certificate. His death was reported in December, 1945.

NORMAN A. YOUNG (Member 8971) was born on May 13th, 1902. He was educated at Le Fevre's Peninsular School, South Australia, and Woodville and Adelaide High Schools, and served his apprenticeship with The Adelaide Steamship Company Limited, of Sydney, N.S.W. He went to sea in October, 1923, as 4th engineer with the Adelaide S.S. Company, Ltd. From December, 1931, to October, 1932, he was 3rd engineer with the Hadley Shipping Company, Ltd., and in March, 1933, joined Messrs. Cable and Wireless, Ltd., with whom he remained three years, being promoted from 5th to 3rd engineer. For ten months in 1936 he was junior engineer with The Glen Line, London, and then for three months was with Messrs. Huddart, Parker, Ltd., of Australia. Mr. Young finally joined Messrs. Burns, Philp & Company, Ltd., of Sydney, and was chief engineer of m.v. "Muliama". He died, through enemy action, on March 27th, 1944, whilst serving as 2nd engineer in the m.v. "Tulagi". Mr. Young was a member of the Australian Institute of Marine and Power Engineers, Sydney, N.S.W.

To the Members, *15th February, 1946.*
THE INSTITUTE OF MARINE ENGINEERS,
85/88, THE MINORIES, E.C.3.

Gentlemen,—

We have to report that we have examined and checked the Accounts of your Institute for the year ended 31st December, 1945, and we set out below our observations.

(1) The Revenue Account shows a surplus of £1,553 2s. 0d. as compared with £679 5s. 9d. last year, an increase of £873 16s. 3d.

(2) The Gross Revenue was £11,436 6s. 4d., an increase of £833 6s. 3d. made up as follows:—

	Decrease. £ s. d.	*Increase.* £ s. d.
Subscriptions	—	728 3 1
Entrance Fees	—	28 10 0
Examination Fees	—	8 10 0
Advertisements	—	105 9 9
Rent Receivable	90 6 3	—
Interest	—	47 4 1
Hire of Hall and Library	—	2 5 0
Sundry Sales	—	3 10 7
	90 6 3	923 12 6
Deduct: Decrease	... ...	90 6 3
Increase as above		£833 6 3

(3) Expenditure charged to Revenue Account amounted to £9,883 4s. 4d., an increase of £199 18s. 0d. made up as follows:—

	Decrease. £ s. d.	*Increase.* £ s. d.
General Expenses	—	263 1 11
Rent, Rates, etc.	45 11 2	—
House Account	—	146 3 11
Repairs	—	74 14 9
Insurance	5 14 9	—
Transactions	203 10 8	—
Transactions (Bound Volumes) ...	—	45 19 2
Library and Reading Room Account	7 11	—
Depreciation	8 0	—
Prizes	—	25 10 9
Transfer to Pension Fund	100 0 0	—
	355 12 6	555 10 6
Deduct: Decreases	... ...	355 12 6
Increase as above		£199 18 0

(4) The increase in Surplus Revenue is made up as follows:—

	£ s. d.
Increase in Income	833 6 3
Less: Increase in Expenditure	199 18 0
	633 8 3
Add: Loss on Redemption of 5% Conversion Loan in 1944	240 8 0
Increase in Surplus Revenue	£873 16 3

(5) *Sales of Handbooks.*

The following profits have been made during the year:—

"The Running and Maintenance of Marine Machinery" £158 4 0
"Electricity Applied to Marine Engineering" £58 6 8
"Naval Architecture and Ship Construction" £179 11 10

(6) *Investments.*

The market value at 31st December, 1945, of the Institute's free Investments standing in the books at £25,408 18s. 8d. was £25,730. During the year £3,500 Local Loans 3% Stock has been purchased out of general funds at a cost of £3,405 19s. 6d.

(7) We have verified the Investments and Bank Balances and have inspected the Insurance Policies and Title Deeds, and we have obtained all the information we have required. In our opinion the Balance Sheet of your Institute has been properly drawn up so as to exhibit a true and correct view of the Institute's affairs according to the information and explanations given to us and as shown by the books of the Institute.

Yours faithfully,
WEST & DRAKE,
Chartered Accountants.

Murdoch Legacy	2 10 0	
		24 0 0
,, Library and Reading Room Account ...		52 5 7
,, Depreciation of Furniture		42 10 0
,, Heat Engines Prizes	52 10 0	
,, *H.M.S. Worcester* Prize	2 2 0	
,, Silver Medal	2 2 0	
		56 14 0
,, Reserve for Repair and Renewal of Premises		1,000 0 0
,, Transfer to Pension Fund		100 0 0
		9,883 4 4
,, Balance, Excess of Income over Expenditure for the year, carried to Balance Sheet		1,553 2 0
		£11,436 6 4

	£11,436 6 4

SOCIAL EVENTS ACCOUNT.

Dr. | *Cr.*

	£ s. d.		£ s. d.
To Payments	874 17 4	By Balance at 31st December, 1944	169 15 5
,, Balance at 31st December, 1945	317 3 1	,, Receipts	1,022 5 0
	£1,192 0 5		£1,192 0 5

LIBRARY AND READING ROOM ACCOUNT.

	£ s. d.		£ s. d.
To Reading Room Expenses	31 3 3	By Sales	11 7 3
,, Book Purchases and Binding...	32 9 7	,, Revenue Account	52 5 7
	£63 12 10		£63 12 10

I ask this company to drink the health of the Institute of Marine Engineers. I couple with this toast the name of my friend the President, Sir Amos Ayre. The fact that he is sitting where he is is a further ground for complimenting the Institute and its members. (Applause).

Sir Amos L. Ayre, K.B.E. (President), who responded, said: First of all, I should like to say that we have received a telegram from the Polish Naval Representative, stating that he regrets being unable to be with us.

On behalf of the Institute, I should like to thank Mr. Jacobs for the very kind remarks he has made in proposing this toast, and to thank this good company for the way in which it has received it. We appreciate those remarks all the more in that they come from the head of that fine old classification society, Lloyd's Register. There is one thing that Mr. Jacobs omitted from his speech; he did not say anything about the rumours we have heard, and of which we have read in the press, regarding an amalgamation of our two classification societies. In these days, when it behoves this country to make all its organisations as strong and powerful as ever it can, it seems to me that the time has arrived for that amalgamation. However, perhaps the subject is *sub judice,* and so I will say no more about it. Mr. Jacob's dissertation on insurance was certainly interesting, particularly to some of us who are concerned with premiums! (Laughter).

In that connection, I sometimes wonder whether it is widely recognized what a change has taken place in recent times in regard to safety at sea; I mean, safety from all the perils of the sea, foundering and so on. Is it realised that at the beginning of this century the losses due to those perils amounted to about 1½ per cent. of the world tonnage afloat in any year, whereas by the beginning of the recent war that rate had been reduced to something less than 0·5 per cent.? I think that a certain amount of credit is due to engineers and shipbuilders and classification societies and all others concerned, but as far as the engineers and shipbuilders are concerned, it would be a very kindly recognition of their part in it if something could be done with regard to premiums.

At the moment, the industry—I am engaged in the production side of it—has very much in mind a close examination into all matters that lead to economy. We have in mind all those services and supplies generally that go to make the finished ship. When all is said and done, marine engineering and shipbuilding are assembling industries, and we therefore look with a jealous regard on all those things that we have to assemble, whether they are goods or services, when the level of prices which they reach looks rather abnormal compared with 1939. I say this particularly because I want to give shipowners the assurance that productive industry is very conscious of their needs. It seems to me that it behoves everyone, whatever part he plays in the whole chain of operations, whether he be the merchant who is purchasing and assembling and collecting materials from the far corners of the earth which come to this country and eventually find themselves going out again in the form of a ship, whether he be concerned with transport or with the processing industries, or with the production of the finished article, to have the fullest regard to what, when all is said and done, spells efficiency.

There are probably some here to-day who yesterday sat for many hours listening to the Prime Minister and other Ministers telling us what a very important part exports are going to play in our life in future, and particularly in the next few years. It is to some extent for that reason that I make this reference to the fact that we must look to our laurels and obtain efficiency so far as our production costs are concerned.

I should like to assure the shipowning industry that technical progress is going on. That is evident to anyone who cares to read the Transactions of the Institute of Marine Engineers. I for one, as a shipbuilder, humbly admit that I have learned a good deal even about shipbuilding in reading those Transactions. But the point is that all that work is going on, sometimes unseen, and I think it is not always realised what a very great benefit it is to the shipping industry of the country.

Mr. Jacobs has referred to the fact that the membership of this Institute is approaching 5,000, and that shows the intense interest of those concerned. He also referred to the Annual Report of the Council, which was presented to the Annual General Meeting this morning and is a most illuminating document; it shows all the various ramifications with which the Institute is concerned, and it indicates the various organisations who seek to consult with our members and our Council, and what a very large part is played in the general make-up of things by the Institute of Marine Engineers.

There was a particular item in that Report which caught my attention, and that was the reference to the Report of the Merchant Navy Training Board. I hope that very full regard will be paid to the very practical amendments which have been proposed by this Institute. Full use should be made of the enormous amount of valuable experience possessed by this Institute in a matter of that sort. Not only has it considerable and very valuable experience of the past, but it is also second to none in its ability to envisage the requirements of the future; and in this connection it is necessary to remember the very rapid advance which has taken place and which is continuing to take place in the design of propelling machinery. A very large part of this endeavour is directed to obtaining greater economy in fuel consumption, and that in turn involves the introduction of more intricate and delicate machinery and equipment. That feature alone demands that the fullest attention should be given to training.

I should also like to refer to the appeal launched by our Past President, Sir William Currie. I should like to take this opportunity of saying how sorry we are that illness prevents him being here to-day. I myself have been associated with him in various capacities of a public and semi-public nature over a long series of years. We all know how much valuable work he has done, and we all appreciate that during his year of office he did a great deal of valuable work for this Institute. (Applause). He was personally responsible for launching the appeal in connection with our new headquarters. As you all know, we shall have at some time or other to vacate our present premises on account of the re-planning of the City of London. The new building, which is to be regarded as the Marine Engineers' National War Memorial, is intended to be a fitting tribute to the 4,500 marine engineer officers who lost their lives during the war. I ask all those into whose hands this very fine appeal, which I understand was issued either yesterday or to-day, comes to respond to it, and I hope that every member of the Institute and every friend of the marine engineers will assist in doing everything possible to achieve this very grand object. (Applause).

In conclusion, I should like to take this opportunity of thanking publicly the membership for the honour they have done me in electing me President of this great body. It is a particular honour to me as a shipbuilder. I appreciate that I am now entering a conclave devoted to a science which is perhaps very much more profound than my own, but I shall do my best to try to keep pace with it. I am reminded of a story I once heard on the Tyne of two shipyard fitters, one of whom left to get a job in a marine engineering firm not far away, making turbines. One night the two cronies met in the local, and the one who still remained in the shipyard was anxious to know how Geordie was getting on in his new job. "Oh", said Geordie, "it's wonderful. They work to thousandths; you can't use a two-foot rule there". "Thousands?" replied Jim, "How many of them go to an inch?" "Blimey", retorted Geordie, "millions!" (Laughter and applause).

"THE GUESTS".

Mr. Robert Rainie, M.C., M.I.Mech.E., M.I.Mar.E., who proposed the toast of the Guests, said: Sir William Currie, our immediate Past President, is unfortunately not able to be with us this afternoon owing to illness. He was to have dealt with this toast, which Sir Amos Ayre has now assigned to me. The Institute of Marine Engineers can congratulate itself on having drawn together on this occasion so many highly placed and prominent people as its guests, and so many guests of its members. I am called upon to propose the toast of these guests. When my friend Alfred Robertson, the Chairman of the Social Events Committee, told me about this, a free translation of what he said would amount to this: "Rainie, you are well down on the toast list. The important speakers will have done their stuff. You are only a stop-gap, anyway; so if not for my sake or your own sake, for heaven's sake be brief" (Laughter). That was good advice, but I am sure you would not have me deal with this job in anything like a perfunctory manner.

While we honour all our guests, I cannot mention everyone of them and may possibly make mistakes in the order of precedence. The civic toast has been dealt with, but I would add that we of the Institute feel that the presence of the Lord Mayor among us will cement, if not for a hundred years, at least for his term of office, the long standing association between the Institute and the Corporation of the City of London. Among the prominent guests on the list is the First Lord of the Admiralty, the Rt. Hon. A. V. Alexander, who is an Honorary Member of this Institute. We are denied the pleasure of his company because of a Royal command to him, which he must obey. The great Service which he so ably guided during the war years is, however, well represented by Vice-Admiral Sir Arthur Power, the Second Sea Lord, and by the Engineer-in-Chief of the Fleet, Vice-Admiral Sir John Kingcome, who, very appropriately, is a Vice-President of the Institute. We accord them a very hearty welcome indeed. I have also the opportunity to offer very sincere greetings and a hearty welcome to one of our Vice-Presidents for the Merchant Navy, Mr. Norman Wright. There are very few social occasions on which he can be with us, and we are very glad to meet him.

We are delighted also to have with us Admiral of the Fleet Viscount Cunningham. (Applause). He has just retired from the post of First Sea Lord and relinquished his most onerous and responsible duties. We wish him in his retirement good fishing and good golf, both of which, peculiarly enough in the case of a Scot, he looks on as recreations. We welcome also the President of the Institution of Naval Architects, Admiral Lord Chatfield (Applause). Between his Institution and our Institute there are the happiest relations, and in fact we have the pleasure of making our premises in the Minories available to its members for their Spring Meetings.

Our gathering is honoured by the presence of one who during the war held in his hands the destinies of the Merchant Fleet in which so many of our members served throughout the war years and are serving to-day. We remember that as Minister of War Transport, Lord Leathers instigated the formation of the Committee whose report on the post-war training of officers and ratings has now been issued. The recommendations in that report are of vital importance to our Institute, as they affect the status of engineers in the Merchant Service. While this Committee has made its recommendations, I should like to refer to the legend of King Robert the Bruce and the spider, and to remind the Institute and its Council that Bruce's spider spun its own ladder.

We also welcome very warmly to-day representatives of several of the United Nations—Belgium, China, Greece, Norway, Poland and Russia, our allies and friends. We give them, as always, a very sincere welcome. (Applause).

I now wish to refer to Admiral Hewitt, of the United States Navy, who is to reply to this toast. (Applause). Admiral Hewitt commenced his naval service in 1903 and reached his present rank in November, 1943. In the war now alleged to be ended (Laughter) he commanded squadrons in the Pacific, and he became directly associated with our squadrons and our Merchant Fleet in 1941 and 1942, when he commanded the Atlantic Fleet Task Group (Applause). Thereafter he held various commands in the Mediterranean, and participated in the operations for the landing in North Africa, the invasion of Sicily and the landing at Salerno. He was for a time under the command of Viscount Cunningham (Admiral Sir Andrew Cunningham, as he then was), and in August last he assumed command of the United States Naval Forces in Europe. What other or better words can I say than "Welcome, friend! Welcome comrade!" (Applause). History records nothing in war or peace to compare during the past six years with the friendship, the comradeship and co-operation between his country and ours, between his Service and ours. (Applause). There are few propositions that I could put to the Council and members of this Institute with the certainty of their unanimous approval, but I know that the proposal that I now make is one of them; and it is that we of the Institute rise and drink to the very good health of our guests. (Applause).

Admiral H. K. Hewitt (Commander, U.S. Naval Forces in Europe), who received an ovation on rising to respond, said: I am not a public speaker, but I feel that this assembly gives me considerable inspiration. When I received my invitation to this very pleasant occasion I was very thankful. I was very much honoured when I was invited to respond to the toast of the guests, and I accepted, though with some trepidation. I must admit that my feeling of trepidation was greatly increased when I received this morning a list of the distinguished guests, and still more when I saw the size of this assembly; but I should like to say that I also felt more honoured than ever, and I accept it as a compliment to my country and to my Service. (Applause).

Not so long ago—in fact, my first trip to sea was made in a steam brig—sailors more or less looked down on engineers; they did not like the cinders on their white decks, and they did not like to have their sails soiled. In our Navy there were many captains who refused to use their engines unless they had to. In those days the story is told in our Navy—you may have heard it—of two ships in company which were trying to go through some narrow waters and were faced with adverse currents and wind. The commodore told the junior captain to take him in tow, which was done, and they towed and towed, but did not seem to be getting anywhere. At last the junior captain sent a signal back to the commodore—

"If wind and tide do not abate
We cannot get you through the strait".

Quickly came the reply:

"As long as you have wood and coal,
You'll tow us through, God damn your soul!" (Laughter).

Nowadays, however, we cannot get anywhere without the marine engineer. Great strides have been made in marine engineering, and great strides have been made particularly during this war period. I bear honour to those marine engineers who lost their lives in the Allied cause. I give praise to the marvellous feats which were accomplished in constructing ships, in keeping them afloat, and in getting them going again when they had been damaged, I give praise to the marine engineers. I know that I speak for all my fellow-guests as well as myself when I say how greatly I appreciate being here and the honour which you have done us. (Applause).

The proceedings then terminated.

THE INSTITUTE OF MARINE ENGINEERS GUILD OF BENEVOLENCE—Twelfth Annual General Meeting.

The Twelfth Annual General Meeting of the Institute of Marine Engineers Guild of Benevolence was held in the Institute Library on Tuesday, 30th April, 1946, at 3 p.m. Mr. James Carnaghan, Chairman of the General and Executive Committees, was in the Chair, and there were present eleven members and officers.

Before proceeding with the business on the agenda, the Chairman read the following letter from Mr. H. A. J. Silley:—

130, Leadenhall Street,
London, E.C.3.

Dear Mr. Carnaghan,

I write to ask your indulgence for this afternoon. Unfortunately, I have a meeting at 3.30 which I cannot possibly put off, and this, I fear, precludes me from attending the meeting of the Guild of Benevolence.

The Report makes very encouraging reading and it is good to see the funds of the Guild mounting year by year. There is no doubt in my mind that you have not yet felt the heavy calls which will be made upon you, arising out of the late war.

Please accept my apologies for my failure to attend the meeting this afternoon.

Believe me,
Yours sincerely,
(Signed) H. A. J. SILLEY.

A letter had also been received from Mr. A. H. Ledger expressing regret for his unavoidable absence due to ill-health.

The Chairman in his opening remarks, said:—

"On behalf of the Guild of Benevolence I tender our sincere thanks to the Institute of Marine Engineers for their continued support by affording us the efficient services of their Secretary and his assistant, Mrs. Watson. If it were not for their gratuitous services the expenses of administration would be increased considerably beyond that of slightly over 6 per cent., the greater present expenses being mainly for postage in distributing relief.

During the past year the Committee have had several interesting cases brought before them. Amongst these the following may be mentioned:—

(a) A Member of the Institute, whose wife was seriously ill, was granted sufficient relief to cover the hospital fees.

(b) A widow to whom, owing to the limitation of the old age and supplementary pensions regulations the Committee were prevented from giving regular relief, was given a grant to aid her after an illness.

(c) The orphan son of a late Member of the Institute, whom the Committee has assisted during his studies, has been placed on the waiting list of Messrs. Clarke, Chapman's Works for entry as an apprentice engineer upon termination of his school career in July next. The Committee has to thank Mr. W. A. Woodeson for this good office.

(d) The son of a late Member of the Institute is being assisted during his education by a grant given to his mother.

In other cases, where children are being assisted during their education, very satisfactory reports have been received regarding their progress.

It may be mentioned that, upon the termination of the war, the Committee gave a special victory grant to each recipient of relief, including a few deserving cases in which relief had not been given owing to the restriction of the supplementary pensions authority. These grants were additional to those given at Christmas time.

At each Annual General Meeting we have pleaded with those Members of the Institute who have not yet become members of the Guild, and we again ask them to do so without further delay in order to assist in the good work of helping those in necessity.

Meanwhile, whether members of the Guild or of the Institute, should they become aware of any cases of distress affecting members or their dependents they should forward particulars to the Secretary, when the Committee will endeavour to grant relief".

The Secretary then read the Annual Report (see page xxviii).

The Honorary Treasurer next presented the official Auditors' Report on the Annual Accounts (see page xxxi), and his own report thereon, as follows:—

"The audited accounts of the Guild of Benevolence for the year ending 31st December, 1945, are in your hands and I have pleasure in reading the Certificate attached to the accounts as given by our official Auditors.

There are not many fresh points upon which I can make any comment. The main thing is that the Guild is extending its usefulness and the total capital funds at our disposal are showing a steady increase, although one has frankly to admit that the increase in our Capital position during the last year is mainly, and in fact almost entirely, due to the generosity of Mr. H. A. J. Silley and Major B. L. Silley.

Looking at the Balance Sheet you will see the Capital Account is increased from £24,687 6s. 6d. to £25,197 10s. 9d., an increase of £510 4s. 3d.

The John H. Silley Memorial Fund is increased by £2,250 to £16,750.

The balance on Income and Expenditure Account is also increased by £430 5s. 5d. to £4,514 7s. 2d.

On the Assets side we have increased our investment of 3 per cent. Local Loans by £250, the Capital Fund being increased by that amount also to £13,971 9s. 5d. There is a small difference of £3 19s. 0d. in this figure, which is accounted for by the price of purchase.

Investments on account of the John H. Silley Memorial Fund show £1,965 4s. 0d. against an actual increase on the other side of £2,250. This is explained by the fact that the difference, viz. £254 16s. 0d. is at the present moment in cash at the Bank and is included in the item of £351 4s. 1d. This will, of course, be invested shortly as further amounts are received.

The freehold Ground Rents remain at the same figures as for the previous year.

Our investments under Revenue Funds also remain exactly the same as last year.

The cash at Bank and in hand which represents the balance at the Bank on Revenue Account, as well as monies invested in the Post Office Savings Bank is higher by £407 3s. 8d., bringing the total to £1,315 9s. 4d. as against £908 5s. 8d. last year.

In the final result our capital assets stand at £46,461 17s. 11d. as compared with £43,271 8s. 3d. last year.

I should like to point out in connection with the increase under the John H. Silley Memorial Fund of £2,250, £1,500 of this is represented by Income Tax reclaimed, £500 from Mr. B. L. Silley and £250 from Mr. H. A. J. Silley. The balance of £750 from Mr. H. A. J. Silley was credited in the previous year.

Turning to the Income and Expenditure Account, it is disappointing to find that the annual subscriptions are actually reduced by £11 7s. 11d. They still only stand at £380 10s. 0d., which is really very small in comparison to what it ought to be if every Member of the Institute became a subscriber to the Guild. This is surely the target to be aimed at but we seem to be making very slow headway in this direction.

We have received another contribution of £250 from the King George's Fund for Sailors.

Our income from dividends is higher by £155 13s. 1d., the total income from dividends, Income Tax recovered, Bank Interest on Deposits and Rents being higher by £222 11s. 9d.

During the past year your Committee have increased the scale of relief to some extent as well as in ways already indicated by the Chairman. You will note with gratification that the amount distributed has been increased from £1,367 6s. 3d. to £1,595 14s. 6d. By doing so the balance of income over expenditure is reduced from £541 2s. 10d. to £433 13s. 11d.

We cannot but feel great satisfaction at the financial position of the Guild as it stands to-day and in reflecting on this very satisfactory position to cast our minds back and remember our Past-President, Mr. John H. Silley, for his work in inaugurating the Guild, and the very fine support which is still being given by his two sons.

Mr. F. M. Jones (Member) in proposing the adoption of the Report and Accounts, said that it would be noted that of the 41 applicants who received relief during the past year, 15 were members and 26 non-members of the Institute or the Guild. He emphasized the aspect that the Guild was of assistance to non-members, which showed the wide scope of its operations; approximately one half of the amount distributed was to people who were not connected with the Institute. With regard to the percentage of members of the

Institute who were members of the Guild, he understood that similar conditions prevailed in kindred institutions, but he urged that nevertheless every effort should be made to increase the number of members from the Institute's Roll. Further, it would be a very good thing if more members could be persuaded to covenant their subscriptions.

The Report just read by the Honorary Treasurer spoke for itself, and he had much pleasure in proposing that the Report and Financial Statement be adopted.

Mr. F. P. Bell (Member) endorsed the previous speaker's remarks and had pleasure in seconding his proposal.

Mr. T. A. Crompton (Member) commented on the fact that both the Honorary Treasurer and Mr. Jones had emphasized the small proportion of members of the Institute included in the Membership Roll of the Guild. In this connection he remarked that this was the first time that no donation had been made by the Institute to the Guild. He personally regretted that the Institute's name did not appear in the list of donors, and he thought that the members generally would share his feeling on this point.

The Honorary Treasurer said that Mr. Crompton had drawn attention to this matter on a previous occasion. He (the Honorary Treasurer) could assure him that if the Guild should be in the position to require a donation to meet its expenditure, it would be forthcoming. He suggested that the main question to which the Committee should devote attention at the moment was that of increasing the Membership.

Mr. Crompton replied that his suggestion was not put forward on financial grounds so much as from the point of view that there should be at least a token donation from the Institute.

The Honorary Treasurer said that this matter would be given due attention by the Council.

The adoption of the Report and Financial Statement was then carried unanimously.

Mr. G. Speck (Member), proposed the re-election of Mr. J. Carnaghan as Chairman of the General Committee for the ensuing year. He referred to the fact that for the past ten years since he took over the office of Chairman, Mr. Carnaghan had regularly attended the meetings of the Committee and had conducted the duties in a highly satisfactory manner, and he (the speaker) did not think they could do better than to ask Mr. Carnaghan to take office for another year.

This proposal was received with acclamation and was carried unanimously.

Mr. Carnaghan thanked the members for this expression of their approval and confidence, and said that he would be happy to carry on for another year.

On the proposal of **the Chairman,** the following were elected to the General Committee for the ensuing year:

Vice-Presidents: R. S. Kennedy, S. N. Kent and F. W. Youldon.
Members of Council: H. S. Humphreys and H. J. Wheadon.
Members of the Guild: T. A. Crompton, W. Lynn Nelson and G. Speck.

Mr. W. A. Christianson (Member) said that he had much pleasure in proposing a vote of thanks to the General and Executive Committees for their work during the past year. To the ordinary members like himself, it was apparent that a lot of work had been done, and they noted that the Committees had held twelve meetings altogether, which meant a lot of time and thought on the part of the Committee Members. He was quite sure that they had done their job well, and speaking on behalf of the members as a whole, he felt that the affairs of the Guild were in good hands.

Reference had already been made to the small number of members of the Institute who were members of the Guild. He agreed that something should be done to remedy this situation, not only as regards the number of members, but also the amount of their subscriptions.

He expressed special appreciation of the services of Mr. Carnaghan, the Chairman, Mr. Robertson, the Honorary Treasurer, and Mr. Curling, the Secretary. He was very glad to note that Mr. Carnaghan was going to continue as Chairman for another year. He proposed that a very hearty vote of thanks be accorded to the General and Executive Committees.

The proposal was carried by acclamation.

The Chairman, in reply, said:

"On behalf of the General and Executive Committees and the Officers of the Guild, I thank Mr. Christianson for his kind remarks. I desire personally to thank the Honorary Treasurer, the Secretary, and his assistant, Mrs. Watson, for the efficient manner in which they have carried out their duties.

I also tender my thanks to the Members of the General and Executive Committees for their loyal assistance during the regular meetings of the past year".

The meeting then terminated.

Twelfth Annual Report of the General Committee.

Applicants who received relief from the Guild in 1945 numbered 41, the total amount of grants being £1,565 14s. 6d., i.e. £217 0s. 3d. in excess of the total amount disbursed in 1944.

The thanks of the General Committee are extended once more to the members and donors who have subscribed to the Guild funds during the year. Further grants from King George's Fund are again acknowledged with grateful appreciation.

The Committee also convey their thanks to the Liverpool Marine Engineers' and Naval Architects' Guild, the Marine Engineers' Association Benevolent Fund and the Royal Alfred Aged Merchant Seamen's Institution, for continuing to share the burden of grants made to several recipients.

The Committee's appreciative thanks are tendered to Mr. J. Routledge, Mr. W. A. Woodeson, and others, for the valuable personal assistance they have tendered in connection with cases.

Meetings of Committees.

Since the date of the preceding Report the General Committee has held five meetings and the Executive Committee seven meetings. Until the staff's return to the Institute premises in May, Mr. J. Carnaghan (Chairman) continued to attend personally to the ordinary business of the Executive Committee, his decisions being confirmed by the Committee at subsequent meetings; the Committee again record their appreciation of Mr. Carnaghan's services.

Applications for Relief.

A summary of the cases dealt with between 1st January and 31st December, 1945, is given on page 6. In 34 of the cases relief was continued from the preceding year.

Membership.

14 Life Members and 43 Subscribing Members have been elected during the year. Allowing for losses by death and resignation, the total membership at the date of this report is 205 Life Members and 457 Subscribing Members. Of the latter 201 have covenanted to continue their subscriptions for seven years, thus affording a considerable addition to the Guild's income.

The John Silley Memorial Fund.

This fund continues to increase due to the generosity of Mr. H. A. J. Silley and Major B. L. Silley, to whom the Committee tender grateful thanks.

JAMES CARNAGHAN,
Chairman of the General Committee.
B. C. CURLING, *Secretary.*

26th March, 1946.

LIST OF DONORS TO THE INSTITUTE OF MARINE ENGINEERS GUILD OF BENEVOLENCE.

From the date of foundation 2nd August, 1934 to the 31st December, 1944.

	£	s.	d.
Abell, Sir Westcott S., K.B.E.	5	0	0
Achille Serre (Employees)	4	0	0
Adams, George (Legacy)	100	0	0
Adams, George (Trustees)	12	10	0
Aitken-Quack, E.	5	5	0
Aiton & Co., Ltd.	10	10	0
Akman, O. M. (2 donations)	2	6	0
Alfa-Laval Co., Ltd.	5	5	0
Allen, W. H., Sons & Co., Ltd. (2 donations)	126	0	0
Alton, W. A. (2 donations)	7	7	0
Anglo-Saxon Petroleum Co., Ltd.	1,000	0	0
Anonymous (10 donations)	65	0	0
Anonymous		8	6
Anonymous (5 donations)	1	18	0
Anonymous (2 donations)	8	0	0
Anonymous (2 donations)	1	11	0
Anonymous (2 donations)		17	0
Anonymous	1	1	0
Anonymous (2 donations)	2	2	0
Anonymous	1	10	0
Aston, J. Herbert, J.P.	1	1	0
Australian Institute of Marine and Power Engineers	1	11	6
Auto-Klean Strainers, Ltd.	10	10	0
Babcock & Wilcox, Ltd.	105	0	0
Barr, H. (5 donations)	2	0	6
Beldam, C. A.	105	0	0
Bennet, J.		5	0
Blundells & T. Albert Crompton & Co., Ltd. (4 donations)	42	0	0
Booty, M. J. (7 donations)	3	13	6
Bridges, F. W. (Legacy)	100	0	0
M.v. "Brisbane Star" (Captain and Officers' Fund)	1	1	0
British India Steam Navigation Co., Ltd.	750	0	0
British Power Boat Co., Ltd.	1	1	0
British Thomson-Houston Co., Ltd.	25	0	0
Brown, A. & R., Ltd. (4 donations)	21	0	0
Brown Bros. & Co., Ltd.	52	10	0
Brown, F. T.		8	6
Brown, G. J.		10	6
Bruce, D. (2 donations)	6	1	0
Bruce, J. W. (2 donations)	1	1	0
Buckton, W. W. (Legacy)	25	0	0
Burrage, E. E. (2 donations)	1	8	6

	£	s.	d.
Burrow, N.		17	0
Butler, E. F.		10	6
Button, W. A.		10	6
Calderwood, J., M.Sc. (2 donations)	4	2	0
Cammell, Laird & Co., Ltd.	105	0	0
Campbell, A. K. M. (3 donations)	1	5	6
Carnaghan, J. T., B.Sc.	2	2	0
Carter, H. D.	2	0	0
Chesterfield Tube Co., Ltd.	105	0	0
Christensen, S. G. (7 donations)	5	16	0
Christianson, W. A. (2 donations)	2	2	0
Clark, A. W.		10	6
Clarke, Chapman & Co., Ltd.	500	0	0
Clegg, A.	1	1	0
Cleveland, E. G.		2	0
Coffyn, Captain T.	5	5	0
Cole, T. E. (2 donations)		9	0
Colinese, S. G. (6 donations)	6	16	0
Collacott, R. A., Flight Lt., B.Sc., Ph.D., R.A.F. (2 donations)	5	5	0
Collings, J. W.	1	0	0
Cookson, F. R. C. (6 donations)	3	11	0
Corr, D. J.	1	0	0
Cottrell, A. B.	10	0	0
Cowan, C. J.	100	0	0
Craigmyle, Rt. Hon. Lord	105	0	0
Crane Packing, Ltd.	10	10	0
Cunard White Star, Ltd. (12 donations)	233	0	0
Darwins, Ltd.	10	10	0
Davey, Paxman & Co., Ltd. (2 donations)	21	0	0
Davidson, Major General A. E., C.B., D.S.O.	2	0	0
Davies, F. S.	3	3	0
Delves, J. V.	3	3	0
Denny, Sir Maurice E., Bt., C.B.E., S.B.	100	0	0
Denny, Wm. & Bros., Ltd.	50	0	0
Dewar, J. M.	2	2	0
Dewrance & Co., Ltd.	26	5	0
Dodds, T. (4 donations)	1	15	6
Dorey, S. F., C.B.E., D.Sc., Wh.Ex.	10	0	0
Drossi, H. H. R.	2	2	0
Drummond, R. M.		13	0
Drysdale & Co., Ltd.	105	0	0

	£	s.	d.
H.T. "Dunera"	5	5	0
Dunster, W. (per F. W. Youldon)	5	0	0
Eagle Oil & Shipping Co., Ltd.	105	0	0
East, A. S.	1	1	0
Ellerman & Bucknall Steamship Co., Ltd.	3	10	0
English Electric Co., Ltd.	105	0	0
Evans, A. F.	3	3	0
Fairfield Shipbuilding & Engineering Co., Ltd.	105	0	0
Farmer, J. D., O.B.E. (2 donations)	8	0	0
Federal Steam Navigation Co., Ltd.	500	0	0
Ferring Local Savings Group (3% Defence Bonds)	15	0	0
Firth, T., and J. Brown, Ltd.	21	0	0
Fleming, S. W. C. (3 donations)	1	18	0
Folland Aircraft, Ltd.	10	10	0
Foster Wheeler, Ltd.	10	10	0
Funnell, A. J. (3 donations)	1	11	6
Furness, Withy & Co., Ltd.	1,000	0	0
Galloway, J. H. (3 donations)	1	11	6
General Electric Co., Ltd.	21	0	0
George, W. R.		10	6
Gerard, A. J.		3	8
Gibson, A. T.		8	6
Gordon-Luhrs, Lt.-Col. H., C.M.G. (3 donations)	5	4	0
Gorringe, H. M.	1	1	0
Gough, R. H. (2 donations)	2	2	0
Graham, W.		18	0
Green, R. H.	100	0	0
Green, R. H. & Silley Weir, Ltd.	500	0	0
Gregg, A. E. C.		12	2
Gregson, Major W., M.Sc.	10	10	0
Guerin, W. R.		10	6
Gullett, T. E. (3 donations)	12	0	0
Hall, J. & E., Ltd. (4 donations)	200	0	0
Hannam, J. R.	1	2	6
Harland & Wolff, Ltd.	250	0	0
Harrington, W. A. (5 donations)	2	12	6
Harrison, F. J.	5	5	0
Hart, N.	1	1	0
Hastie, J. & Co., Ltd.	105	0	0
Hawthorn, R. & W., Leslie & Co., Ltd.	250	0	0
Heenan & Froude, Ltd.	10	10	0
Heriot, J. C.		19	0
Higgs, H. A.		16	0
Homewood, Miss B. E.	2	2	0
Hood, J. E. V.		10	0
Hopes, T.		8	6
Hopewell, G. H. (2 donations)	21	0	0
Houston, W. C.	5	0	0
Howden, James & Co., Ltd.	21	0	0
Hunter, Mrs. R. A.	1	1	0
Hutchinson, G. H. M.		10	0
Hutchinson, G. R. (4 donations)	102	2	6
Hutchison, M.		5	0
I.C.I. Metals, Ltd.	10	10	0
I.C.I. Metals, Ltd., Birmingham (Employees)	50	0	0
Imrie, W.	1	0	0
Inchcape, Rt. Hon. Earl of	1,000	0	0
Institute of Marine Engineers (10 donations)	1,424	9	6
Jackson, D. H.		10	6
Jones, F. M., B.Sc.	1	1	0
Jordan, H. J.		5	2
Kincaid, J. G. & Co., Ltd.	105	0	0
King George's Fund for Sailors (6 donations)	1,000	0	0
Kirkaldy, W. H. (4 donations)		14	6
Kirkbright, G.	1	0	0
Klinger, Richard, Ltd.	21	0	0
Kuske, Z. (3 donations)	3	18	0
Lang, L.	1	4	6
Lang, W. V.	2	2	0
Laurence Scott and Electromotors, Ltd.	21	0	0
Lees, T. R.	3	3	0
Leslie, R.	1	11	6
Lloyd's Register of Shipping (3 donations)	78	15	0
Logan, A.		10	6
Longmuir, T. W. (6 donations)	6	5	0
Lovatt, G. H. V.		7	6
Luckly, S. F.	5	0	0
Manganese Bronze and Brass Co., Ltd.	52	10	0
Mather, A. H.		10	6
Mather & Platt, Ltd.	10	10	0

	£	s.	d.
Mellor, W. H. (7 donations)	7	7	0
Middleton, J. D. (3 donations)	1	11	6
Middleton, W. J.	1	1	0
Mitchell, J.		7	6
Mountstuart Dry Docks, Ltd.	100	0	0
Mumford, N. (4 donations)	13	8	0
Murray, A.		6	0
Murray, John & Pilot Press, Ltd.	25	0	0
Macdonald, T.	5	5	0
McIntosh, G.		10	0
McKie, H.	1	1	0
McKinlay, R. D. M.	2	2	0
McLean, H. (5 donations)	6	18	0
Naylor, H. (5 donations)	2	2	6
Nelson, W. Lynn, O.B.E.	25	0	0
New Zealand Steam Ship Co., Ltd.	500	0	0
Nicholl, Com'r. Sir Edward, K.B.E., R.N.R.	105	0	0
North Eastern Marine Engineering Co., Ltd.	100	0	0
Orient Line, Ltd.	500	0	0
Ormiston, G.	5	5	0
Oswald, J. H.	1	0	0
Owen, G. H. L.	1	1	0
Painter, R. E.		8	2
Parker, A. H.	3	0	0
Parkin, F.		10	6
Parsons Marine Steam Turbine Co., Ltd.	100	0	0
Paxman, E. P., M.A. (Annual)	2	2	0
H.N.P.	1	1	0
P. & O. S.N. Co., Ltd.	750	0	0
Petree, J. Foster	10	10	0
Petters, Ltd.	21	0	0
Pip	1	1	0
Pirie, H. L.	2	2	0
Poli (Cartoonist at the Conversazione)	2	0	0
Pollock, James, Sons & Co., Ltd. (2 donations)	10	10	0
Porn, M.	10	10	0
Preece, Eng. Vice Admiral Sir George, K.C.B. (2 donations)	6	6	0
Preece, S. G.	10	10	0
Prentice, C. (4 donations)	3	12	6
Preston, J. J. (2 donations)	5	6	2
Quarrell, A. P. (3 donations)	2	19	0
Quin, Park, Fleming Benevolent Committee	4	0	0
Raimes, G. W. B. (4 donations)	1	10	0
Ramsay, J. W. (3 donations)	8	11	6
Reavell & Co., Ltd.	25	0	0
Rebbeck, Sir F. E., D.L., J.P.	25	0	0
Reed, G. H.		10	6
Reid, F. H., B.Sc., Wh.Ex.		10	6
Richmond, Sir J. R., K.B.E.	1,000	0	0
Riddell, A. M.	10	10	0
Risoe, A.		6	0
Ritchie, F. G. (2 donations)	10	10	6
Roberts, W. H.	1	1	0
Robertson, A. (Annual)	5	5	0
Robinson, E. F. B. (3 donations)	1	11	0
Robinson, J.	5	0	0
Rooks, G.	1	1	0
Roux, A. E.		6	10
Royal Mail Lines, Ltd.	105	0	0
Rubery, Owen & Messier, Ltd.	10	10	0
Ruston & Hornsby, Ltd. (2 donations)	42	0	0
Ryland, E. T.	1	1	0
Scott, H.		10	6
Scott's Shipbuilding and Engineering Co., Ltd.	105	0	0
Sellex, J. E.		10	0
Serck Radiators, Ltd.	26	5	0
Shaw, Savill & Albion Co., Ltd.	525	0	0
Shipmaster	1	0	0
Silley, John H., O.B.E.	500	0	0
Simpson, Major P. A. M., R.E. (4 donations)	7	15	6
Sinclair, F. T.		10	6
Skinner, D. B. (3 donations)	2	12	6
Snell, J. (4 donations)	2	4	9
Soanes, E. G. (2 donations)	6	5	6
Somers, Walter, Ltd.	52	10	0
Soulsby, Sir L. T. G.	5	0	0
Spanner, E. F., R.C.N.C.(ret.)	10	0	0
Spanner, W. F., R.C.N.C.	1	0	0
Speirs, H. J. (Legacy)	450	0	0
Stein, J. & Co., Ltd.	21	0	0

	£	s.	d.
Step, A. G.	1	6	4
Stephen, Alexander & Sons, Ltd.	50	0	0
Stephenson, B.	10	10	0
Stone, J. & Co., Ltd.	25	0	0
Sulzer Bros. (London), Ltd.	10	10	0
Superheater Co., Ltd. (6 donations)	52	10	0
Swanbrow, C. J. (2 donations)	2	2	0
Swansea Members	5	5	0
Tait, W. A. (9 donations)	5	17	0
Thomas, J. K. (8 donations)	3	18	0
Thompson, John (Wolverhampton), Ltd.	21	0	0
Thornycroft, John I. & Co., Ltd.	21	0	0
Timpson, A. F. C., M.B.E.	1	1	0
Train, J. T. (2 donations)	1	10	0
Trenchard, L. D. (2 donations)	2	1	0
Tube Investments, Ltd.	25	0	0
Turnbull, F. (3 donations)	1	13	0
Tyrrell, H. R., Major, I.A.O.C. (2 donations)	7	2	0
Vickers-Armstrongs, Ltd.	250	0	0
Wailes Dove Bitumastic, Ltd.	26	5	0
Wallace, W. E. G. (3 donations)		19	6
Wallis, R. Pendennis, Ph.D., M.Sc., Wh.Ex. (2 donations)	2	2	0
Wallsend Slipway and Engineering Co., Ltd.	105	0	0
Ward, J.	1	1	0
Watson, G. O.	2	2	0
Watts, Fincham, Ltd. (3 donations)	6	6	0
Weir, Andrew & Co., Ltd.	1,000	0	0
Weir, G. & J., Ltd.	1,000	0	0
Weir, James (Trust Fund)	2,000	0	0
Weir, Rt. Hon. Viscount, of Eastwood, P.C., G.C.B., D.L.	1,000	0	0
Weir, J. G., C.M.G., C.B.E.	1,000	0	0
White, J. Samuel & Co., Ltd.	25	0	0
Whitehall Technical Press	21	0	0
Wight, R. B. (5 donations)	2	10	0
Williams, Mrs. B.	2	2	0
Wilson, G. M. (Bequest)	200	0	0
Wiltshire, E. F.	3	12	0
Wood, F. (2 donations)	2	2	0
Wren, C. W. Limpricht (2 donations)	2	2	0
Yarrow & Co., Ltd.	52	10	0
Yorkshire Copper Works, Ltd.	26	5	0
Youldon, E.		10	0
Youldon, F. W. (collecting box—5 donations)	4	10	0
Young, J. (3 donations)	3	3	0
Young, R.		2	6

Donations from 1st January to 31st December, 1945.

	£	s.	d.
Mrs. R. Hunter (2nd donation)	1	1	0
J. Snell (5th donation)		12	6
P. Ewing		10	6
L. D. Trenchard (3rd donation)	1	1	0
H. D. Carter (2nd donation)	2	12	0
Major P. A. M. Simpson, R.E. (5th donation)	1	0	0
W. Mellor (Covenanted)	1	1	0
P. J. Marshall		5	0
A. N. Platford	1	1	0
F. Turnbull (4th donation)		10	0
R. Pendennis Wallis, Ph.D., M.Sc., Wh.Ex. (3rd donation)	1	1	0
J. W. Bruce (3rd donation)		10	6
J. K. Thomas (9th donation)		10	0
J. E. V. Hood (2nd donation)		13	0
W. A. Tait (10th donation)		10	0
S. W. C. Fleming (4th donation)		7	6
A. J. Cant		10	6
L. Lang (2nd donation)		7	6
F. Wood (3rd donation)	1	1	0
F. R. C. Cookson (7th donation)		10	6
J. C. Walker		10	6
R. H. Gough (3rd donation)	1	1	0
W. R. Guerin (2nd donation)		10	6
J. Ellson	1	1	0
R. S. Kennedy	1	1	0
G. R. Hutchinson (4th donation)		15	0
R. S. Blackledge		12	0
J. D. Black		10	6
J. Denny	1	12	6
A. Paszyc	1	10	0
W. A. Alton (3rd donation)	2	2	0
F. W. Youldon's Collecting Box (6th donation)	1	13	0
A. G. Step (2nd donation)		8	0
T. E. Gullett (4th donation)	4	0	0
E. E. Burrage (3rd donation)	1	1	0
J. Herbert Aston, J.P. (2nd donation)	1	1	0
T. Hindmarch	10	10	0
R. B. Wight (6th donation)		10	0
A. P. Quarrell (4th donation)	1	1	0
R. D. M. McKinlay (2nd donation)	2	2	0
Mr. and Mrs. W. F. Spanner	2	10	0
Watts, Fincham, Ltd. (4th donation)	2	2	0
W. C. Grootenhuis	1	1	0
E. F. Butler (2nd donation)		12	0
J. J. Preston (3rd donation)		7	2
A. H. Ledger	2	2	0
G. H. L. Owen (2nd donation)	1	1	0
J. W. A. Jack		10	0
Anonymous (6th donation)		13	0
Major H. R. Tyrrell (3rd donation)	4	10	0
P. Ewing (2nd donation)	20	0	0
Sulzer Bros. (London), Ltd. (2nd donation)	10	10	0
Lt.-Col. H. Gordon-Luhrs, C.M.G. (4th donation)	2	2	0
Anonymous	3	0	0
A. Robertson (Covenanted)	5	5	0
Major-Gen. A. E. Davidson, C.B., D.S.O. (2nd donation)	2	0	0
Cunard White Star (13th donation)	20	0	0
H. Y. Mosey	1	5	0
Annal's Trust	2	2	0
T. Dodds (5th donation)		10	0
W. E. G. Wallace (4th donation)		8	0
C. J. Swanbrow (3rd donation)	1	1	0
J. J. Preston (4th donation)	1	1	0
Anonymous		18	4
D. B. Skinner (4th donation)		10	6
Superheater Company (7th donation)	10	10	0
Davey, Paxman & Co., Ltd. (Covenanted)	10	10	0
W. A. Alton (4th donation)	2	2	0
D. H. King	10	10	0
A. Cross	2	10	0
A. J. Paszyc (2nd donation)		18	5
E. F. B. Robinson (4th donation)		10	0
G. H. Hopewell (3rd donation)	10	0	0
B. Rogers	2	10	0
Anonymous (11th donation)	10	0	0
Anonymous (2nd donation)	7	10	0
Cunard White Star (14th donation)	20	0	0
A. E. C. Gregg (2nd donation)	2	0	0
W. J. S. Glass	1	5	6
O. M. Akman (3rd donation)	1	5	0
S. G. Christensen (8th donation)		17	6
King George's Fund for Sailors (Main Fund)	200	0	0
King George's Fund for Sailors (Sea Services Sunday)	50	0	0

Donations received from 1st January, 1946 to 27th March, 1946.

	£	s.	d.
F. Wood (4th donation)	1	1	0
W. A. Tait (11th donation)		10	0
W. Mellor (Covenanted)	1	1	0
J. K. Thomas (10th donation)		10	0
L. Wood	1	1	0
E. Burrage (4th donation)	1	1	0
J. Ellson (2nd donation)	1	1	0
Major P. A. M. Simpson, R.E. (6th donation)	1	0	0
J. W. Bruce (4th donation)		10	6
E. F. Butler (3rd donation)		8	0
A. Martin	1	0	0
H. D. Carter (2nd donation)	1	18	0
A. N. Platford (2nd donation)	1	1	0
R. Pendennis Wallis, Ph.D., M.Sc., Wh.Ex. (4th donation)	1	1	0
Mrs. R. Hunter (3rd donation)	1	1	0
J. Snell (6th donation)		12	6

THE INSTITUTE OF MARINE ENGINEERS GUILD OF BENEVOLENCE.

Balance Sheet, 31st December, 1945.

LIABILITIES.	£	s.	d.	£	s.	d.
Capital Account						
Balance at 31st December, 1944	24,687	6	6			
Add:						
Life Membership Subscriptions ...	169	10	0			
Donations to Capital	340	14	3			
				25,197	**10**	**9**
The John Silley Memorial Fund						
Capital Fund				**16,750**	**0**	**0**
Income and Expenditure Account						
Balance at 31st December, 1944	4,061	11	9			
Add Excess of Income over Expenditure for the year	433	13	11			
	4,495	5	8			
Subscriptions received in advance	13	16	6			
Creditor	5	5	0			
				4,514	**7**	**2**

ASSETS.	£	s.	d.	£	s.	d.
CAPITAL FUNDS.						
Free Investments						
As valued 2nd August, 1934:—						
£1,937 London Midland & Scottish Railway 4% Preference Stock...	1,515	14	0			
£500 New South Wales 4% Stock 1942/62	505	12	6			
£250 3½% War Loan	259	16	3			
At Cost *Less* Sales:—						
£7,100 3½% Conversion Loan, 1961 ...	7,585	12	10			
£1,779 0s. 11d. 3% Local Loans ...	1,696	15	6			
£1,417 12s. 3d. 3% Savings Bonds, 1960/70	1,422	18	4			
£985 3% National Defence Bonds ...	985	0	0			
				13,971	9	5
(Market value 31st December, 1945, £13,949).						
Investments held for account of the John Silley Memorial Fund						
£3,770 4s. 10d. 2½% Consolidated Stock...	3,000	0	0			
£9,000 3% Savings Bonds, 1960/70 ...	9,000	0	0			
£4,645 5s. 10d. 3% Local Loans ...	4,465	4	0			
				16,465	**4**	**0**
(Market value 31st December						

	£ s. d.
F. R. C. Cookson (8th donation)	10 6
D. G. Webster	18 0
A. P. Quarrell (5th donation)	1 8 0
G. R. Hutchinson (5th donation)	1 1 0
R. H. Gough (4th donation)	1 1 0
A. J. Cant (2nd donation)	10 6
W. C. Houston (2nd donation)	3 0 0
W. R. Guerin (3rd donation)	10 6
J. D. Black (2nd donation)	18 0
E. F. Spanner, R.C.N.C.(ret.) (2nd donation)	5 0 0
W. Kerr	10 6
T. E. Gullett (5th donation)	3 3 0
Anonymous (7th donation)	13 0
G. E. Arundel	10 6
R. D. M. McKinlay (3rd donation)	2 2 0

PARTICULARS OF THE CASES ASSISTED BY THE GUILD,

from 1st January to 31st December, 1945.

Case No.	*Age.*	*Qualification.*	*Amount of Relief Granted.*
1	67	Widow of former Member of The Institute	67 0 0
3	78	Member of The Institute	144 0 0
6	64	Daughter of Marine Engineer	35 10 0
8	65	Widow of Marine Engineer	38 8 0
19	89	Widow of Marine Engineer	34 10 0
20	80	Marine Engineer	28 0 0
44	67	Widow of Marine Engineer	21 10 0
47	65	Widow of Marine Engineer	28 0 0
51	66	Widow of former Member of The Institute	21 10 0
53	68	Widow of Marine Engineer	21 10 0
58	68	Widow of Marine Engineer	23 0 0
72	66	Widow of Marine Engineer	1 0 0 (Christmas grant only)
76	66	Widow of Marine Engineer	11 0 0
80	66	Sister of former Member of The Institute	54 0 0
85	72	Widow of Marine Engineer	16 0 0
88	80	Member of The Institute	12 8 0
96	70	Widow of former Member of The Institute	54 0 0
97	74	Widow of Marine Engineer	31 10 0
98	78	Marine Engineer	15 0 0
101	79	Marine Engineer	30 6 0
103	47	Widow of Marine Engineer	46 4 0
104	80	Marine Engineer	1 6 0 (Christmas grant only)
106	16	Son of former Member of The Institute	28 0 0
107	59	Widow of Marine Engineer	34 10 0
109	63	Widow of Marine Engineer	20 5 0
114	72	Marine Engineer	30 6 0
120	56	Marine Engineer	34 10 0
122	59	Widow of Marine Engineer	34 10 0
123	45	Widow of former Member of The Institute	83 6 0
125	48	Member of The Institute	55 15 0
126	55	Widow of former Member of The Institute	59 4 0
127	56	Widow of former Member of The Institute	65 0 0
128	74	Widow of Marine Engineer	34 10 0
130	18	Daughter of Marine Engineer	52 0 0
131	52	Widow of Marine Engineer	34 10 0
133	66 & 56	Daughters of former Member of The Institute	120 5 0
134	76	Widow of former Member of The Institute and Guild of Benevolence ...	22 10 0
135	49	Widow of Marine Engineer	28 5 0
136	64	Member of the Institute	31 10 0
137	38	Widow of former Member of The Institute	40 0 0
138	42	Widow of Marine Engineer	21 12 6

LIST OF MEMBERS AT DATE OF PUBLICATION OF THIS REPORT.

Life Members.

Adie, P. I.
Alexander, Claud
Allen, H. G., M.A.
Allen, Norman G.
Allen, Sir R. W., C.B.E., D.L.
Allen, Rupert S.
Allen, W. K. G.
Andrew, George
Armstrong, Hugh
Arthurson, M.
Aston, J. H., J.P.
Atkinson, W. A. R.
Austin, J.

Bailey, W. H.
Balmer, H. S.
Bedford, G. E.
Berlie, R. S.
Blair, D. E.
Blevin, W. N.
Bramah, David, C.B.E.
Brettell, W. G.
Bruce, W. J. Willett, O.B.E., R.D., M.Eng., Eng. Capt. R.N.R.(ret.)
Buchanan, H. D.
Burke, N.
Burrage, E. E.

Carswell, D. B., O.B.E.
Chamberlain, J. H., Comd. Engr., D.S.C., D.S.M., R.N.
Christensen, S. G.
Christie, J. G.
Clarke, R. T.
Clough, E.
Coates, W.
Collins, W. H.
Conoley, C. W.
Cormack, J.
Cowan, R. S.
Crighton, A. E.
Crompton, T. A.
Crompton, T. M.
Crookston, D. D.

Davidson, A. E., Major-Gen., C.B., D.S.O.
Davis, Gordon, Lt.(E.), R.N.V.R.
Denny, W.
Dougan, A. S.
Drossi, H. H. R.
Drysdale, Ian

Easthope, R. J.
Espin, W. L.
Evans, Frank S.

Farmer, J. D., O.B.E.
Foley, Sir E. Julian, C.B.
Froggart, L.

Gamage, L. C.
Gillies, R. M.
Goldup, D. R.
Goodsir, D.
Gordon, S. G.
Grange, G. R., Lt. Col., D.S.O., M.C., B.Sc.
Grant, Sir Allan J., J.P.
Grant, W. C.
Green, R. H.
Greenfield, Eric
Greig, K. E.
Groom, R. W.
Gummer, R. H.

Hamley, F. J.
Handley, C. E.
Hardy, J., O.B.E.
Henderson, J.
Henderson, J. M.
Hillier, H., O.B.E.
Hindmarch, T.
Hoare, H. J.
Holly, R. J. W.
Hood, R.
Houlder, M. C.
Houston, W. C.
Hulbert, W.
Hume, Crawford W.
Hunter, Sir Summers
Hutchinson, G. R.

Imrie, W.

Johnson, John
Johnson, P. B., B.A.
Jones, W. C.

Kedzlie, J. E.
Kennedy, R. S.
Kent, S. N.
Kincaid, Randal G.
Knipe, W. D.
Knopp, L., M.Sc.

Lamb, John
Levick, R. S. H.
Lewer, L. J.
Lewis, J. B.
Lowrie, J. C.

Maddick, W.
Marshall, J. S. Clayton
Martin, C. E.

Mather, A. H.
Maundrell, H. B. H.
Mearns, E. A.
Mellor, W.
Milne, J. A.
Mitchell, P. G. Mylne
Moore, C. K.
Morrison, S. A.
Moseley, O. H. G. K.
Macdonald, T.
MacKay, A. M.
McCormick, A. P.
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The Fundamentals of Ship Form.

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On Tuesday, December 12th, 1944, at 5.30 p.m. at 85, The Minories, E.C.3.

Chairman: S. A. SMITH, M.Sc. (Chairman of Council).

Synopsis.

The resistance experienced by a ship arises from a number of different sources—skin friction due to the motion of the hull surface through the water, wave making brought about by the variations in pressure around the moving vessel, eddying behind bossings and other appendages, and the resistance of the upper structure moving through the air. The best form to adopt for a particular design of ship depends upon the interplay of all these elements, and the study of the fundamentals of ship form must evidently begin with a consideration of those of ship resistance. Our present knowledge of this latter subject is therefore first reviewed, and then applied to the problem of ship form. The most efficient shape of hull varies widely with the dimensions, proportions and speed of the ship, the emphasis shifting from skin friction to wave making resistance with varying conditions, and this change is traced throughout the speed range from slow, full cargo ships to destroyers. No attempt has been made to give detailed guidance on the design of lines, but only the broad principles have been dealt with, and it is shown how they lead to types of lines for different craft which have in general been derived originally from long experiment, both with models and full-scale ships.

Introduction.

When I was asked to prepare this paper for presentation to your Institute, I accepted the invitation with a full appreciation of the difficulty of giving anything approaching a complete account of such a large subject within the compass of a single paper.

The choice of shape for a ship's hull depends upon the various elements which make up the total resistance experienced by the ship when she moves through the water, and their relative importance in the particular design in question. Our survey, therefore, must evidently begin by an examination of the fundamentals of ship resistance.

In addressing the Institute of Marine Engineers, I have tried to remember the fact that many of its members, particularly the younger ones, have not had the time or the opportunity to delve very deeply into naval architecture. With this in mind, and fortified by the expressed wishes of several members, and by the title chosen by your Council, I have treated the subject "fundamentally", assuming no previous knowledge of ship resistance. In doing so, I must ask the indulgence of those who are familiar with the subject, and hope that they may find a few points of interest new to their experience.

I have, indeed, been asked why a marine engineer should wish to have a knowledge of ship form. Admittedly, the design of the form and the lines do not normally fall within his province, yet he works in very close contact with the naval architect during both the designing and building of a ship, and such co-operation is likely to be made both closer and smoother if both parties have an understanding of at least the fundamentals of each others' problems. Such knowledge is likely to prevent one partner from making unjustifiable demands upon the other, and generally to smooth the paths of both. Moreover, the superintendents of most shipping companies are engineers by training and experience, and they should have a certain knowledge of the basic principles of ship resistance and form if they are to serve their companies to the greatest good, both in the upkeep and efficient running of the existing fleets, and in the design of new tonnage.

If I can contribute to this end to however small an extent, I shall feel my labour in preparing this paper has not been in vain.

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2.—The Elements of Ship Resistance.

The resistance of a ship is usually considered to be the force which would be necessary to tow her through perfectly smooth water, no account being taken of any interaction between hull and propeller or of the resistance of appendages.

These latter factors always have some effect, and maybe an important one, upon the resistance, but for simplicity are omitted from a first survey.

The power necessary to overcome this resistance is called the tow-rope or effective horsepower (e.h.p.).

The principal elements contributing to the resistance of a ship in smooth water are:—

(1) Skin friction drag, due to the motion of the hull through a viscous fluid;

(2) Wave making resistance, representing the energy continually being supplied by the ship to the wave system which she creates on the surface of the water;

(3) Eddy resistance, due to the energy carried away by eddies formed around stern fittings, bossings, or local regions on the hull where the curvature is so sharp that the water is unable to follow the shape and breaks away; and

(4) Air resistance experienced by the above-water structure advancing through the air.

In addition, for a ship at sea, various other elements enter into the problem—the pitching and heaving motion engendered by waves both increase the resistance, and the air resistance is modified when a wind is blowing to an extent depending upon the latter's strength and direction.

Whilst, for convenience, the total resistance is so divided up, it is as well to realise from the outset that the separation is by no means as rigid as it might appear. Thus, if serious eddying occurs over a part of the surface of the hull, the increased resistance may be partly compensated for by a reduction of skin friction drag over that area. Again, at high speeds, the area of surface of the hull in contact with the water may be augmented due to the wave profile along the ship's side, and the skin friction drag thereby increased.

3.—Model Experiments.

A great deal of our knowledge of ship resistance has been derived from experiments with models. Such small scale work is much quicker and cheaper to carry out than experiments with full size ships, and much easier to control. Full scale work is also subject to so many variables due to weather, wind, tides, condition of hull surface and different types of engines and propellers, that it is extremely difficult to repeat any set of conditions again. This is not to deny the vital importance of full-scale work, and one of the primary functions of any model experiment establishment must be

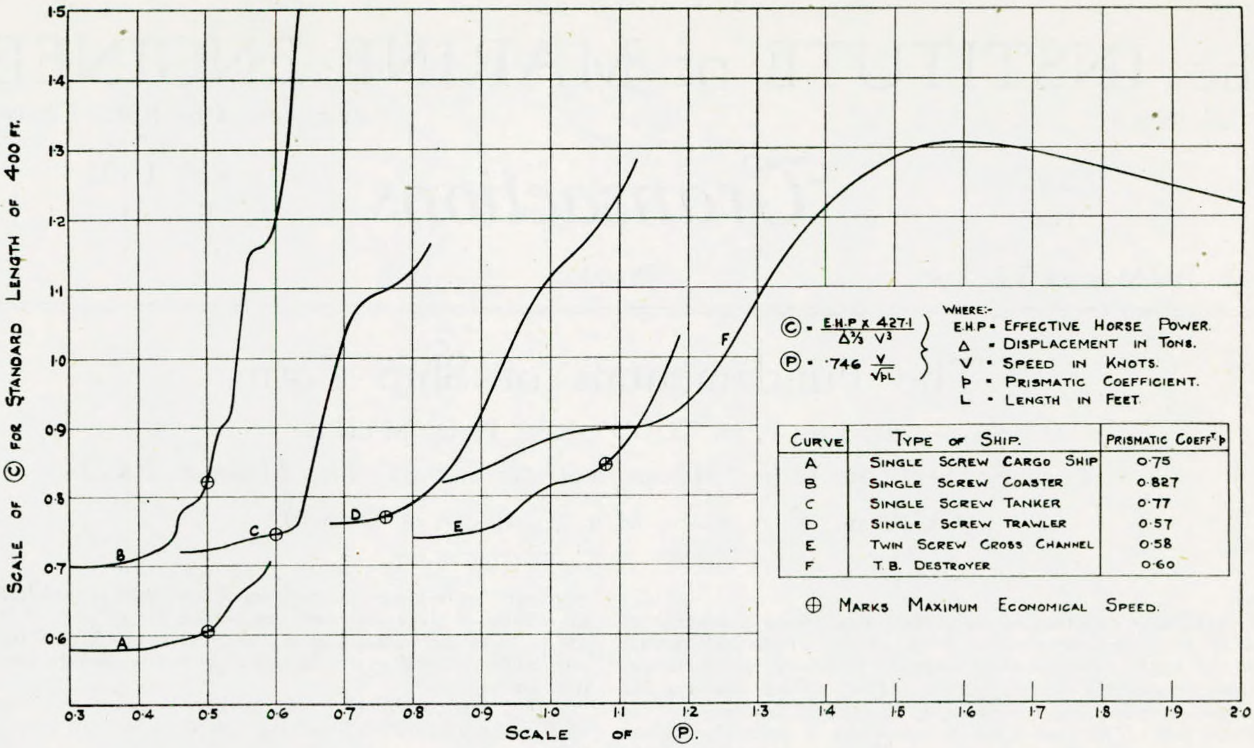


FIG. 1.—*Typical* Ⓒ *curves.*

to seize every opportunity to collect reliable full scale data for comparison with model results. If, as a result, the latter can be shown to afford a basis for the correct prediction of full scale performance, model work will afford a ready, quick and cheap method of obtaining a good shape of hull for any new design.

Experience over the last 70 years has shown that this can be done, and all the maritime nations now possess model ship testing tanks in which such work can be carried out. It is not intended to give here any detailed description of such a tank, which may be found in other papers [1]*. Briefly, it consists of a waterway along which models can be towed at different speeds and their resistance measured.

The models are made of paraffin wax or wood, and may be 16 to 24ft. in length, and when ballasted to represent to scale the loaded ship, weigh 2,000 to 3,000lb. They are thus large enough for the necessary accuracy to be attained in their shaping and in the measurement of their resistance.

The results are corrected to apply to the ship—by methods to be described later—and usually, in this country, presented in the form of curves of Ⓒ to a base of a speed function $\frac{V}{\sqrt{L}}$ or Ⓟ

The resistance constant Ⓒ is defined as:

$$\textcircled{C} = \frac{R}{V^2\Delta^{\frac{2}{3}}} \times 2937{\cdot}7 = \frac{\text{e.h.p.} \times 427{\cdot}1}{V^3\Delta^{\frac{2}{3}}} \quad \dots \quad \dots \quad (1)$$

where

R = resistance in tons;
V = speed in knots;
Δ = displacement in tons;
and e.h.p. = effective horse power.

$$\text{and } \textcircled{P} = 0{\cdot}746 \frac{V}{\sqrt{pL}}. \quad \dots \quad \dots \quad \dots \quad (2)$$

where V = speed in knots;
p = prismatic coefficient;
and L = length of ship in feet.

In Fig. 1 are shown some typical Ⓒ curves for different classes of vessels. The peculiar shapes of these curves, the regions where resistance is increasing rapidly or slowly with speed, well illustrate the difficulties of choosing the most efficient form to suit a given set of circumstances.

4.—Skin Friction Drag of Smooth Surfaces.

The importance of the skin friction resistance of a ship will be appreciated when it is realised that it amounts to some 85 per cent. of the total resistance of a slow cargo ship, and to very nearly half the total for a destroyer.

As a flat smooth surface such as a plate moves through a viscous fluid, the fluid near it is carried along with it, there being no relative movement at the surface. Some distance out from the surface the fluid is unaffected by the passage of the plate and remains at rest. There is thus set up a velocity gradient in the fluid along lines normal to the surface, and the resistance experienced by the latter will depend upon this gradient and upon the viscosity of the liquid. The fluid so set in motion, lying between the surface and the undisturbed outer liquid, is called the "boundary layer" or "frictional wake". Imagining the surface to be a very thin flat plate advancing into water, the relative velocity across a section normal to the plate and in line with its leading edge will be everywhere equal to the velocity of the plate, V (Fig. 2). As the plate moves on, it will drag the water immediately in contact along with it at velocity V, and this water will set in motion that just outside it, in virtue of the tangential forces due to viscosity. This effect will spread outwards gradually, so that the boundary layer will become wider and wider towards the rear of the plate, as shown by the line aaa in Fig. 2. Beyond the after end, the layer will cease to widen, and the energy put into the water by the plate, which represents the work done by the plate and is a measure of the resistance it experiences, is dissipated in eddies and heat. Since the change in velocity from the

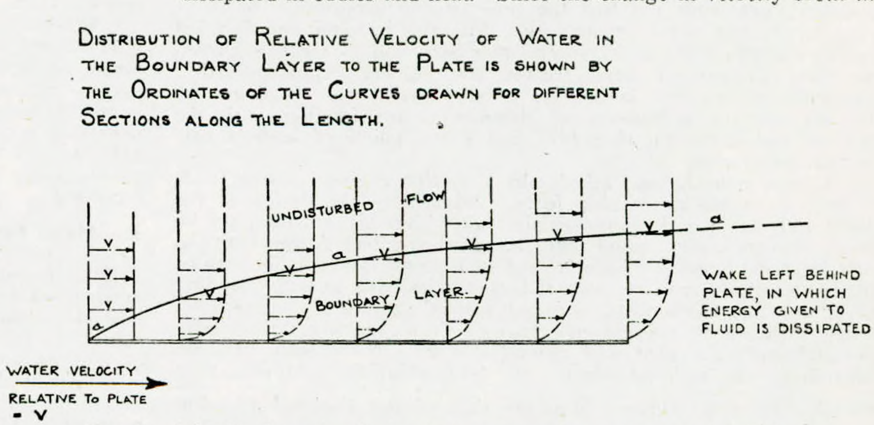


FIG. 2.—*Distribution of velocity in boundary layer along a flat plate.*

* Numbers refer to papers listed on page 20.

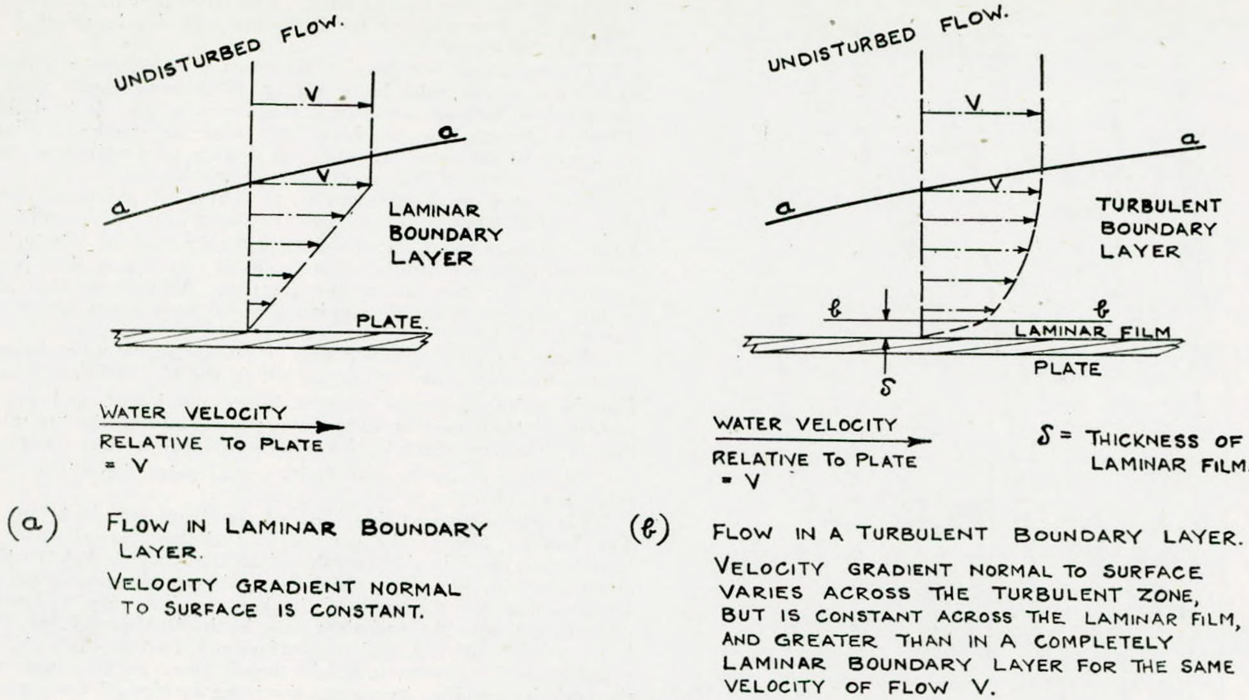


FIG. 3.—*Laminar and turbulent wakes.*

surface of the plate to the undisturbed water just outside the layer is everywhere V, it follows that the velocity gradient normal to the surface decreases as we go aft along the plate.

The movement of water inside the wake may follow two patterns. In either case it is assumed that the actual water next to the surface has no motion relative to the surface, but is carried along with it. If between this and the outer edge of the wake, where the fluid is absolutely at rest, the water moves in a series of layers such that no mixing occurs, and the velocity gradient in passing outwards is constant, the flow is said to be *laminar* (Fig. 3a.).

On the other hand, if the flow is such that eddying occurs in the wake, with consequent mixing of the layers and an interchange of energy, and a varying velocity gradient across the boundary layer, the flow is said to be *turbulent* (Fig. 3b). Even so, there is still a very thin film of fluid near the surface in which the flow is still laminar, shown by the line bb in Fig. 3b and called the *laminar film*.

Which of these flow régimes will be set up in given circumstances depends upon the relative predominance of inertia and viscous forces, the former favouring turbulent flow, the latter laminar. It may be shown that the ratio of these two forces is represented by the parameter $\frac{VL}{\nu}$

where V = speed of the surface relative to still water;
L = length of surface in direction of motion;
and ν = coefficient of kinematic viscosity of the fluid

$$= \frac{\text{coefficient of viscosity}}{\text{mass density}} = \frac{\mu}{\rho}$$

This parameter is called the Reynolds number (R) of the motion, Osborne Reynolds being the first to demonstrate the fundamental differences between laminar and turbulent flow in pipes [2]. It follows that small values of R will be associated with laminar flow, and large values with turbulent.

The shear force between adjacent layers of a viscous fluid, and therefore ultimately the drag on a plate moving through it, depends upon the coefficient of viscosity μ and the velocity gradient between the layers. Hence, as the fluid immediately in contact with a smooth surface is carried along with it, the resistance will be a function of the fluid properties and the velocity gradient only, and will not depend upon the exact nature of the surface, so long as it is smooth. By a combination of theory and experiments, the latter carried out both in air and in water, the resistance to be expected for both laminar and turbulent flow over a smooth surface has been determined.

Since the resistance is expected to differ with type of flow, which in turn depends upon the value of $\frac{VL}{\nu}$, it is usual to plot results to a base of Reynolds number, R.

The ordinates must represent drag or resistance. This depends upon the density of the fluid, ρ, the area of surface in contact with the fluid, S, and the velocity V, and we could write

$$R = C_f \rho S V^n.$$

Now it is found that for turbulent flow, with which engineers are normally concerned in full scale hydraulics, n is very nearly 2, and for simplicity a quadratic law is adopted. Also, the dynamic pressure associated with a velocity V is $\frac{1}{2}\rho V^2$, and we accordingly write

$$R = C_f \tfrac{1}{2} \rho S V^2$$

$$\text{or } C_f = \frac{R}{\frac{1}{2}\rho S V^2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (3)$$

C_f is the coefficient of skin friction drag, and will depend upon the Reynolds number of the flow, and must also take into account any departure of the index n from the value 2.

The results of a number of experiments are shown in Fig. 4, which illustrates very clearly the two different types of flow.

At low Reynolds numbers the flow in the whole boundary layer is laminar, and the resistance then varies directly as the velocity, i.e. n = 1, and consequently C_f falls along the line I for laminar flow over smooth surfaces.

As R increases, the boundary layer begins to break up towards its rear end into turbulence. and this change gradually spreads forward until the complete turbulent flow is established, when C_f lies on the Curve II for turbulent flow over smooth surfaces. The curve of C_f now falls only slowly with increasing Reynolds number, showing that for such turbulent flow n is a little less than 2.

The value of C_f for turbulent flow is greater than that for laminar, and this is to be expected. since the velocity gradient in the laminar film in the former case is greater than that in the completely laminar boundary layer.

Between these two régimes there is a transition region where C_f lies between the two curves I and II, and in which the flow is unstable.

If we consider a plank of given length L in a fluid of kinematic viscosity ν, increasing Reynolds number means increasing speed, and the fall in C_f is indicative of an index of speed less than 2.

On the other hand, if we run planks of different lengths all at the same speed V in the same fluid, the longer planks will have a higher Reynolds number, and a lower C_f. This shows that the specific resistance per sq. ft. of surface decreases as we go aft, and this would be expected, since with the increasing width of boundary layer the velocity gradient will be smaller.

5.—Effect of Roughness on Skin Friction Drag.

When a surface is rough instead of smooth, a further factor is

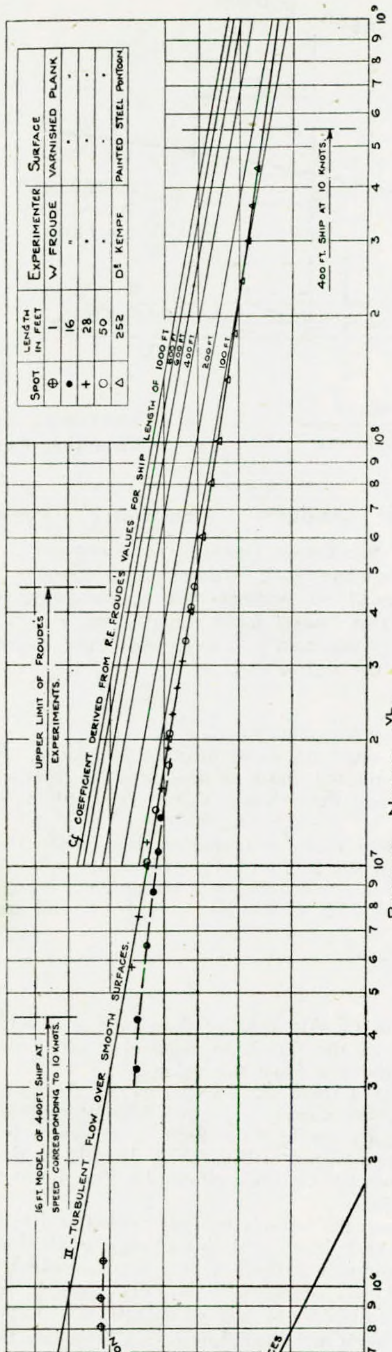


FIG. 4.—*Curves of skin friction resistance.*

introduced into skin friction drag. The latter now no longer depends only on the properties of the fluid, but will also be affected by the finish of the surface.

The most complete data on the effect of roughness are those due to Nikuradse and Schlichting [3], in which experiments were made on the flow through artificially roughened pipes. It is difficult to define accurately the roughness met with in practice. Nikuradse used sand of definite grain size and density of distribution over the surfaces. Some of his results are shown in Fig. 5.

With very small sand grains, the curve of resistance coefficient C_f is of the laminar type at first, changes over to the smooth turbulent curve as for a smooth plate, and only at some relatively large value of Reynolds number does it leave this curve, then becoming parallel to the base line of the diagram. This shows that above a certain value of Reynolds number the resistance for a rough surface varies as V^2.

As the roughness is increased (for example, by using larger sand grains) the Reynolds number at which the C_f coefficient leaves the smooth turbulent curve becomes lower and lower, and finally the transition takes place straight from the laminar to the "rough" condition. The coefficient C_f for rough surfaces is thus constant once the transition range is passed, its actual value depending upon the relative roughness.

The explanation of this effect of roughness may be briefly stated. The laminar film at the surface in turbulent flow is very thin—usually measured in thousandths of an inch—and is indicated by the dimension δ in Fig. 3(b). So long as the roughness of the surface are less than the thickness of the laminar film, they will not come into contact with the turbulent flow in the boundary layer, and will have no effect upon it, and the surface will be "smooth". When the roughnesses are greater in height than δ, however, they protrude into the turbulent region, increasing the irregularities of flow, setting up eddies and experiencing increased pressures on their forward sides and decreased ones behind, all leading to an increase in resistance. The bigger the height of the roughnesses, the further they protrude into the turbulent region and the larger C_f.

It can be shown that δ, the thickness of the laminar film in turbulent flow, decreases with increase in Reynolds number—hence a roughness height which does not come through the film at low Reynolds numbers will subsequently do so if the value of R is sufficiently increased, and the greater the height of roughness, the sooner will the "smooth" surface act as a "rough" one.

6.—Experimental Data on Skin Friction.

Many experiments have been carried out in both air and water, using either towed plates or pipes with fluid running through them. When the results are plotted as C_f to a base of $\frac{VL}{\nu}$, they conform to the general pattern described above, as is evident from Fig. 4.

The best known of these results to naval architects and marine engineers are those due to W. Froude, published in 1872 and 1874 [4], and the coefficients for ship frictional resistance in general use to-day are those derived by the Froudes, father and son, from these experiments. The latter were carried out with planks of different lengths, the longest being 50ft., and the highest Reynolds number attained was $4{\cdot}6\times10^7$. Now the Reynolds number for a 400ft. ship at 10 knots is $5{\cdot}5\times10^8$ and for an 800ft. ship at 30 knots is $3{\cdot}3\times10^9$, or 12 and 72 times as high as the largest value reached by Froude. To use such experiments at low Reynolds number to predict the correct C_f for the much higher value for the ship is a problem fraught with great difficulty, involving as it does a great range of extrapolation. Froude in 1874 produced coefficients for lengths up to 500ft. assuming that the resistance was varying as $V^{1{\cdot}825}$ and giving values of a coefficient f for different lengths to be used in the formula

$$R_f = f.\ S.\ V^{1{\cdot}825} \quad \ldots \quad (4)$$

but it is not known how he derived these from the plank results. The theory of turbulent flow was not then developed (Osborne Reynolds paper appeared in 1883). It was assumed for many years that Froude took the resistance per sq. ft. of all the surface more than 50ft. aft of the leading edge as being the same as that of the 50th foot, but Payne has recently shown that this method does not give Froude's published figures [5]. R. E. Froude in 1888 extended the coefficients to lengths of 1,200ft., making some further small adjustments [6].

As the theory of turbulent flow developed, it was natural to see how Froude's coefficients complied with the known dependence of C_f on Reynolds number, and Baker in 1915 [7] made such a comparison, and by plotting on a logarithmic scale obtained a straight line through the experimental spots and extrapolated this to the necessary higher Reynolds numbers.

Reference to Fig. 4 will show that Froude's coefficients, con-

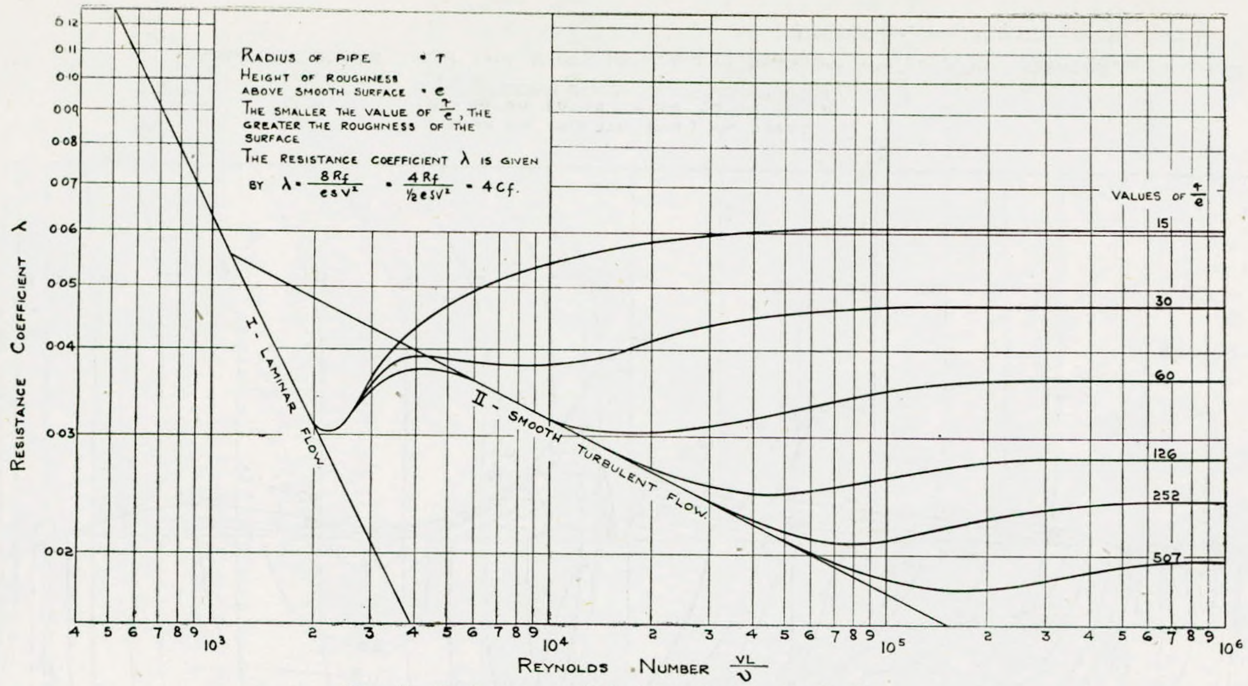


FIG. 5.—*Resistance coefficient for flow in rough pipes.*

verted to the C_f form, do not conform to the law of dependence on the parameter $\frac{VL}{\nu}$, which is necessary for dynamical similitude, but for different lengths of ships give rise to a series of lines nearly parallel to the theoretical smooth turbulent curve, but mounting steadily above it with increase in length. This latter curve is well established by experiments in other spheres than naval architecture, and a good case can be made out for a complete reconsideration of the present methods of calculating skin friction resistance. The Continental and American Tanks before the war had in many cases already done so, using the smooth turbulent curve for the correct Reynolds number for the ship and adding to it an allowance for roughness which depended upon the type of ship, condition of surface and arrangement of butts, laps and seams.

For a 400ft. ship at 10 knots, the Reynolds number is $5{\cdot}5\times10^8$, and the C_f value for smooth turbulent flow is 0·00177. Experiments by Kempf [8] on long rafts have shown that this figure is increased, when the surface has two coats of ships' paint applied over butts, laps and rivets, by 17 per cent. up to 0·00207. It is remarkable that Froude's coefficient for a 400ft. ship at 10 knots is 0·00209—in other words, his values as extrapolated to the ship lengths virtually include an allowance of the correct order for roughness such as is present on a clean, plated, freshly painted hull. Whether he included any such allowance deliberately or not we shall probably never know, but its presence accounts for the success of the coefficients in predicting ship resistance and their continued use in most experiment Tanks to-day.

7.—The Prediction of Ship Resistance from Model Results.

We have seen that skin friction resistance depends upon the value of the Reynolds number $\frac{VL}{\nu}$. From dimensional considerations it can be shown that wave making resistance depends upon another parameter, $\frac{V}{\sqrt{gL}}$, called the Froude number, where L is the length of the ship and g the acceleration due to gravity. The frictional resistance coefficient will be the same for model and ship when $\frac{VL}{\nu}$ is the same for both, whilst for the wave making coefficients to be identical, the values of $\frac{V}{\sqrt{gL}}$ must be equal. For experiments in water, ν and g are the same in model and in ship, and we see that it is intrinsically impossible to fulfil both requirements in a single model test, since the absolute model speed would have to be very much higher than that of the ship to fulfil the constancy of VL and very much lower to make $V/\sqrt{L}$ the same in each case.

Froude was the first to clearly show that when a model and a ship are running at the same values of $\frac{V}{\sqrt{L}}$ the wave formations are exactly similar, and that then the wave making resistance R_W of the ship is given by

$$R_W = r_W\lambda^3 \quad \ldots \quad (5)$$

where r_W = wave-making resistance of model
and λ = scale ratio of ship to model.

Such speeds are called "corresponding speeds".

But the measured resistance of the model includes both skin friction and wave-making resistance, and the difficulty was to separate them. Froude assumed that the frictional resistance of the model or ship hull was the same as that of a flat surface having the same total area and length. By the use of his coefficients, r_f for the model could be calculated and subtracted from the total model resistance, giving the residuary or wave-making resistance r_W. This could then be used to find the residuary resistance R_W for the ship from equation 5, to which could be added the frictional resistance R_f calculated from his appropriate ship coefficient, giving the total resistance of the ship. This splitting up of the resistance into two components was a great step forward, and Froude was enabled by so doing to convince the Admiralty of the usefulness and reliability of model experiments. Nevertheless, a moment's reflection will show that the assumption that the resistance of a flat and a curved surface of the same length and area will be the same cannot be theoretically justified. We shall return to this point later, but in the meantime, it is well to remember that this is still the method in use to-day to determine the ship resistance from the results of model tests.

8.—Wave Making Resistance.

When a ship passes over the surface of water, a wave pattern is generated, and the energy which is being continuously supplied to the wave system appears as wave making resistance.

The earliest account of the way such waves are formed was given by Kelvin in 1887 [9] and elaborated in 1904 [10]. He imagined the ship to be an isolated pressure point travelling over the water, sending out groups of waves, which he showed would give rise to two systems travelling along with the point, one a divergent pattern spreading out on either side of the line of travel, the second a series of transverse waves behind the point.

When a ship hull moves through the water, the pressure along the length will vary, there being generally an area of high pressure near the bow and stern and of low pressure along the middle portion. In the case of a completely and deeply submerged vessel such as a submarine, this will not give rise to waves, but when the pressure disturbance is near the surface, the latter is disturbed and wave systems are formed having their initial crests or hollows some distance aft of the points of maximum and minimum pressure. This is well illustrated by experiments made by Eggert in the Washington Tank [11], in the course of which he measured the pressure distribution over the ends of a model and compared it with the observed wave profile (Fig. 6). By taking the longitudinal components of these

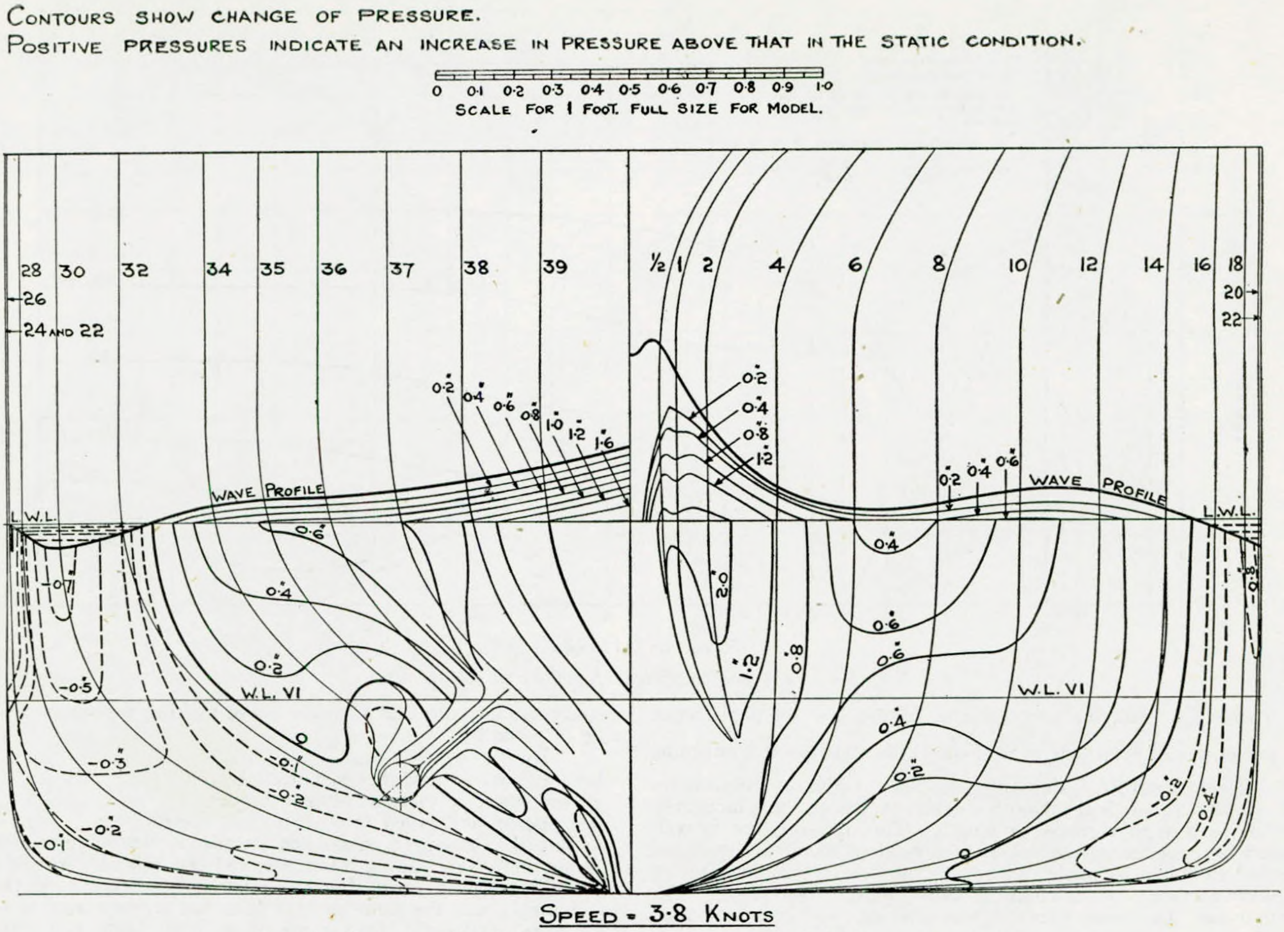


FIG. 6.—*Pressure distribution measured over a model hull.*

pressure forces and integrating them over the length (Fig. 7) he was able to show that the resulting resistance agreed quite closely with that measured on the model after the estimated skin friction had been subtracted.

The wave resistance experienced by a ship can therefore be looked upon as the resultant net fore and aft force acting on the hull due to the pressure distribution around it. For a ship of mathematical form moving in a perfect fluid, this resultant force can be calculated, as was shown in 1898 by Michell [12].

Alternatively, the wave resistance may be calculated from energy considerations once the wave pattern at a great distance behind the ship is known, as shown by Havelock [13]. Naturally both these methods lead to the same mathematical expressions.

Various experimenters have taken up this subject, and compared the calculated and measured wave resistances of models having mathematical forms. There are various restrictions on the method, due to the assumptions which are necessary in order to make the mathematical work amenable to treatment, but it was very soon found that the greatest discrepancy was due to the neglect of viscosity in the calculations. Havelock in 1935 [14] suggested a method by which this difficulty might be overcome empirically by comparison of calculated and observed results for models, and Wigley followed this up at the National Physical Laboratory, obtaining a viscosity correction from the results of a number of models, which could then be applied to future calculations [15]. This viscosity correction gave calculated curves of wave resistance Ⓒ$_W$ which agreed quite closely with those measured, as is evident from Fig. 8, taken from paper 15. Whilst we are still some way from being able to calculate the actual wave making resistance of a ship, the qualitative agreement shown above is such that the mathematical theory can be used to study the fundamentals of wave resistance.

Perhaps the clearest idea of these can be derived from a study of the wave making of a very simple wedge-shaped form described by Wigley in 1931 [16] having a waterline made up of a parallel centre section with equal wedge shaped ends (Fig. 9). He showed that the expression for the wave profile along the hull contained five terms :—

(i) a symmetrical disturbance of the surface, dying away quickly fore and aft, and which absorbs no energy because of its symmetry.

and four wave systems, generated at

(ii) the bow, and beginning with a crest;
(iii) the forward shoulder, and beginning with a trough;
(iv) the after shoulder, and beginning with a trough; and
(v) the stern, beginning with a crest.

These four systems are shown in Fig. 9. Considerably aft of the form, all four systems become sine curves of continuously

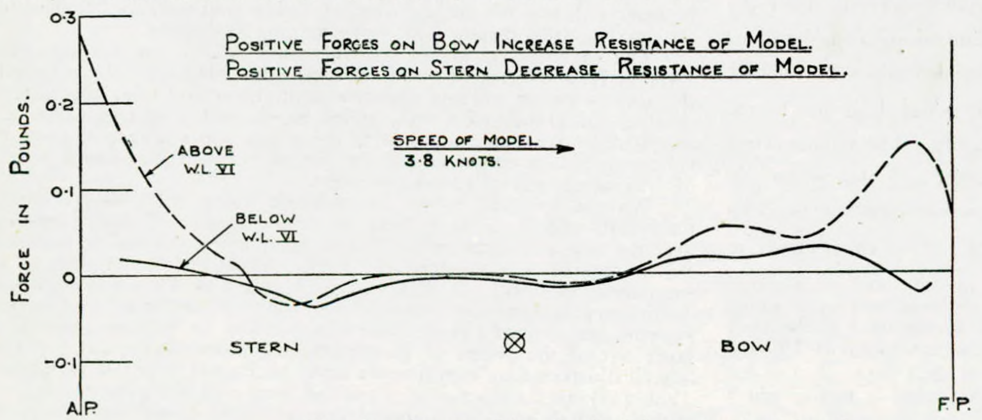


FIG. 7.—*Curves of longitudinal force per inch length.*

diminishing amplitude of a length appropriate to a free wave travelling at the speed of the model, this length being reached after about two complete waves.

The calculated profile along the model will be the sum of these five systems, and the model profile as measured was in general agreement with that derived theoretically in so far as shape and positions of the crests and troughs were concerned, but the heights of the actual waves towards the stern were considerably less than calculated, due principally to the effects of viscosity.

The complete wave profile, and therefore the energy to maintain it, and so finally the wave resistance, will vary with speed, since the component wave systems lengthen with speed and the relative positions of their crests will alter. This will give rise, as speed is increased, to oscillations in the wave resistance which account for the humps and hollows seen in the Ⓒ curves of Fig. 1.

In this simple, straight line form two types of interference can occur :—

(i) between two systems of the same sign, i.e. bow with stern, or between the shoulder systems ; and

(ii) between systems of opposite sign, e.g. bow and shoulder system.

The second type is the more important, because the primary hollow of the shoulder system can coincide with the first hollow of the bow system, before the latter has been materially damped by viscosity. In the first type, the primary crest of the stern system can only coincide with a crest of the bow system which has already lost much of its height by viscous damping.

The second type, in this particular form, occurs between bow and aft shoulder and between forward shoulder and stern at the same time, because of symmetry, and the separation of these points is (1+a) or pL (Fig. 9).

The maxima of resistance will occur when the final wave system has the greatest heights, i.e. when the crests (or troughs) of the two systems coincide, which will happen when

$$pL = \tfrac{1}{2},\ \frac{3}{2},\ \frac{5}{2},$$

etc., of a wave length.

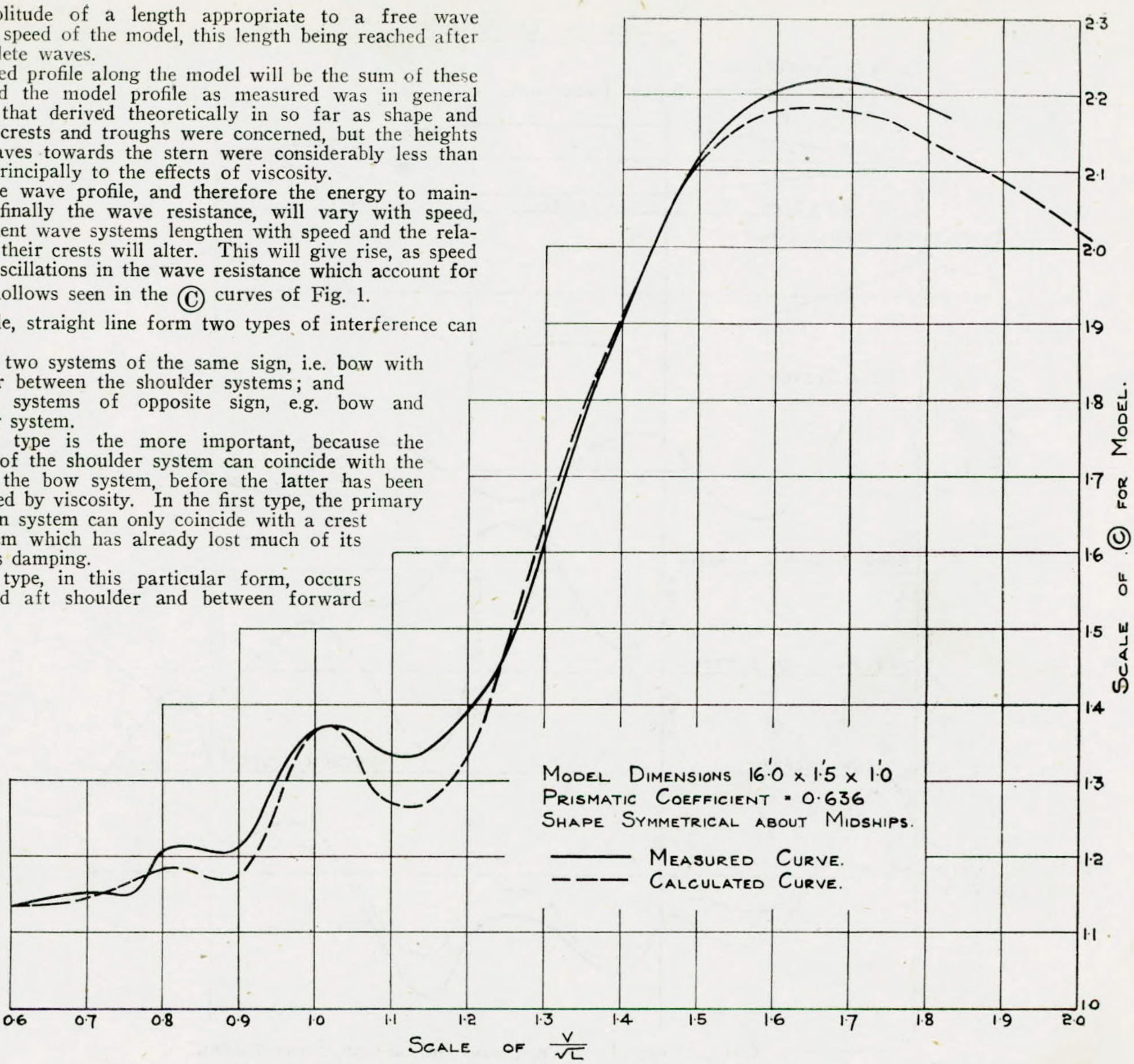


Fig. 8.—*Comparison of measured and calculated* Ⓒ *curves.*

Similarly, the minima of resistance will be found when the final wave system has the least height, i.e. when the crests of one system coincide with troughs of the other, and then

pL = 1, 2, 3, etc. wave lengths.

Now Ⓟ as defined in equation (2) is the ratio of the ship speed to the speed of a wave of length pL*. If the waves forming the different systems had all a length appropriate to their speed, we could say that maxima and minima of the wave resistance should occur when‡

$$Ⓟ_{max.} = 1{\cdot}414;\ 0{\cdot}818;\ 0{\cdot}634;\ 0{\cdot}535\ \ \ldots\ \ldots\ \ldots\ \ldots$$

$$Ⓟ_{min.} = 1{\cdot}000;\ 0{\cdot}707;\ 0{\cdot}578;\ 0{\cdot}500\ \ \ldots\ \ldots\ \ldots\ \ldots$$

Actually, the first waves of any system formed by a ship are a little shorter than given by the trochoidal theory, and the coincidence of crests or troughs does not occur until slightly higher speeds than those given above are reached—for the simple form being discussed, Wigley has shown the critical speeds to be

$$\left.\begin{array}{l} Ⓟ_{max.} = 1{\cdot}434;\ 0{\cdot}821;\ 0{\cdot}634;\ 0{\cdot}535\ \ \ldots\ \ldots\ \ldots\ \ldots \\ Ⓟ_{min.} = 1{\cdot}007;\ 0{\cdot}709;\ 0{\cdot}579\ \ \ldots\ \ldots\ \ldots\ \ldots\ \ldots \end{array}\right\} 6$$

The next most important interference will be that between the bow and the forward shoulder, and here for maximum resistance we shall have

$$L_E = \tfrac{1}{2},\ \frac{2}{3}\ \text{etc. wave lengths.}$$

where L_E = length of entrance from bow to fore shoulder. These correspond to speeds given by

$$V = 1{\cdot}92\sqrt{L_E};\ 1{\cdot}10\sqrt{L_E};\ 0{\cdot}88\sqrt{L_E}\ \ \ldots\ \ldots\ \ldots\ \ldots\ (7)$$

The first of these is, for normal forms, obscured by the hump at Ⓟ = about 1·5 ; the last, and all beyond it, are at such low speeds that

---

$$* \ \frac{\text{Speed of ship}}{\text{Speed of wave of length pL}} = \frac{\text{V (knots)}}{\sqrt{\dfrac{g(pL)}{2\pi}} \times \dfrac{60}{101{\cdot}33}} = \frac{0{\cdot}746\ V}{\sqrt{pL}} = Ⓟ$$

‡ If λ is the length of the waves generated, then the speed of the waves, and therefore of the ship itself, is given by $\sqrt{\frac{g\lambda}{2\pi}}$. Hence

$$Ⓟ \text{ for that speed is} = \frac{\sqrt{\dfrac{g\lambda}{2\pi}}}{\sqrt{\dfrac{g(pL)}{2\pi}}} = \sqrt{\frac{\lambda}{pL}}$$

For maxima of resistance,

$$pL = \tfrac{1}{2}\lambda,\ \frac{3}{2}\lambda,\ \frac{5}{2}\lambda,\ \text{etc.}$$

$$\text{whence } Ⓟ = \sqrt{2},\ \sqrt{\frac{2}{3}},\ \sqrt{\frac{2}{5}},\ \text{etc.}$$

$$= 1{\cdot}414;\ 0{\cdot}818;\ 0{\cdot}634,\ \text{etc.}$$

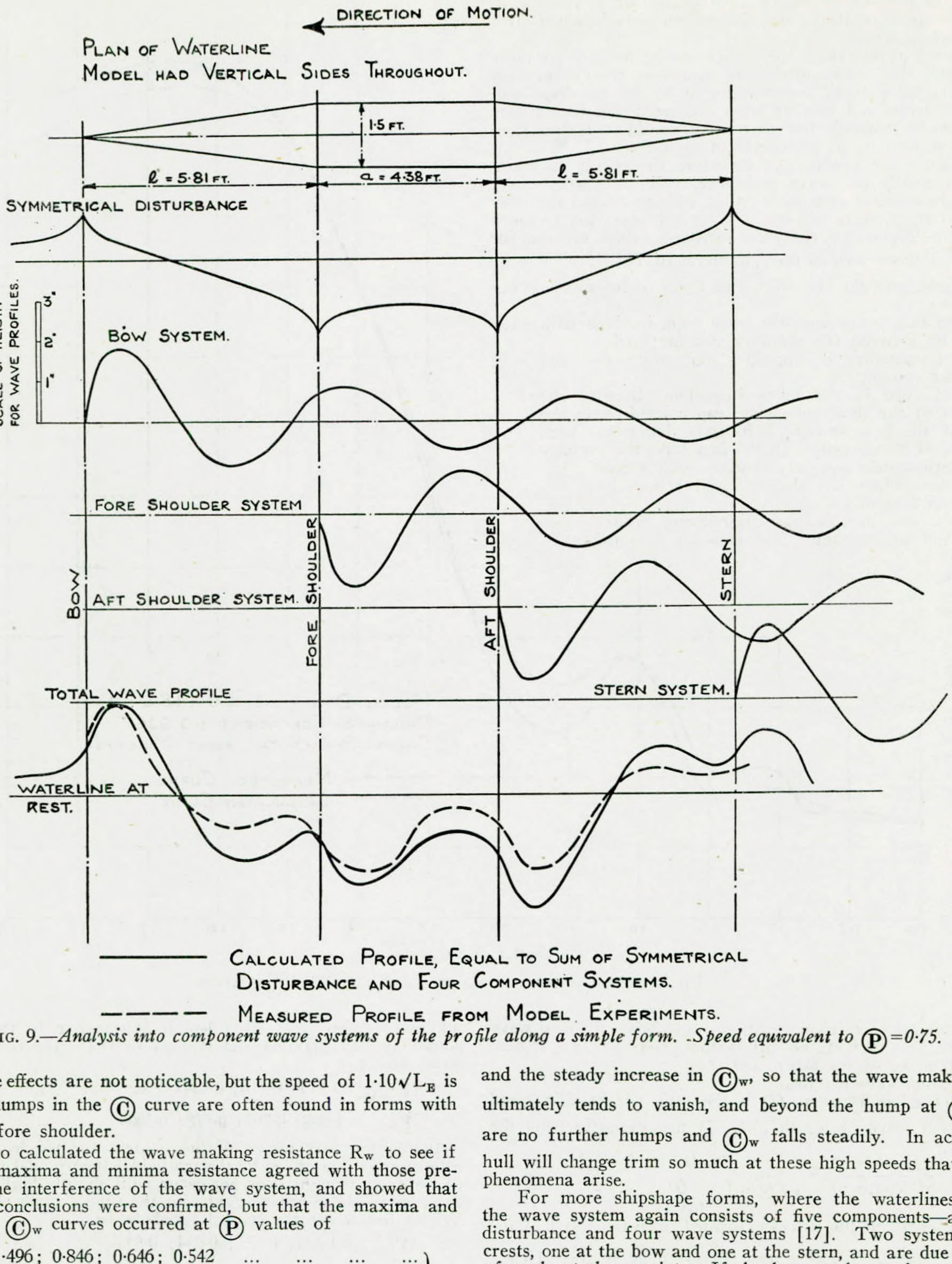


FIG. 9.—*Analysis into component wave systems of the profile along a simple form. Speed equivalent to* Ⓟ*=0·75.*

the interference effects are not noticeable, but the speed of $1{\cdot}10\sqrt{L_E}$ is one at which humps in the Ⓒ curve are often found in forms with a pronounced fore shoulder.

Wigley also calculated the wave making resistance R_W to see if the speeds of maxima and minima resistance agreed with those predicted from the interference of the wave system, and showed that all the above conclusions were confirmed, but that the maxima and minima of the $Ⓒ_W$ curves occurred at Ⓟ values of

$$\left.\begin{array}{l} Ⓟ_{max.} = 1{\cdot}496;\ 0{\cdot}846;\ 0{\cdot}646;\ 0{\cdot}542 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \\ Ⓟ_{min.} = 1{\cdot}044;\ 0{\cdot}726;\ 0{\cdot}589 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \end{array}\right\} \quad (8)$$

The expression for the wave making resistance R_W is of the form

$R_W \propto V^6$ (constant term + four oscillating terms)

and therefore

$$Ⓒ_W \propto V^4 \text{ (constant term + four oscillating terms)} \quad \ldots \quad \ldots \quad (9)$$

The $Ⓒ_W$ curve is thus made up of a steady increase varying as V^4 due to the constant term and four types of interference (Fig. 10). These latter ultimately, at very high speeds, cancel both each other and the steady increase in $Ⓒ_W$, so that the wave making resistance ultimately tends to vanish, and beyond the hump at Ⓟ$=1{\cdot}5$ there are no further humps and $Ⓒ_W$ falls steadily. In actual fact, the hull will change trim so much at these high speeds that entirely new phenomena arise.

For more shipshape forms, where the waterlines are curved, the wave system again consists of five components—a symmetrical disturbance and four wave systems [17]. Two systems begin with crests, one at the bow and one at the stern, and are due to the change of angle at these points. If the bow angle on the waterline is the same as for the straight line form, the wave system commencing there will be the same. The other two systems, like the shoulder systems in the straight line form, begin with hollows, but are no longer tied to a definite point, since the change of slope is now gradual and spread over the whole entrance or run. They commence at the bow and after shoulder respectively, as shown in Fig. 11, much more gradually than in the previous case of the wedge shaped form. The one due to bow curvature may be looked upon as a progressive reduction of that due to bow angle as the slope of the waterline becomes less in going aft from the bow.

Since the origins of the wave systems are now spread out along

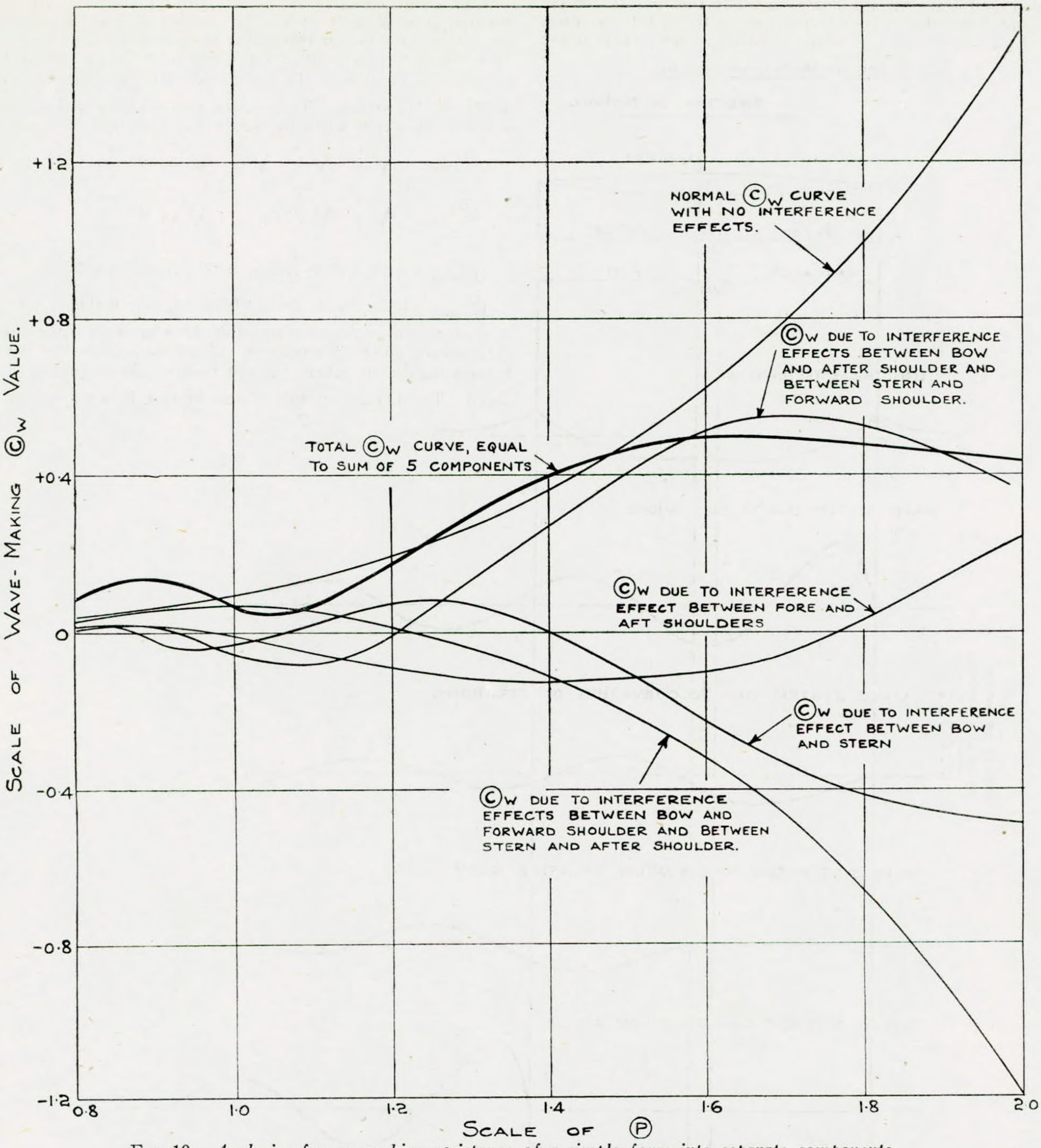


FIG. 10.—*Analysis of wave making resistance of a simple form into separate components.*

the curved entrance and run, the wave making length becomes much less definite, but if the values of Ⓟ for the humps and hollows on the resistance curve are worked out for a parabolic form having 60 per cent. and no parallel body in the length, the following values are obtained :—

60 per cent. parallel body.

$$\left.\begin{array}{l} Ⓟ_{max.} = 1{\cdot}52;\ 0{\cdot}85;\ 0{\cdot}65;\ 0{\cdot}54\ \ldots \\ Ⓟ_{min.} = 1{\cdot}07;\ 0{\cdot}73;\ 0{\cdot}59\ \ldots \end{array}\right\} \quad (10)$$

0 per cent. parallel body.

$$\left.\begin{array}{l} Ⓟ_{max.} = 1{\cdot}55;\ 0{\cdot}89;\ 0{\cdot}73;\ 0{\cdot}62\ \ldots \\ Ⓟ_{min.} = 1{\cdot}07;\ 0{\cdot}79;\ 0{\cdot}67\ \ldots \end{array}\right\} \quad (11)$$

A comparison of these figures with those given for the straight line form in equation (8) shows that the Ⓟ values for maximum and minimum resistance for the parabolic form with 60 per cent. parallel length agree very closely with those for the straight line form, showing that in this case pL is still a reasonable approximation to the wave making separation length. Such a form will have ends approximating to the wedge shape. With no parallel body the ends will be much less so, and here we see that the agreement in Ⓟ values is not so good, and the wave making separation must differ more from the value pL. Of course, the existence of interference effects of this kind was known to naval architects long before the mathematical work outlined above was started. Froude demonstrated them in a striking manner by running a number of models consisting of the same fore and after bodies separated by different lengths of parallel [18]. For a given speed the phase of the fore and after body wave systems changed with the addition of more and more parallel, giving rise to oscillations in the wave making resistance (Fig. 12). These curves also show that the actual waves were shorter than those to be expected from the trochoidal theory for the same speed. Baker and Kent, in 1913, were actually the first to analyse Froude's results and other work of their own at the N.P.L. on much fuller merchant vessels with a view to finding some criterion for predicting the interference speeds [19]. They were led to the conclusion, from a study of a large number of wave profiles measured on models of different types, that the product pL was a satisfactory measure of the wave interference characteristics of a ship form, and accordingly introduced the speed constant $\textcircled{P}$ which is still in use at the N.P.L. to-day. They stated that maxima and minima resistances would occur when the speed was such that

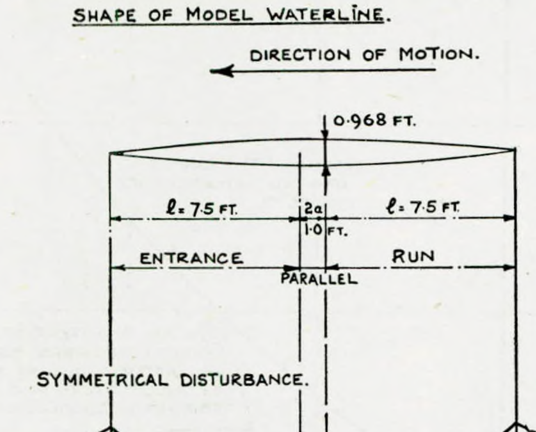
$$\textcircled{P}_{max.} = \sqrt{\frac{4}{1}};\ \sqrt{\frac{4}{5}};\ \sqrt{\frac{4}{9}};\ \sqrt{\frac{4}{13}} \text{ etc.}$$

$$\textcircled{P}_{min.} = \sqrt{\frac{4}{3}};\ \sqrt{\frac{4}{7}};\ \sqrt{\frac{4}{11}}:\ \sqrt{\frac{4}{15}} \text{ etc.}$$

or

$$\left.\begin{aligned} \textcircled{P}_{max.} &= 2{\cdot}00;\ 0{\cdot}895;\ 0{\cdot}667;\ 0{\cdot}555;\ 0{\cdot}485;\ 0{\cdot}437 \quad \dots \quad \dots \\ \textcircled{P}_{min.} &= 1{\cdot}15;\ 0{\cdot}756;\ 0{\cdot}603;\ 0{\cdot}516;\ 0{\cdot}460;\ 0{\cdot}417 \quad \dots \quad \dots \end{aligned}\right\} \quad (12)$$

A comparison of these values with those given in equations (10) and (11) shows good agreement at all points except for the last and highest maximum, where the $\textcircled{P}$ theory fails to predict the correct speed. The reason for this is now known, it being due to a change



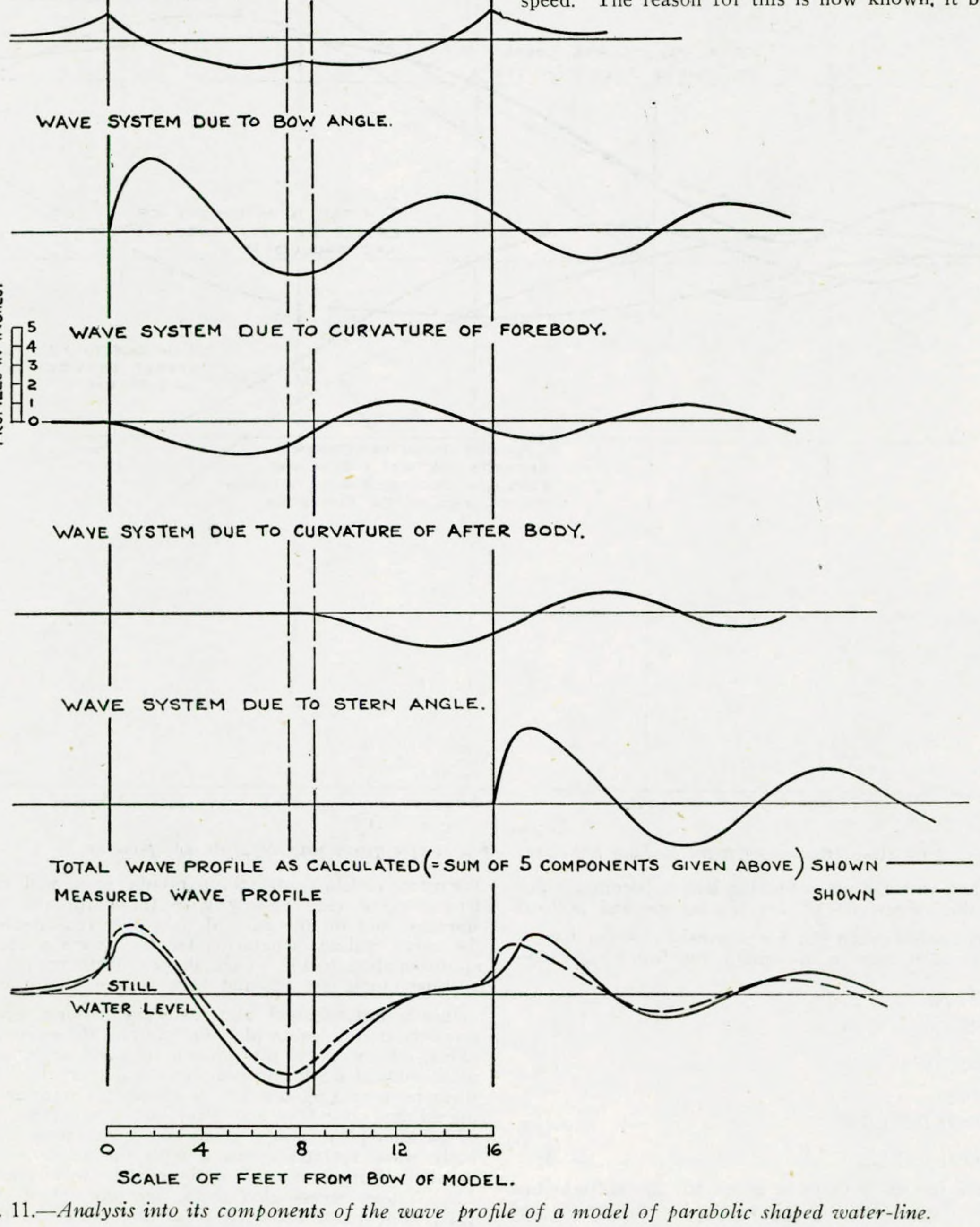


FIG. 11.—*Analysis into its components of the wave profile of a model of parabolic shaped water-line.*

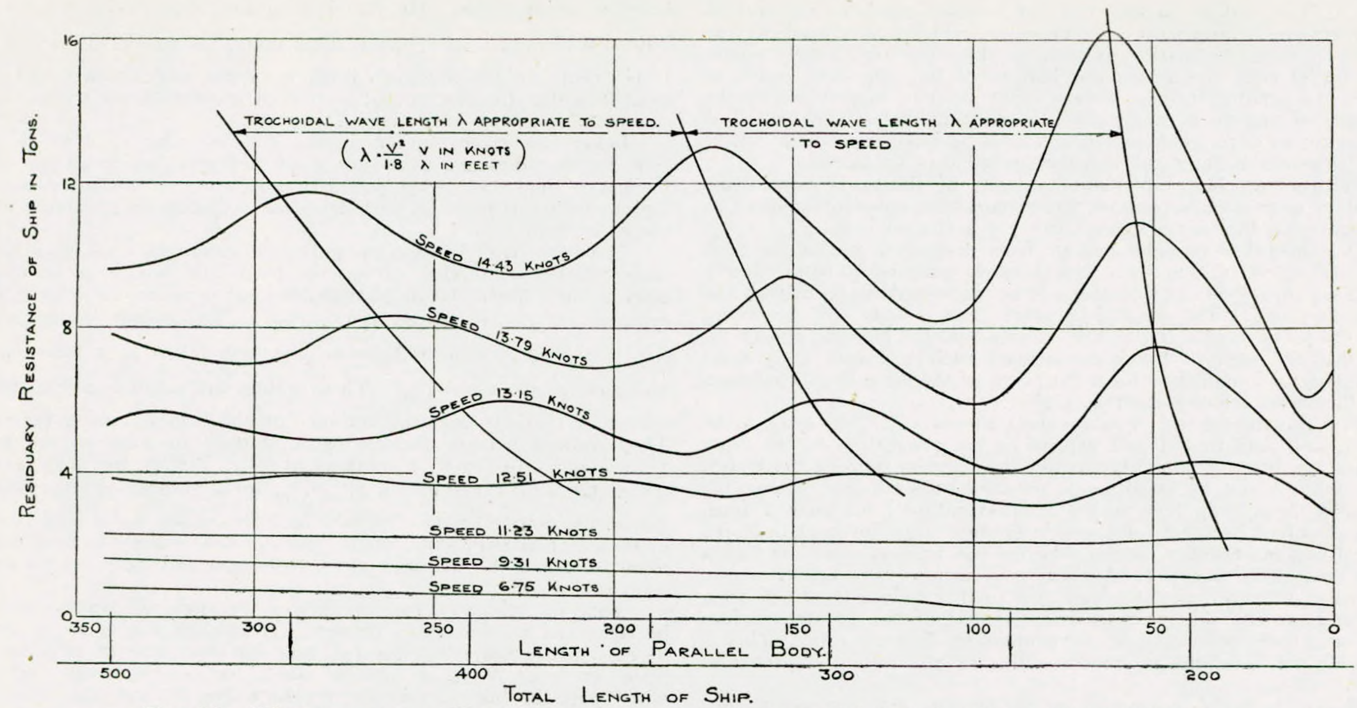


FIG. 12.—*Effect on wave making resistance of interference caused by varying length of parallel body.*

in the position of the first crest of the bow system which takes place at such high speeds, and the last maximum of the Ⓒ curve actually occurs at Ⓟ between 1·5 and 1·6.

With this reservation, the Ⓟ theory gives the naval architect a valuable guide to the best and worst wave making speeds to be experienced in a new design, and enables him to take the necessary steps either to avoid a maximum point or, if this is impossible, such as are practicable to reduce its effect as much as possible.

It is interesting to note that Baker and Kent also gave in their first paper referred to above the speed for entrance wave making as $v = 1{\cdot}09\sqrt{L_E}$, which agrees exactly with that given in equation (7) from the mathematical analysis.

9.—Form Resistance.

From the discussion on skin friction drag and wave making resistance outlined above, we can imagine the total Ⓒ curve as being made up of two parts, Ⓒ$_F$ and Ⓒ$_W$, due to skin friction and wave making respectively. In Fig. 13, AA represents the total Ⓒ curve as measured in the Tank experiments. As already described, Ⓒ$_F$ can be calculated on the assumption that the skin friction resistance of the hull is the same as that of a flat surface of the same area and length. If we restrict ourselves for the moment to the model results, this can be done without introducing any doubts as to the method of extending the skin friction coefficients to ship lengths. The curve of Ⓒ$_F$ will be almost a straight line such as BB, sloping slightly down as the speed (and Reynolds number) of the model increases. If the model has been run to quite low speeds, the lowest part of the Ⓒ curve will be found to be sensibly parallel to the curve of Ⓒ$_F$ and situated some little distance above it. At such speeds the wave making resistance is negligible, and the additional resistance over and above that estimated from the plank friction data, has been called the form resistance or form drag, and is indicated in Fig. 13 as ΔⒸ$_F$.

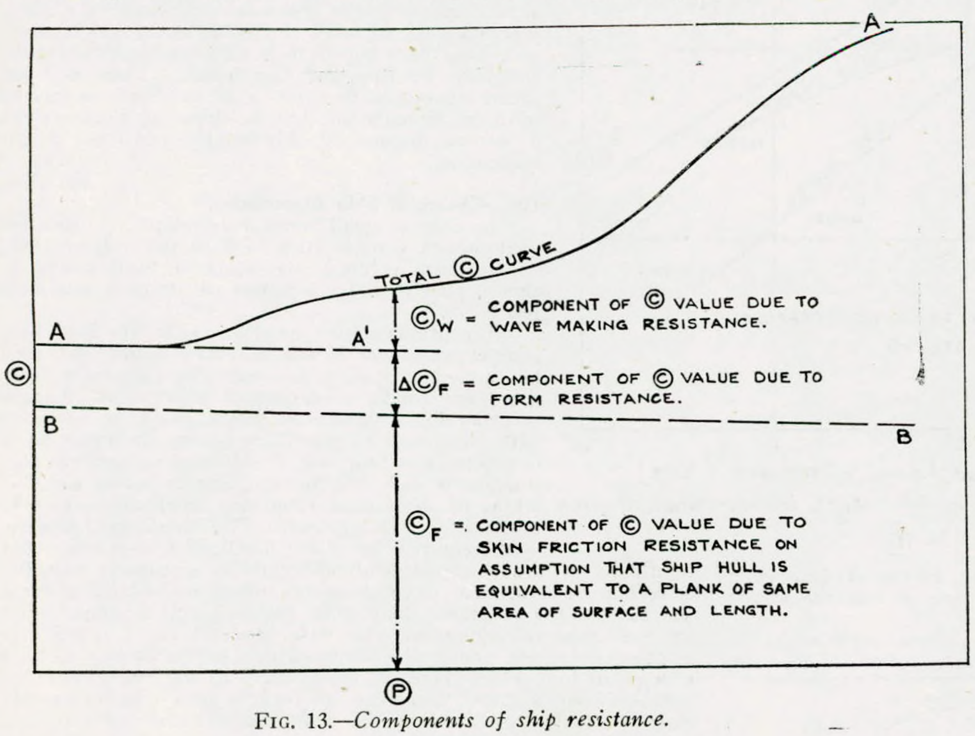


FIG. 13.—*Components of ship resistance.*

This form drag is made up of two components. In the first place, if the stern of the model is very full and short, or the bilge has too small a radius, eddies may be shed, and the energy lost in this way will increase the resistance. To avoid such eddy-making resistance, the after end waterlines of the ship should have a gentle curvature and the tangent to the lines should, if possible, not exceed an inclination of 18° to the ship's centreline. This is not always possible, of course, but the slope should be kept as near to this figure as other factors will allow. The bilge radius can be made smaller on slower speed vessels—values such as to make the midship area coefficient as high as 0·98 can be worked if care is taken to avoid corners where the parallel ends and if the flat bottom of the ship also begins to rise fairly rapidly at these points. But even in models where the presence of any such eddy-making is most unlikely, there is still a component of form resistance which is to be attributed to the difference between the flat plank and the curved ship surfaces.

With a flat plate, the relative velocity of the water outside the boundary layer will be constant and equal to the speed of advance of the plate, but this is no longer true for a shaped body.

It is useful to consider this problem first for a streamline body—a solid of revolution such as a torpedo or airship form—deeply immersed in a fluid, so that there is no wave-making to disturb the streamline flow. The normal pressure on the body will now vary over the surface, as will also the velocity, and the physical consideration that the path of the water around such a shaped body must necessarily be longer than for a flat plank of the same length indicates that the mean velocity must be higher.

For this reason we should expect the skin friction drag to be higher, also, and that it will depend on the proportion of the body in question, being smaller the greater the fineness ratio of the body*. This is borne out by experiments on such bodies in air, where, for example, the airship R33 with a fineness ratio of 8·2 gave a form drag of only 4 per cent. of the skin friction drag for a plate at the same Reynolds number, whilst "Akron" of fineness ratio 5·9 had a form drag of 7·7 per cent. Reduction in fineness ratio beyond a certain point, however, whilst it may still further reduce the form drag, will increase the skin friction drag because of the greater surface area, and there will thus be some optimum fineness ratio. This is probably not a definite figure but will vary also with the particular shape.

When the body is brought to the surface, and becomes a ship, the form effect is still present, but is further complicated by the fact that the variation in pressure along the hull now gives rise to wave systems, which alter the amount of wetted surface and the velocities over the hull. These latter effects are usually credited to the wave resistance, and the form drag is taken as the excess of drag over that of the equivalent flat plate at such low speeds that the wave-making resistance is negligible.

Perring in 1925 published the results of some experiments at the N.P.L. with models of ships and of simple forms of different beam to draft ratios. He found in general that $\Delta \textcircled{C}_F$ was about 0·10 to 0·12 on a total $\textcircled{C}_F$ of about unity, i.e. an increase of 10 to 12 per cent., the lower figures being for beam to draft ratios of 2·0, nearest to that for one half of a solid of revolution, for which form resistance is known to be small.

Baker has given similar figures, of the order of 4 to 15 per cent. for warships and passenger ships, and going up to 25 per cent. for cargo ships, but as the prismatic coefficient of the latter was as high as 0·80, this probably includes some eddy-making resistance over the after body.

In recent years Wigley has published measured resistances for a large number of models of narrow beam and fine form in which there is little likelihood of eddy-making aft or along the bilge. The ordinate of the measured $\textcircled{C}$ curve at the lowest speed, when $\textcircled{C}_F$ has been subtracted from it, has been taken as a measure of the form resistance $\Delta \textcircled{C}_F$. These values are plotted in Fig. 14 to a base of the half angle of entrance on the load waterline forward. They show a definite decrease with increase in angle of entrance, from about 0·10 for 5° to nothing at 20°. Wigley has also carried out a statistical investigation of $\Delta \textcircled{C}_F$ for a number of ship models run in the course of the ordinary tank test work, and found that it increased from very small angles with hollow waterlines to a maximum for about 10°, and thereafter, with more and more convex lines, decreased again.

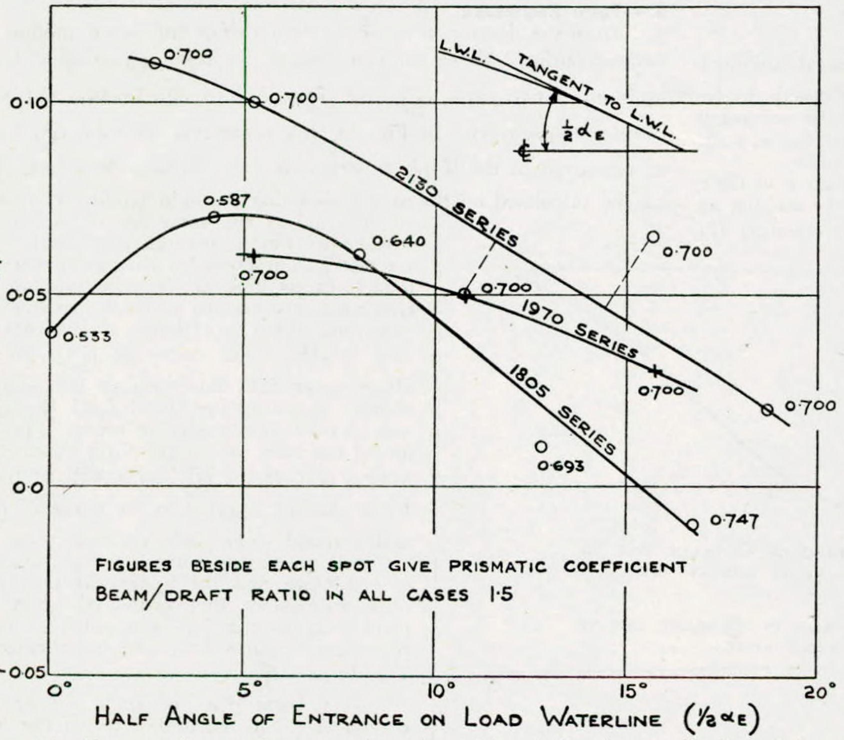


FIG. 14.—*Form resistance for a number of models.* $\Delta \textcircled{C}_F$ *is contribution of form resistance to total* $\textcircled{C}$.

Thus for minimum form resistance the angle of entrance should be large and the waterlines convex. To explain this effect, it seems necessary to assume that the full bow has the effect of pushing the water in front of it, so slowing down the relative motion of the water past the hull just in the region where the greatest frictional resistance is normally experienced. As a result, the relative velocity all along the hull is reduced, and in extreme cases the frictional resistance is actually less than that for the equivalent plank. The increased pressure over the fore part of the bow will, of course, give rise to some additional wave resistance, but at very low speeds this will not be important, and a net gain results. This is borne out by the experiments of Eggert's referred to above. The model he used had a very pronounced bulbous bow, with very high pressures on its forward side, but the form resistance was very definitely negative over the lower two-thirds of the speed range, as distinct from earlier results of his with non-bulbous bows, where the form resistance was positive. This can only be achieved at the cost of increased wave resistance, however, and is therefore only to be recommended at low speeds where the wave resistance is a small percentage of the total. Such full waterlines forward have long been known to be beneficial at slow speeds, and here we have the explanation. They have the added advantage that for a given displacement the stern can be made fine and the slopes kept low enough to ensure absence of eddy-making resistance at the same time.

10.—Choice of Ship Dimensions.

In only a small number of ships is speed the predominant consideration, and in the ordinary field of merchant shipping the shape of hull cannot be chosen purely on the grounds of attaining minimum resistance.

The first condition most generally laid down by a prospective owner is that a certain deadweight must be carried at a certain speed. In addition to this, there are usually a number of restrictions. Length is generally a dimension which could be increased with advantage on purely resistance grounds, but it is expensive in first cost, it is limited by strength considerations and it is inconvenient in many cases in taking up more quay room and requiring long locks in canals or dock entrances. The scantlings and equipment required by the Classification Societies and the Board of Trade also depend on length as a primary variable. In certain cases a small increase in this dimension, whilst it might be beneficial for resistance, may bring the ship into a higher grade for scantlings or equipment. Increase in draft is of benefit for reducing resistance, and is also reflected in a corresponding increase in depth of hull, which increases the strength of the hull girder, and is accordingly a cheap dimension as regards cost. Unfortunately, draft is usually restricted by the depth of water in harbours and

$$\text{*Fineness ratio} = \frac{\text{length in direction of motion}}{\text{maximum diameter}}$$

particularly over the sills of docks.

Increase in beam without a corresponding decrease in fullness is generally bad from a resistance point of view, but a minimum beam to draft ratio is essential for stability.

The naval architect is thus faced with the problem of designing a hull which, whilst conforming to certain limiting conditions, will be the most economical to drive. Such a design must evidently be a compromise, and in the solution he must make use of the knowledge of ship resistance which has been outlined in the first part of this paper.

11.—Length and Prismatic Coefficient.

In order to carry a given displacement, the choice of length and prismatic coefficient are interdependent.

Whilst the reduction of first cost, port and other dues demands as short a length as possible, this dimension cannot be cut below a certain minimum without incurring an unreasonable penalty in increased power and lack of seaworthiness. Kent has shown [21] that two conditions give rise to maximum pitching—when the ship's natural pitching period is equal to the period of encounter with the waves, and when she is meeting with waves of such size that the ratio $\frac{\text{ship length}}{\text{wave length}}\left\{=\frac{L}{\lambda}\right\}$ is somewhat less than unity. Accordingly, a ship should have a length somewhat longer than that of the waves most prevalent on the trade routes along which she is to ply. For minimum pitching, Kent states that $\frac{L}{\lambda}$ should be about 1·7, whilst for minimum heaving, the value should be 1·2 [22]. His experience of weather in the North Atlantic in winter showed that the most commonly encountered wave had a length of some 275 to 300ft., so that for minimum pitching a length of about 500ft. would be necessary.

In the North Sea much shorter waves are normally met, of length 150 to 200ft., and the length for minimum pitching would be from 260 to 340ft. Whilst many of the vessels regularly plying to the Continent would pass this test, a great number coming into the coaster class would not do so, and it is known that such small vessels do feel the weather very much sooner and to a greater degree than their larger sisters.

Whilst the requirements of seaworthiness indicate a lower limit to the length, they also set an upper one to the permissible fullness. In a series of model tests in waves, covering experiments on five forms of prismatic coefficients ranging from 0·80 to 0·60, Kent found that the maximum prismatic coefficient for good speed-keeping properties should not exceed 0·75 [23]. The fullest model of the series shipped water over a smaller range of wave lengths than did the finest, but when it was shipped the fuller form took more on board, and was in some cases completely swamped. These conclusions from model tests have been confirmed at sea, as is shown by the figures in Table I, obtained by Kent [24].

TABLE 1.

Ship.	Length in ft.	Block coefficient.	Speed in smooth water, knots.	% Loss of speed in waves 6ft. high for same value of $\frac{\text{s.h.p.}}{\text{Dispt.}}$
"Berengaria" ...	883·6	0·60	24·0	4·2
"Montcalm" ...	546	0·71	16·5	6·7
"London Mariner"	450	0·73	14·3	7·3
"Oroyo"	530	0·70	13·6	8·1
"Oropesa" ...	530	0·745	13·0	10·4
"San Alberto" ...	442	0·742	12·7	13·4
"San Tirso" ...	420	0·785	10·25	21·0
"San Gerardo" ...	530	0·83	11·30	32·7

The percentage loss of speed in 6ft. waves increases very slowly with block coefficient up to a value of 0·74, but above this the loss increases very rapidly.

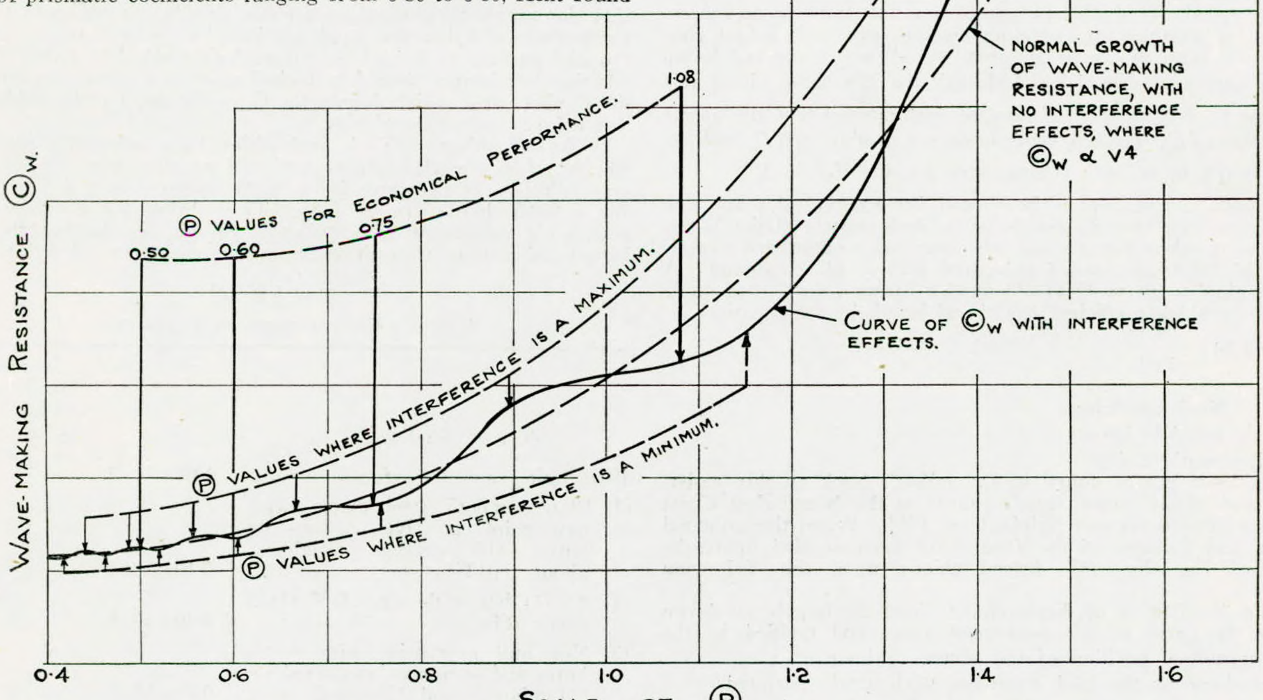


FIG. 15.—*Economical speeds for minimum wave making resistance.*

Excessive fullness forward also promotes a tendency to slam, and care should be taken to avoid any flat areas on the bottom forward. Transverse sections should not have too much U shape at the bottom, and the floor lines should commence to lift immediately the parallel body ceases so as to give a V shape which will allow the hull to enter the water smoothly when pitching.

As we have seen when discussing wave-making resistance, the product of length and prismatic coefficient, pL, in the form of the speed constant Ⓟ, will give an indication as to whether or not the ship is running at a favourable wave making speed. The Ⓟ values previously given for maximum wave making were 0·485, 0·555, 0·667, 0·895 and 1·50. These give the speeds at which the interference resistance is a maximum, that is, the points where the actual Ⓒ$_w$ value departs farthest above the mean wave resistance Ⓒ$_w$ curve, which we have seen varies as V^4 (Fig. 15). They do not, as a rule, indicate absolute maxima, but just above these speeds the Ⓒ curve flattens out before beginning the rise to the next hump. For economical performance, it is desirable for a ship to run at a Ⓟ value on this flat part, and the service speed should not be too near the beginning of the rise, in order that the form may remain good to a somewhat higher speed, a feature which is of great assistance in making up in fine weather time lost in bad. From Fig. 15 we see that suitable maximum values of Ⓟ are about 0·50, 0·60, 0·75 and 1·08. If these are exceeded, the higher speed will only be achieved at the expense of a disproportionate increase in power.

In a very full ship, such as the coaster in Fig. 1, the low speed humps are well developed, and the maximum economical speed will be given by

Ⓟ$=0{\cdot}50.$

The tanker form with a prismatic coefficient of 0·77, can be driven to the next speed of Ⓟ$=0{\cdot}60$ without undue expenditure of power.

For still finer forms, such as the trawler, the low speed humps are not very marked, and the first serious rise occurs above the speed given by Ⓟ$=0{\cdot}75$. The cross-Channel vessel, whilst actually a little fuller than the trawler, has the advantage of length, and here, where speed is becoming of greater importance the combination of p and L is such that the rise in the Ⓒ curve about Ⓟ$=0{\cdot}75$ is not prohibitive, and the vessel can be driven to Ⓟ$=1{\cdot}08$ without unreasonable expenditure of power.

Where speed is absolutely of paramount importance, as in destroyers, for example, and economy is not, of itself, a first consideration, the form has to be driven to speeds above the last hump in the Ⓒ curves at Ⓟ$=1{\cdot}5$. Although the Ⓒ value above this speed begins to fall steadily, it must be remembered that the power is still rising rapidly, since it depends on the product ⒸV^3, and the slow fall in Ⓒ in no way compensates for the rise in V^3.

The length and fullness to be chosen for economical propulsion at a given speed are thus intimately associated, and the choice is one in which the naval architect must rely upon his accumulated experience and the large amount of published data at his command. A formula originally due to F. H. Alexander forms a very good guide —it relates the block coefficient, speed and length by the equation

$$C_B = 1{\cdot}04 - \frac{V}{2\sqrt{L}}$$

where

C_B = block coefficient.
V = speed in knots.
and L = length in ft.

Further guidance can be found in Dr. Baker's book on ship resistance [25] and in Sir Amos Ayre's papers to the North-East Coast Institution of Engineers and Shipbuilders [26]. When the principal dimensions and fullness of the form have been decided upon, the resistance of the ship will depend chiefly upon the following features:—

(1) The distribution of displacement along the length, as shown by the curve of cross-sectional areas, and typified by the longitudinal position of the centre of buoyancy;
(2) the shape of the load waterline, particularly forward;
(3) shape of transverse sections near the ends; and
(4) the type of stern.

The choice of the correct shape of area curve and load water line depends upon the Ⓟ value at which the vessel is to run, and hence upon the prismatic coefficient chosen. We have seen that, as a first approximation, the total resistance can be divided into frictional, form and wave making resistance, the former being considered as that due to the equivalent plank surface, whilst the latter two kinds must be considered together, usually under the name of residuary resistance.

12.—Frictional Resistance.

If the frictional resistance of a ship is considered to be equivalent to that of a plank of the same area of wetted surface S and length L, we can write, as before,

$$R_f = C_f \tfrac{1}{2} \rho S V^n.$$

The resistance will be least when S and C_f are kept as small as possible consistent with the other requirements of the design.

We can take it that L has already been fixed in association with p and V, and therefore the only choice we have left to reduce S is that of the most suitable ratio of beam to draft, B/d. Taylor has expressed the wetted surface of a ship by the formula

$$S = C\sqrt{\Delta L}$$

and given contours of C over a range of midship section area coefficients and B/d ratios [27], which indicate that the minimum wetted surface will be attained with a B/d ratio of about 3·0. But such a high value is not usually acceptable on other grounds. For a given midship area, it involves a large beam and this in turn will mean increased wave-making resistance should the ship be running at high speeds. Also, it will lead to large metacentric heights, and consequently to stiffness and discomfort to passengers. It is usual to find the B/d ratio for merchant vessels nearer to 2·0 than 3·0, a very common value being about 2·3. In vessels such as cross Channel ships, of restricted draft, values as high as 3·0 may be used, and here the consequent additional GM is no drawback in view of the large amount of superstructure and deck load carried. The beam to draft ratio is thus usually fixed on grounds other than the attainment of minimum resistance.

In order to keep C_f as low as possible, the surface should be kept clean and smooth and free from abrupt features such as plate edges.

Some idea of the additional resistance due to roughness can be obtained from the curves in Fig. 5 and from Kempf's work [8]. He has given values of a coefficient C_k to be added to the smooth coefficient C_f for various types of roughness tested both on pontoons in the Hamburg Tank and by means of plates let into the sides of ships. The results are summarised in Table 2. It would appear that the roughness present on a clean ship is not sufficient to make the resistance follow the quadratic law, i.e., behave as a completely "rough" surface as defined by Nikuradse's work, but rather that the additional resistance should be looked upon as a constant augment to the sloping curve which defines the C_f coefficient, but the evidence on this point is not yet conclusive.

The Washington Tank authorities have adopted Geber's coefficients for smooth surfaces, and add an allowance for roughness amounting to 14 per cent. for a 400ft. cargo ship and 22 per cent. for a 900ft. battle cruiser [28]. These bring the coefficients into reasonable agreement with ordinary Froude results, but the latter in general appear to underestimate the resistance of a hull, since

TABLE 2.

KEMPF'S EXPERIMENTS ON ROUGHNESS.

Type of Surface.	C_k	Increase as percentage of smooth C_f value for 400ft. ship.
400ft. ship, smooth surface	$1{\cdot}60\times10^{-3}$	—
(1) Plane, smooth steel plates, with new paint, no rivets, seams or butts, with average roughness about 0·012"	$0{\cdot}10\times10^{-3}$	6
(2) As (1) but with butts 0·8" thick every 16ft.	$0{\cdot}40\times10^{-3}$	25
(3) New hull, new paint, with rivets, butts and straps as measured on "Hamburg" and "Europa" ...	$0{\cdot}75\times10^{-3}$	47
(4) Copper-sheathed hull of "Greyhound"	$0{\cdot}75\times10^{-3}$	47
(5) Plane surface with sand particles 0·04" diameter covering 100% of area	$1{\cdot}0\times10^{-3}$	62
(6) Plane surface with barnacles 0·12" to 0·16" high, covering 25% of area	$3{\cdot}0\times10^{-3}$	187

Kempf's results for ordinary shell plating show percentages considerably greater than those adopted by Washington. The position of our knowledge in this field is not at present satisfactory, but it is sufficient to show that considerable gains could be made by the improvement of the present type of surface.

One way in which this can be done is by careful attention to the condition of the surface when repainting, and any additional time and expense incurred in this way would soon be repaid in reduced fuel bills. The introduction of welding allows of the elimination of seams and laps and rivets, and from the evidence of Table 2 this should enable a considerable reduction in skin friction drag to be made, since the C_k coefficient drops from $0{\cdot}75\times10^{-3}$ to $0{\cdot}10\times10^{-3}$ for such a change, although the latter coefficient might not be attained on a large structure because of a certain roughness and distortion of the surface at the welds.

In some riveted ships the butts and seams have been smoothed off with a plastic composition applied so as to form a tapered wedge. This has been done in a liner built a few years ago, and the saving in power was about 7 per cent. This, of course, represents a considerably greater percentage of the skin friction resistance. Some experiments by Baker [25] with models showed that nearly half of the saving in power resulting from such flushing of the butts and seams could be achieved if the change were restricted to the first one eighth of the length from the bow. Trial results from two sister ships, in which 20 per cent. of the length from the bow was smoothed off by composition, showed a gain of some 4 per cent. in power.

Similar increases in power may be expected when the surface becomes further roughened by fouling, as instanced by item (6) in Table 2. Taylor has given figures for two cases—a U.S. destroyer eight months out of dock in the North Atlantic and a U.S. battleship 10 months in Californian waters—in which the additional resistance represented a C_k value of $3{\cdot}62\times10^{-3}$ and $2{\cdot}43\times10^{-3}$ respectively, in close agreement with Kempf's experiments. The average increase in power for a large number of American ships 4, 5 and 6 months out of dock, has been stated to be 7·8, 9·6 and 11·8 per cent. respectively, but the figures for individual ships vary widely with the time of the year, time spent at sea and in port, the region in which they trade and so on. Thus Baker gives figures of 20 per cent. after three months out of dock in the Tyne, and as much as 11 per cent. after only 40 days in the Clyde, the latter being exceeded by Sir Archibald Denny's figure of ½ per cent. per day for fouling growing on ships in the fitting out basin at Dumbarton.

These figures should be sufficient to indicate to all concerned with the building, maintenance and running of ships the importance of keeping the paint surfaces smooth and clean and of eliminating the structural roughnesses in the original shell whenever possible.

13.—Wave Making and Form Resistance.

Whereas the factors leading to a low skin friction drag are applicable to all ships, the problem of the most suitable shape of hull for minimum residuary resistance is much more difficult. Due to the interplay of wave making and form resistance, the requirements for minimum residuary resistance will, in fact, depend upon the actual speed-length ratio $\left(\frac{V}{\sqrt{L}}\right)$ or $\textcircled{P}$ value at which the ship is to run.

It is convenient in the first instance to study the requirements for minimum wave making resistance, and later to see how these must be modified to take account of form effect.

Some interesting deductions can be drawn from the results of a series of models run at Teddington by Wigley [29]. These all had a prismatic coefficient of 0·700, the parent form being symmetrical about amidships. In the other two, fore and aft asymmetry was introduced, so as to give two forms with the L.C.B. respectively 4·08 and 6·12 per cent. of the length from midships. By running these two forms both ways round, a series of five models was obtained with a progressive decrease in angle of entrance and a corresponding movement aft of the L.C.B. The principal dimensions of the models are given in Table 3.

The calculated wave making $\textcircled{C}_W$ curves for these models are shown in Fig. 16.

At low speeds, up to $\frac{V}{\sqrt{L}}=0{\cdot}75$, the wave resistance is less the finer the angle of entrance. Above $\frac{V}{\sqrt{L}}=0{\cdot}70$, the $\textcircled{C}_W$ curve for the form with the finest angle of entrance begins to rise more rapidly than the others and mounts above each one in succession until at $\frac{V}{\sqrt{L}}=1{\cdot}0$ it is exceeded only by that with the fullest angle of entrance —that is the same model run the other way round. With further increase in speed the two $\textcircled{C}_W$ curves come closer together, and finally merge at $\frac{V}{\sqrt{L}}$ about 1·4, after which the wave making resistance is the same for this model either way round. The mathematical theory shows that in a perfect fluid this would be the same at all speeds, the difference between the $\textcircled{C}$ curves in an actual fluid being due to viscosity, and the disappearance of this difference is indicative of the small effect of viscosity at high speeds.

The model with the next finest angle of entrance becomes the best at $\frac{V}{\sqrt{L}}=0{\cdot}75$, but presently begins to rise rapidly, and above $\frac{V}{\sqrt{L}}=0{\cdot}90$ the model with straight waterlines and an angle of entrance of 10·7° is the best and retains its superiority to the highest speeds.

These changes in relative resistance can be broadly explained by applying the knowledge of wave making resistance already outlined.

At low speeds, the main resistance is due to the wave system formed at the bow, and this depends upon the angle of entrance so that the smaller this is made, the less the resistance. At somewhat higher speeds the resistance due to the curvature of the entrance becomes important, and the maximum slope of the waterlines along the entrance must be greater the finer the bow angle (since all have eventually to reach the same beam amidships), with the result that the finest-angled forms lose their superiority. Finally, at high speeds, the symmetrical form with intermediate bow angle and straight waterlines is the best, but there is not a great difference in any of them, and at such speeds it has been shown by Wigley [30] that shape is relatively immaterial and the $\textcircled{C}_W$ value depends only on the ratio of length to displacement.

The above conclusions must be modified, especially at the lowest speeds, when the effect of form resistance is considered. The measured curves of residuary resistance for the same five models of Table 3 are shown in Fig. 17. The residuary resistance is obtained from the total measured resistance by subtracting the skin friction assessed on the usual Froude assumptions, i.e. in our earlier notation $\textcircled{C}_R=\textcircled{C}_W+\Delta\textcircled{C}_F$.

The values of $\Delta\textcircled{C}_F$ for these five models at the lowest speeds have already been given in Fig. 14, and since all models have almost identically the same wetted surface, the $\textcircled{C}_F$ will be the same for all. Hence their relative merits will be defined by the curves of residuary $\textcircled{C}_R$.

An examination of Fig. 17 shows some very interesting features. We have seen that $\Delta\textcircled{C}_F$ the form resistance, decreases with increasing angle of entrance, which is exactly opposite to the

TABLE 3.

Model No.	Direction of running.	Type of water-line forward.	$\frac{L}{B}$	$\frac{B}{d}$	C_p	$\frac{1}{2}\alpha_E$	L.C.B. from amidships as % L.
2130B	Fine end leading	Very hollow	10·66	1·50	0·700	2·7°	6·12 aft.
2130A	,,	Hollow	,,	,,	,,	5·3°	4·08 aft.
1970B	Symmetrical	Straight or slightly convex	,,	,,	,,	10·7°	Amidships
2130A	Full end leading	Convex	,,	,,	,,	15·7°	4·08 fwd.
2130B	,,	,,	,,	,,	,,	18·2°	6·12 fwd.

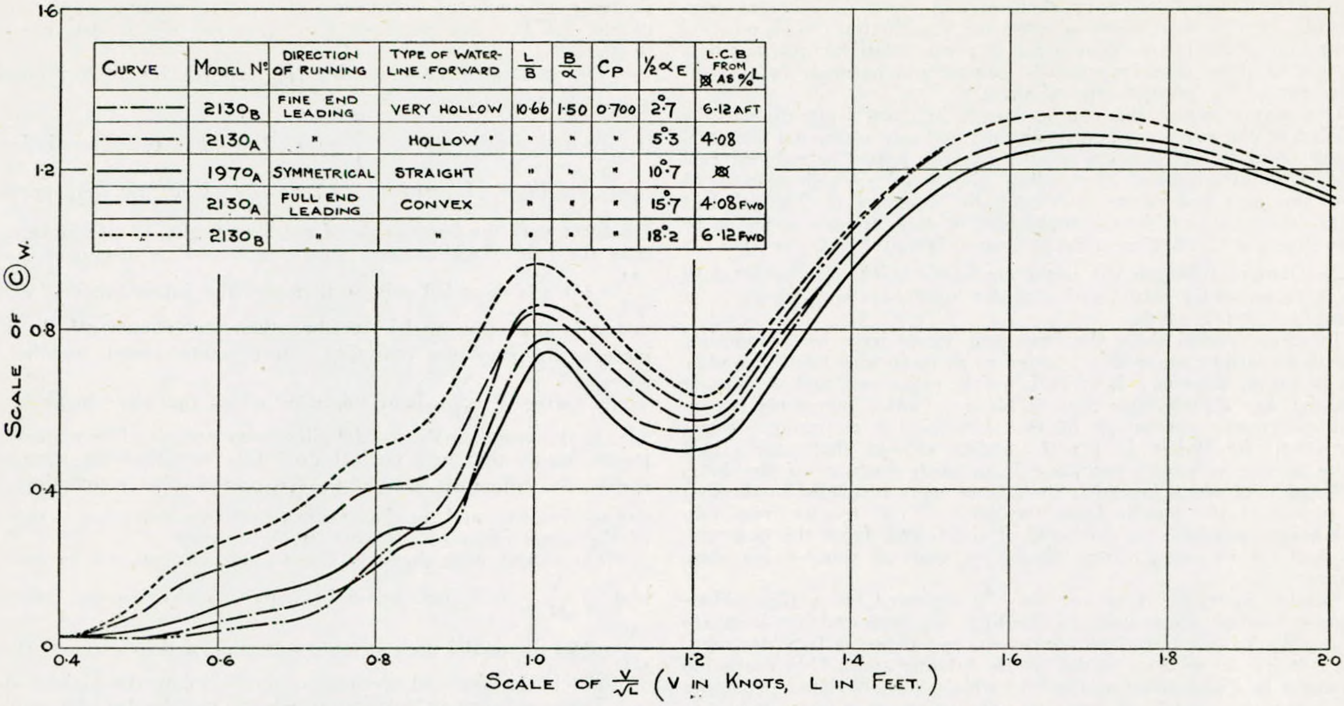


FIG. 16.—*Calculated curves of wave making resistance constant* ©$_W$.

change in wave resistance at low speeds. At such speeds, the form effect, being much larger than that due to wave making, completely outweighs it, and reverses the order of the models. Thus, for speeds below a value of $\frac{V}{\sqrt{L}}$ about 0·5, the model with the L.C.B. furthest forward and the fullest angle of entrance is the best of all, whilst the worst is that with L.C.B. furthest aft and the finest angle. The curves of ©$_R$ all practically intersect at $\frac{V}{\sqrt{L}}=0{\cdot}5$, and immediately above it the order is reversed, from that speed to 0·75 the two forms with L.C.B. aft of midships being very nearly indistinguishable. At this speed the ©$_R$ for the finest form begins to mount, as we saw before, and a gradual change in bow lines from very hollow towards straight with L.C.B. amidships is indicated, the latter becoming the best of all at speeds above $\frac{V}{\sqrt{L}}=1{\cdot}0$. These results, using what are admittedly not shipshape models, nor of normal proportions, are summarised in Table 4.

These conclusions are well illustrated graphically in Fig. 18. The base of this diagram may be considered either as angle of entrance or position of L.C.B., and the curves are drawn, each for a constant value of $V/\sqrt{L}$, to show the difference in ©$_R$ from

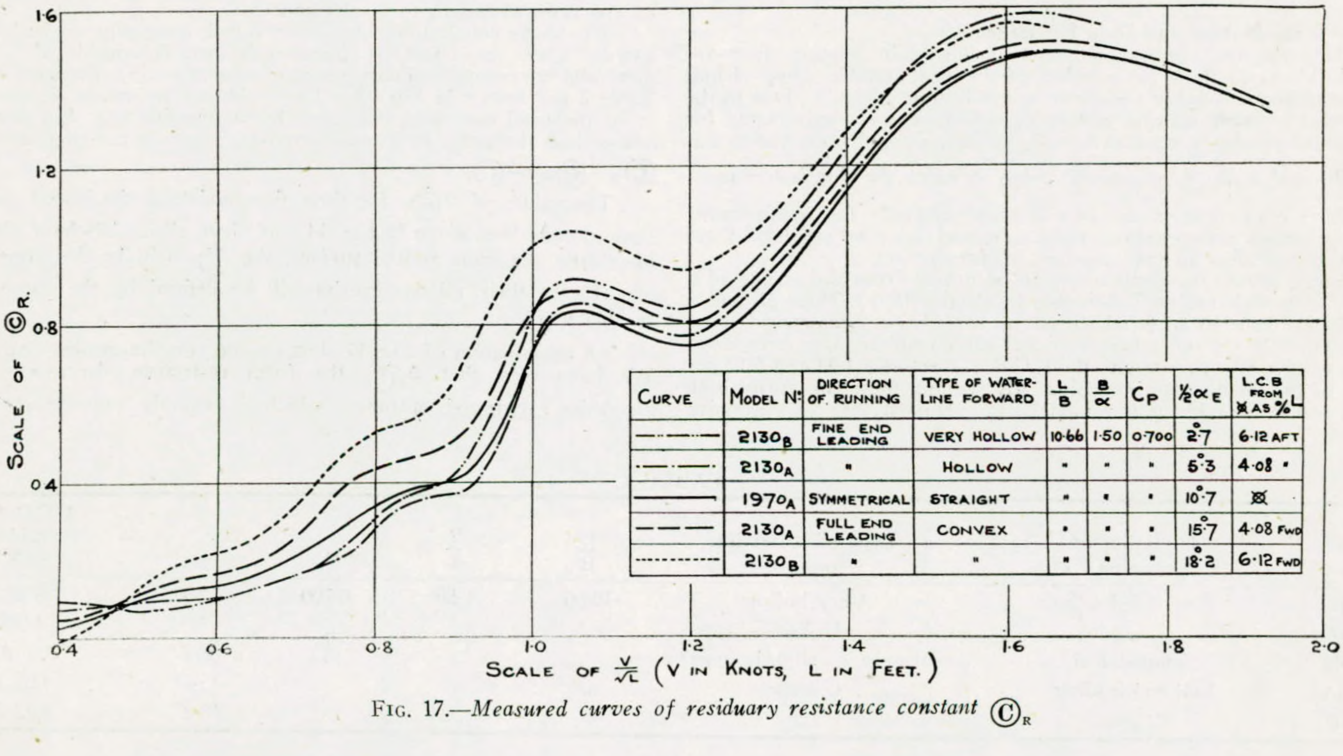


FIG. 17.—*Measured curves of residuary resistance constant* ©$_R$

TABLE 4.

Speed-length ratio $V/\sqrt{L}$	Below 0·5	0·5	to	1·0	Above 1·0
Best type of bow water-lines	Convex with fairly large angles of entrance	Hollow and small angles of entrance	becoming	straight with increase in $V/\sqrt{L}$	Straight, with medium angle of entrance
Best position of L.C.B.	Forward of midships	Aft of midships	changing to	midships at high speeds	Amidships

that for the middle model of the series, i.e. the symmetrical one with L.C.B. amidships. At $\frac{V}{\sqrt{L}}=0{\cdot}4$ the superiority of the full bow is apparent from the slope of the curve for that speed-length ratio. For $\frac{V}{\sqrt{L}}=0{\cdot}6$ and 0·8 this slope is reversed, showing the advantage of the fine bow, whilst at still higher speeds any departure from the symmetrical model involves an increase in residuary resistance.

Although the form resistance has such a large effect on the the total Ⓒ at very low speeds, a study of the curves in Figs. 16 and 17 suggests that this effect seems rapidly to disappear, since the relative order of the models at higher speeds is quite unchanged by the inclusion of form effect. If the latter were due solely to the augment of skin friction drag due to the higher average velocity of the water along the curved surface of the hull as compared with the plank, one would expect ΔⒸ$_F$ to remain much the same over the whole speed range. Yet for model 2130B run both ways round, the very large difference in Ⓒ$_R$ at low speeds, attributed to the difference in form resistance, has completely disappeared at high speeds. Thus the form resistance must change in character quite quickly with increase of speed, and we do not yet know enough of the different elements of resistance to explain this phenomenon.

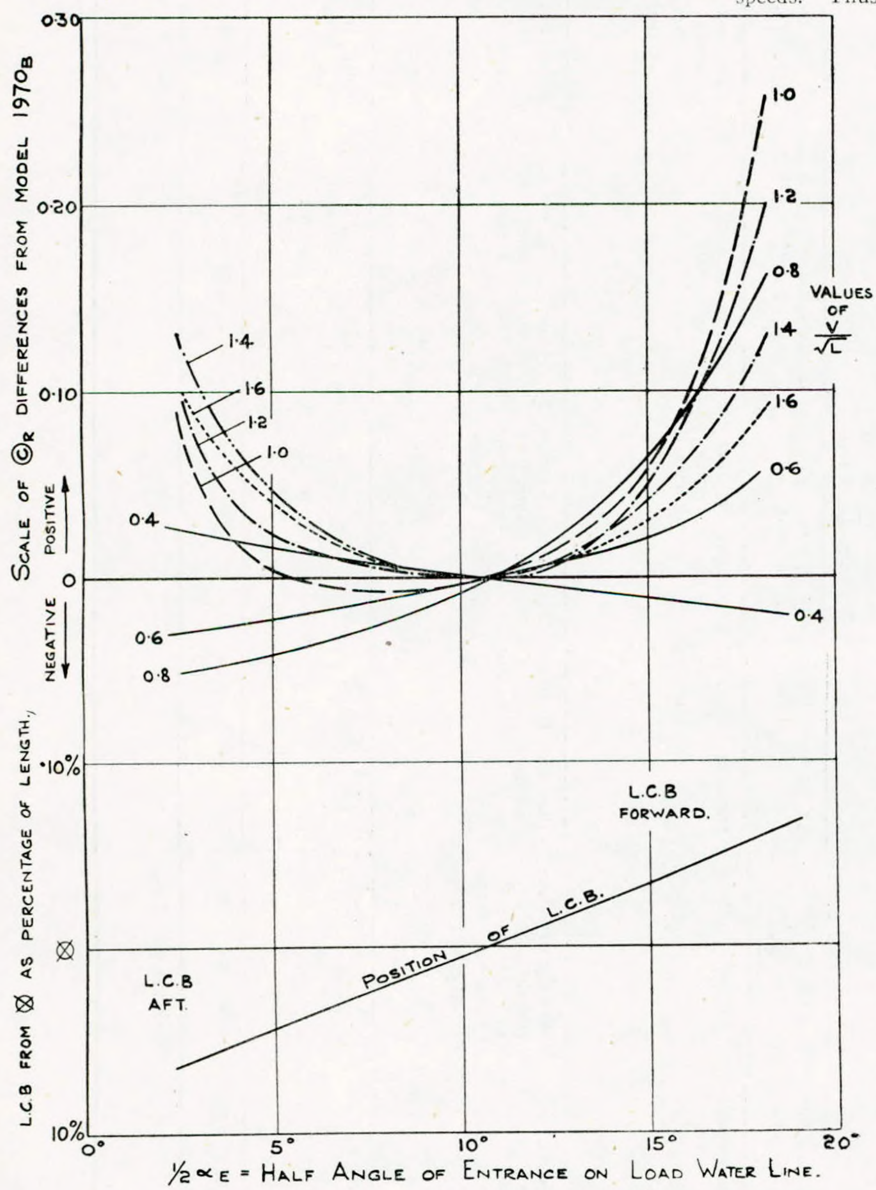


FIG. 18.—*Curves of constant values of* $\frac{V}{\sqrt{L}}$, *showing differences in* Ⓒ$_R$ *values from that for the symmetrical model 1970B.*

All these models were very fine and of narrow beam, and it is unlikely that they suffered from any eddy-making resistance. But in an actual ship this possibility has to be guarded against, and to this end the bilge radius should not be too small—a point which has been rather lost sight of in the past—abrupt changes of curvature should be avoided at the shoulders, and the slopes of the waterlines of the after body should not be too steep, the angles to the centre line being limited to 18° where possible. In the fastest of all, such as destroyers, the waterlines are usually made very full, and the stern cut up in a long gentle slope as being the only way to achieve this without prohibitive loss of deck space, at the same time providing an easy path for the water to the screws.

In Table 5 are given the salient features known to be necessary to ensure a good performance for various types of ships working over different speed ranges. These have been developed as the result of many years of experimenting with models in Tanks and with actual ships, and bear a close resemblance to those that would be expected from the above reasoning, as a comparison between Tables 4 and 5 will show.

Slow and Medium Speed Cargo Ships.

This class includes vessels with prismatic coefficients in the range 0·82 to 0·75, running at speeds from Ⓟ$=0{\cdot}4$ to 0·6. The slowest and fullest ones must take advantage of the small form resistance obtainable by having a large bow angle (up to 35°) and consequently have a short entrance, the L.C.B. well forward of midships, and convex waterlines forward. With coefficients above 0·78 it is almost impossible to avoid eddy-making at the stern, unless the vessel is fitted with a small diameter, fast running screw, so that a good cruiser stern can be worked into the lines. Forward, the large angles of entrance make the vessel sensitive to sea conditions, and in order to avoid still larger angles above water, which will be immersed when pitching in waves, the stem should be well raked, successive waterlines practically parallel, and the forward transverse sections of V shape.

In the finer vessels in this range running at speeds approaching a Ⓟ value of 0·6, the bow angle should be reduced to about 27°, the forward waterlines made nearly straight, and the entrance and run of nearly the same length. The stern lines can now with care be kept down to the limiting slope of 20°.

Cargo Liners.

These vessels, with prismatic coefficients of 0·75 to

TABLE 5.

Type of ship	Slow speed cargo ships	Medium speed cargo ships	Cargo liners	Intermediate liners	High speed liners and fast coastal passenger vessels	Cross-Channel vessels	T.B.D's.
p. (prismatic coefft.)	0·82 — 0·78	0·78 — 0·75	0·75 — 0·70	0·70 — 0·65	0·65 and below	0·65 and below (Best results 0·57)	0·65 and below
Ⓟ	0·4 — 0·6	0·5 — 0·60	0·55 — 0·65	0·60 — 0·80	0·70 — 0·90	1·05 — 1·40	1·50 and above
Length of parallel body	34%	Up to 25% depending on beam	Up to 25% Up to 20%	10% with hollow LWL fwd. 0% with straight LWL 0%	None	None	None
Entrance / Run	0·6 — 0·8	0·8 to 0·9 1·00	1·0 L_E must be long enough to avoid $V=1{\cdot}09\sqrt{L_E}$ hump	1·0	1·1	1·2	1·2
L.C.B. as % L from amidships	2% fwd.— 1·0% fwd. S.S.	2% fwd.— 1·0% fwd. S.S.	1½% to ½% fwd. S.S.	1·0% fwd. to 1·0% aft. S.S. " " " 2·0% " T.S.	1½% aft. to 2% aft. T.S.	2% to 3% aft. T.S.	1% to 1½% aft. T.S.
Shape of area curve	Straight ends	Straight ends Medium hollow forward	Straight ends Hollow curve forward	Fine entrance essential	Fine ended curve of areas. Bulbous bow useful above Ⓟ=0·75	Fine ended Fuller ends, using bulbous form	Maximum area aft of amidships. For highest speeds, straight or slightly convex forward. Good buttock lines aft.
Shape of L.W.L.	Bow—slightly convex throughout. Stern—fairly straight. Slope not greater than 20°.	Bow convex Bow convex to straight	Bow lines *either* straight and long entrance *or* hollow and short entrance	Bow lines hollow Bow lines straight	Fine L.W.L. fwd., hollow	Fine end forward Fuller ends by making WL endings straight or hollow with bulb	Maximum beam as far aft of amidships as possible. LWL fwd. quite straight or even a little convex. Aft quite full to act as cover to screws
½ α_E on L.W.L.	35° 32°	30° 27°	24° 16° straight or 12° hollow	18° 12° hollow or up to 16° straight	Down to 6° with hollow	6° — 7° 6° with hollow, 9° with straight	10° — 12°
Midship section coefficient	0·98 — 0·99	0·98	0·98	0·98	0·95	0·90 — 0·95	0·80 — 0·85
Cruiser stern	Reduces resistance up to 6%					Essential to increase length	Essential to increase length and cover screws

0·70, and running at speeds corresponding to Ⓟ values of 0·55 to 0·65, are in a region where transverse wave making is becoming important, and hence care is necessary to avoid the worst effects of interference, one of the hump wave making speeds being at Ⓟ=0·555. It so happens that in these vessels the entrance wave-making hump given by $V=1{\cdot}09\sqrt{L_E}$, already described, occurs at speeds very near to those corresponding to Ⓟ=0·555, and a very bad result may occur. This coincidence can be avoided if the entrance can be made long enough, and in such a case the bow waterlines should be straight, with an angle of entrance in the neighbourhood of 16°. If the necessary length of entrance cannot be attained, it should be made shorter and the bow angle made smaller, say 12°, with hollow waterlines. This has the effect of reducing the bow wave-making and so reducing the hump in the Ⓒ curve due to the critical Ⓟ value. With straight waterlines, the Ⓒ curve rises steadily over most of the useful speed range, whilst with the hollow lines it rises more slowly at first, but turns up earlier and crosses the Ⓒ curve for the straight waterline form in the neighbourhood of Ⓟ=0·60. At this particular Ⓟ value equally good results can be obtained with either type of entrance—below it, hollow lines are better, above it straight ones.

Intermediate Liners.

The prismatic coefficient lies between 0·70 and 0·65, the corresponding speeds being about Ⓟ=0·60 and Ⓟ=0·80. In this range there are two critical Ⓟ values to avoid—0·56 and 0·67—and at the top speed of Ⓟ=0·80 we are approaching the 0·9 hump.

Very little parallel can be worked in such vessels—say 10 per cent. as a maximum—and in general a hollow waterline forward gives the best result, although at Ⓟ=0·80 a straight line bow is becoming a possibility again.

High Speed Liners.

These vessels have prismatic coefficients of 0·65 or less, and are running at speeds approaching Ⓟ=0·90, which is the interference hump caused by the coincidence of the second hollow of the bow wave system with the first hollow of that due to the stern curvature. In order to reduce this interference as much as possible, the bow wave system must be made small, and hence a very small half angle of entrance is required, in the neighbourhood of 6°, with consequently a hollow waterline. Such a fine entrance means that it must be long to avoid a sharp shoulder amidships, and consequently the transverse station having the maximum area is usually abaft half length. For speeds above Ⓟ=0·75, a bulbous bow is of some advantage, reducing the Ⓒ value by perhaps 2 to 3 per cent. The bulb may be looked upon, to a first approximation, as a sphere situated below the water and centred on the fore perpendicular. Such a sphere run by itself, at the same depth below the water surface, would cause a surface wave system beginning with a hollow, and if the bulb is correctly placed on the ship this hollow may be used to reduce the first crest of the bow wave system and hence the total resistance.

Cross-Channel Vessels.

The prismatic coefficient for such vessels is about 0·60, and they are running above the hump at Ⓟ=0·90, the speed lying between Ⓟ=1·05 to 1·40. At Ⓟ=1·0 a fine ended waterline can be used, with a half angle of 6° or 7°, but as Ⓟ approaches 1·4 the ends must be made fuller by straightening the waterlines or, in some cases, using a bulbous bow. The resistance, as we approach the 1·5 hump, comes to depend mostly on the ratio of length to displacement, as we have already seen, and any increase in length, whether actual by using a cruiser stern or virtual by filling the ends of the form and fining elsewhere, is extremely valuable in reducing resistance. To obtain a long fine entrance, the section of maximum area should be some 5 per cent. of the length aft of midships.

Destroyers.

These vessels are run at speeds above Ⓟ=1·5, where the last hump in the Ⓒ curve occurs. At this hump, the additional interference resistance is caused by the first hollow of the bow wave system coinciding with the first hollow of the afterbody system, thus causing an exaggerated wave disturbance abaft the ship. As speed is increased above Ⓟ=1·5, the hollow of the bow system continues to move aft and begins to cancel the first crest of the afterbody system, thus leading to reduced wave making. This proceeds progressively as speed is increased, and it should be noticed that now there is no other hollow of the bow system to coincide with the first stern hollow, and so there can be no further hump with increasing speed, and as the first stern crest is more and more cancelled by the first bow hollow, the Ⓒ curve continues to fall. Additional reduction in all the wave systems results from the change in trim of the ship at high speeds.

Under such conditions, and for a given displacement, length is all important, and should be increased virtually as much as possible by making the ends full and amidships fine. Thus the midship area coefficient will be reduced to 0·82 or so, and the ends filled out, forward by making the waterlines straight or even convex, with half angles on the load line of 10° to 12°, and aft by keeping the waterline breadth at full width almost to the stern, and cutting up underneath on a long easy slant to give good water flow to the propellers.

A comparison of the analysis shown in Table 5, and described briefly in the foregoing paragraphs, with that in Table 4, derived from reasoning on general theoretical and mathematical grounds and deduced from experiments on a series of models, will show that all the main features of the progressive changes necessary in ship form with increasing speeds can be accounted for from the knowledge of wave making and form resistance previously described. There are speed ranges where the features for a good design are definite and easy of attainment; there are others, in the regions of transition between the predominance of one form of resistance and another, where the problem is by no means so easy of solution. It is here that the judgment of the naval architect is called for in no small measure, and to-day, in all countries which have pretensions to being merchant sea powers, he is able to have recourse to experiment in a tank in order to check his ideas and ensure that the ship when built will be a worthy example of his skill.

14.—Appendages and Other Features.

Before leaving our subject, a few words may be said about stern fittings and other appendages.

Bilge keels and shaft bossings should be so designed as to interfere as little as possible with the normal flow along the hull, and should therefore be placed to conform as nearly as possible with the streamlines. This can easily be done when model tests are being made, since the streamlines along the bilge and over the run can then be determined. Suitable shaft bossings may then be drawn out, and with outward turning screws the inclination of the web to the horizontal is usually between 20° and 30°. A symmetrical bossing is usually better than one with a flat top, and the taper at the end of the shaft web casting should be made easy, the slope to the fore and aft centre line not exceeding 15°. In the ordinary ship, nothing is to be gained propulsively by fitting A brackets in place of bossings, but in very fine, high speed vessels, the latter become very large, with consequently a big resistance, and correctly proportioned A brackets are then an advantage, but it is difficult to ensure that the arms are in the correct position to offer minimum resistance to the flow.

We have so far considered the hull design solely from the point of view of obtaining minimum resistance. Such a hull will also, in general, be the easiest to drive when fitted with a propeller, but there are certain requirements which must be fulfilled in order that the propeller may work efficiently. The finer the run of the ship, the easier and more uniform the flow of water to the screw and the more efficiently we might expect it to work. This is broadly true but, like most things, can be overdone. The propulsive efficiency depends both on the efficiency of the screw itself and upon the wake and thrust deduction conditions it finds behind the ship. These latter are combined in a single factor called, rather curiously, hull efficiency, and the higher this is the better the propulsive coefficient. The hull efficiency in single screw ships is of the order of 1·2. In a slow speed ship, when the stern lines are fined down and the bow filled out, the resistance would normally be decreased, and the hull efficiency increased, with a happy overall result. But if the fining of the run is carried too far, the wake is reduced without a compensating fall in thrust deduction, and consequently hull efficiency and propulsive efficiency are reduced, and cases are on record where this has more than counterbalanced the fall in hull resistance. It is thus quite possible to have a ship which would be easier to tow but harder to propel than another, and this feature really prevents the filling of the fore body and fining of the run in slow speed ships being carried too far, which is also a good point for the preservation of satisfactory seagoing qualities, since too bluff a bow makes a ship feel the weather sooner.

Other points which must be watched to secure good propulsive efficiency are the clearances between propeller and hull, rudder and sternpost, which must be sufficient also to avoid vibration trouble.

Rudders and sternposts can give rise to quite unnecessary resistance if a little thought is not paid to them. The single plate rudder is quite resistful, and is now fortunately rapidly disappearing, being replaced by a smooth, double plate rudder. The sternpost should be shaped on the forward side to give a fin, so that a square surface is not presented to the propeller race, whilst if the body post forward of the propeller can be shaped also, so much the better. Experiments on models [31] have shown that the resistance of a square post and single plate rudder may amount to as much as 12½ per cent. of that of the naked hull, which can be reduced to 5 per cent. by fitting a symmetrical fin to the fore side of the post, and streamlining the rudder. The net gain in resistance of some 7 per cent. was exactly reflected in the reduction of horsepower at the propeller, and such a reduction, so simply obtained, is extremely worth while when turned into fuel costs.

Although, in a general way, V sections in the afterbody are the best for low resistance, filling out on the lower levels so as to club-foot the end sections is beneficial in improving hull efficiency, even though the resistance itself may thereby be slightly increased.

15.—Conclusion.

In this paper I have tried to give a brief account of our present knowledge of the individual items which together make up the total resistance of a ship, and of how their interaction at different points of the speed range calls for different treatment of the shape of hull in order that minimum resistance may be experienced.

The lines of ships to-day are not so much the outcome of such a logical process as the result of years of experience in the running of ships and of models, but I have shown that both methods of approach have led to the same broad picture, and that all the apparent peculiarities in design can be explained from theoretical and experimental knowledge.

To try to cover such a subject as the "Fundamentals of Ship Form" in a single paper was almost to attempt the impossible. I have purposely confined myself to general considerations, and made no attempt to give detailed guidance on the design of lines, nor on the estimate of power. For such purposes there is a vast storehouse of knowledge waiting to be used in the Transactions of our Institutions and in the books on ship resistance.

Our knowledge in this field is still, however, far from complete, and many points can only be cleared up by co-operation between the scientist, the experimenter and the operator. There is a great need for information from full scale trials and from ships running on their everyday tasks, in order that the fullest benefit may be derived from model experiments. But the collection of such information is difficult and costly. In the past our progress has suffered accordingly, but we may be hopeful that with the formation of the twin Research Associations for Shipbuilding and Marine Engineering, this country may in the future maintain the proud position won for her by the marine engineers and naval architects in the past.

16.—Acknowledgment.

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Discussion.

The Chairman said that Dr. Todd, who was presenting the paper that evening, had written a great number of papers on the vibration of ships, and also on the subject to be discussed on the present occasion. He was the Senior Scientific Officer, Ship Division, National Physical Laboratory, and it was well known that those who came from that Laboratory were of such eminence that it was very difficult to criticise anything that they put forward; but it was to be hoped that speakers in the subsequent discussion would at any rate be able to draw from the author additional information. The paper was an excellent one, and compared experimental work with practice, something not often to be found in what might be described as the "professorial" type of paper.

Dr. E. V. Telfer, D.Sc., Ph.D., in opening the discussion, said the paper was a difficult one for a naval architect to discuss before an audience of marine engineers. Actually, marine engineers were curious people; once they had reached a certain degree of eminence, and had been admitted to the Institution of Naval Architects because of their marine engineering qualifications, they then, in addition to "Consulting Marine Engineer" on their plate, put up "and Naval Architect". One fault, therefore, which he had immediately to find with the paper was that it was giving far too much information to marine engineers, and helping them to carry on that unworthy condition of affairs! However, the author had also succeeded in putting into the paper most of the major controversies in naval architecture, so that personally he would not mind the marine engineer being simultaneously so ably advised and confused.

He would like to use the opportunity to discuss some of the naval architectural theories of the paper, the chief of which was the Ⓟ theory. Fortunately, in presenting the paper, the author did not greatly stress this theory, though presenting it in the most favourable light from the point of view of securing its acceptance. Personally, he would like to emphasise to marine engineers that it was at best a very rough and a very approximate theory. It was used only in this country, and hardly recognised at all abroad. There were some who whenever they had the opportunity of discussing it tried to tear it to pieces as rapidly as possible. He did not want to do that on the present occasion, but he would like the author to realise that the use of the prismatic coefficient in the Ⓟ formula was only a coarse first approximation. It had been known ever since Froude's time that the use of $\frac{V}{\sqrt{L}}$ with the root sequence was the basis approximation. Kent and Baker had realised that the primary wave-making length was something of the order of pL, but it was now desirable to go a stage further and have other alternatives to the prismatic coefficient.

The author had given a clue to that in illustrating the work of Eggert, and some Japanese work, which showed how important the top belt of the displacement was in relation to the total wave making. This at once suggested that it was the load waterline which had the maximum effect on interference phenomena. The use of the load waterplane coefficient (particularly the forebody) instead of the prismatic coefficient might do a good deal towards making the idea of the Ⓟ theory acceptable to naval architects in general. Perhaps the author would give some consideration to that.

The author had not very much time to deal with roughness, but there he came to one of the major controversies in frictional resistance. The figure which he gave applied solely to the flow of water in pipes and only to one type of roughness, the sharp or sand roughness type; but many other roughnesses had been tried in pipes, particularly in German laboratories, such as the studded roughness, and that gave entirely different results. Then there was the undulating roughness, which caused a very much less resistance increase. It was difficult to know how one was to get a true calibrator of roughness. If one took pyramid roughnesses and had them a certain spacing apart one would get one result; on closing them up one would get another result. The real significance of roughness was not yet appreciated.

It was desirable to emphasise, in connection with the figures given, mainly from Kempf's work, in Table 2, that those were in all cases local roughnesses; they were not roughnesses for the whole ship. That was a very important distinction to make, because if in a ship one roughened the bow very heavily, and then roughened the stern one would not necessarily detect the effect of that stern roughness. It was already in "roughened" water, and it was not acting as it would have done had it been added to the bow. He wanted to mention that fact so that marine engineers would appreciate that the whole story was not yet known, and some of the very high figures which the author gave, such as $0{\cdot}75\times10^{-3}$ for C_K, or the last figure, of 187 per cent. increase over a smooth surface, would not be obtained for the whole plane roughened as stated, and a very much less effect than that would be felt.

Those who were interested in the subject, if they wanted to know more about it, should read Dr. Kempf's paper in the 1937 *Transactions* of the Institution of Naval Architects, and particularly Dr. Baker's discussion of it. Dr. Baker expressed many doubts as to the validity of the theory that the Germans were developing at the time. Personally, he knew of the existence of no intervening fundamental work on the subject, and the time was ripe for a really comprehensive examination of the whole question of the roughness effect on ship resistance.

In Table 5 the author summarised his experience in the design, best proportions, coefficients, etc., of various types of ship, from the slow speed cargo ship to the torpedo boat destroyer. It would be desirable for that table to be accompanied by a corresponding diagram; many people could see the whole picture very much better in a diagram than from tables, and if the author would do that the value of the paper would be enhanced. At the same time, probably the author could also embody in the table the values of the relative length in relation to the displacement of the various models, what was called the Froude Ⓜ value. That would help to explain the difference between cross-Channel vessels, for example, and T.B.D's.

One point on which he disagreed with the author was the significance which the author put on form resistance. The author suggested that by increasing the angle of entrance on the load waterline the form resistance was reduced, but personally he would not admit that for one moment; he thought that the author was being forced to this deduction because of erroneous model experiments, and that what he was actually measuring there was the sensitivity of various types of bow angle and entrance to the sustaining or production of laminar flow in the model. In those models he assumed that no attempts were made artificially to ensure turbulence, and if that was the case he denied the author's right to draw the conclusions he did from those particular results. If the author wished to prove his point, he should start always with the same after-end. There should be no corresponding fining of an after-end at the same time as he increased the angle of the forward water-line.

To test the effect of increasing the waterline angle of bow, keeping the after-end constant, the author should by progressively roughening the bow show that no further increase in form resistance could be induced by further roughening, and having done that, he could proceed to compare form effects. Many people had investigated this point. There was, for example, the work of Kempf and Sottorf on the frictional resistance of small plates. Those small plates showed a preponderating laminar flow when they had a rounded leading edge. Once that leading edge was sharpened to a very small extent, turbulence was induced over almost the whole plate, the resistance was practically doubled, not because of a form effect but due to the elimination of laminar flow.

A further set of tests may be mentioned. These were carried out at the Hamburg Tank and were on six geometrically similar models of 4 to 12 metres in length, one series for a fast passenger ship form and the other for a cruiser form. The results were reported by Graff in June 1939 in the Schiffbautechnische Gesellschaft research bulletin. Every model showed an appreciably different form resistance, the highest being some two and a half *times* the lowest in the same series. No artificial turbulence induction was used. If Dr. Todd still believed his own results after a study of Graff's work he had more faith in promiscuity than had Dr. Telfer.

The author might enlarge on the difference between laminar flow and turbulent flow. Turbulent flow did not mean the eddying flow accompanying large vortices. It was a streamline flow, because turbulent flow was required so that the Bernoulli law was obeyed. A perfect fluid, in practice, was turbulent flow, which allowed the full plus or minus pressure changes induced by the form to take place. The likelihood of model laminar flow was the major point of objection which he would like the author to meet, because if the author was right on that point there was a new line of research opened up which had an application to actual ships. If he himself was right, he maintained that the application was a false one, and would not only have no bearing on improving ships but would probably produce worse ships.

In common with the author, he would like to hear the views of some of the marine engineers present, so that they could give a lead as to the type of information which they would like to have placed at their disposal, in addition to the present and possible future papers. His own attitude towards marine engineers was that he liked to give them means of measuring power more correctly—he had published several papers on that subject—so that they were then in a position to give accurate results of service data. In a recent newspaper article it was stated that the chief trouble with the British sailor (and in that generalisation the British marine engineer might be included) was the fact that his life was one of continual boredom. If marine engineers could be induced, for example, to measure wave profiles, they could provide interesting information which could be checked on the model, and their boredom would be somewhat relieved.

He would like the author to give the reference to Froude's establishing that between one model and a larger model the wave profiles at corresponding speeds were exactly the same. He could not remember the reference himself, and he was inclined to doubt it; such data as he had showed that the wave profiles did not agree, nor did the attitudes or angle of squat. The whole subject appeared to have very little law and order about it. That did not, however, dispose of the fact that under all this model work there was fundamental truth, and the author was to be congratulated on exposing some of this truth in the paper. He hoped it would lead marine engineers to co-operate more with naval architects so that their knowledge of ship resistance and propulsion could be extended.

Mr. W. S. Burn, M.Sc. (Member) congratulated the author on presenting so lucidly and concisely a scientific analysis of the elements of ship form. He was glad that the paper was not too mathematical —a fault of most papers by naval architects—and therefore could be appreciated by maritime engineers like the speaker, who was almost as interested in ship design as in engine design. If engineers were to give shipbuilders the most suitable marine engines, it was essential for them to have a keen appreciation of the rudiments of ship design. The present tendency to considerably higher speeds would entail considerable changes in hull form in order to reduce resistance as well as requiring much greater engine power. It seemed evident that we were approaching the era of the fast cargo liner with much finer lines not only below the L.W.L. but also *above sea level,* so that the difference in power required in smooth and rough weather would be substantiallv reduced compared to present standards; Table I was very interesting to engineers in demonstrating this point. With a length of 500ft. and a prismatic coefficient of about ·65 and with fine deck lines at bow and stern, the extra power required to maintain schedule speeds in rough weather would be kept within reasonable limits.

It had been established in the U.S.A. by actual experimental construction that fine lines with a small parallel body was even less expensive than one having a considerable parallel body and bluffer ends; this conclusion was rather different from that arrived at by most British shipbuilders, but the American man-power comparison was undoubtedly carried out scientifically. This conclusion would have some interesting repercussions in the future and it would be interesting to have from the author some figures of comparative resistance of 500ft. (overall) ships with a constant displacement of, say, 14,000 tons, a speed of 18 knots and with an alternative beam of from, say, 63ft. to 69ft. 6in. with prismatic coefficients to suit. There was evidence that the tendency to increased beam had much from several practical points of view, to recommend it, and especially when the engines were of such a weight as to permit them to be placed aft, thereby giving the shipowner the full benefit of a wide beam for cargo stowage amidships.

From the shipowner's cargo carrying point of view, the space at bow and stern was of a low grade value, and as there was a wise world tendency to eliminate crew accommodation from the forecastle and poop, there was a logical inducement to fine down the above water lines at bow and stern, and especially the latter.

The speaker had actual sea experience of a vessel with a very fine stern and was satisfied that the tendency to poop was negligible even in very bad weather. In the case of the bow, there was much to recommend the placing of a broad streamlined bridge structure right forward at the shoulder to serve as a weather shield for the rest of the deck and to enable the use of a fine bow with negligible flare rather than the wide and rounded bow deck lines so common to-day. This meant that the foredeck must be completely watertight but it was submitted that this was not difficult to achieve. The universally accepted principle of designing ships to have a dry foredeck by giving the bow a rapidly increasing buoyancy as the vessel encountered waves, resulted in excessive pitching and pounding and it was submitted that, in the case of a 500ft. ship especially, greater bow wave-immersion could be accepted, provided a secondary breakwater about 100ft. from the bow was provided in the form of a suitable wind and water deflecting bridge structure, the foredeck freed of excrescences and given good draining properties in the form of a gentle turtle deck; that is, with negative sheer and ample camber and a slight flare disposed well back towards the shoulders.

In the case of the stern there was ample practical evidence to prove that the stern deck lines could be made very fine indeed without a greater freeboard than the weather deck and the recent tendency of certain Admiralty cargo liners towards a high and rounded poop seemed to have been a step in the wrong direction and the U.S.A. C.3 type of ship seemed preferable.

As speeds exceeded 14 knots, the speaker suggested that there was a case for a widely different design of ship from the conventional type. It was, however, most desirable to make substantial reductions to the weight of the machinery to enable the engines to be placed right aft, so that the aft machinery weight would no more than counterbalance the forward bridge structure and all the ship's equipment which could be placed forward. One way of reducing engine weights was by the use of indirect drives and high speed engines, but the speaker thought there was a good case for direct drive double acting Diesel machinery provided the propeller revolutions could be substantially increased. It would be of great interest to have Dr. Todd's considered opinion as to the possibilities in this direction without appreciable sacrifice of efficiency, by special design of the stern and propeller. It seems that the future 18 knot cargo liner of 10,000 tons deadweight would require a single screw Diesel power of about 10,000 s.h.p. and if the propeller speed could be raised to 150 r.p.m. the speaker could envisage a direct drive main engine weight of not exceeding 300 tons (excluding auxiliaries) and a propeller of reasonable size. Would the elimination of deadwood aft improve the propeller efficiency?

Fig. 6 was of special interest in view of the differences in the bow shape of warships in the U.S.A. and this country and a similar diagram from a conventional pointed bow would be of interest. The speaker would be interested to have Dr. Todd's opinion as to whether there was likely to be any saving in having a bulbous bow for 18 knot cargo liner types. As speeds increased the ugly continental bow with its highly raked stem and curved forefront seemed to be less and less desirable.

Dr. Todd had once again made evident the great importance of skin frictional resistance in merchant ships and this was of major interest to the superintendent engineer, whose duty it was to keep the ship's hulls clean in service. Table 2 well showed the need for clean smooth plates without riveted joints. It would be interesting to know whether there was reliable experimental data available to establish the relative resistance of welded and riveted joints, the latter with alternatively machine and hand welding. At a paper recently read before the Institute, the speaker had suggested that projecting metal on welds on the ship's side should be ground off to improve the fatigue resistance, and it would be interesting to have assessment of the likely gain from such a proposal due to the reduced skin friction.

Dr. Todd had mentioned that plate distortion caused by welding might have an injurious resistance effect and the plating of some vessels built in this country certainly had a definite "facet" appearance, but the speaker thought that the concave plate distortion between vertical frames at the bow due to weather or immersed bodies was likely to be much more serious. This effect was most noticeable on certain welded ships used in northern convoys but could be seen to a greater or less degree in most ships. It would be interesting to know what effect these concavities had on resistance; it seemed to the speaker that the transverse framing system was fundamentally unsuitable at the forward end of a ship. In the case of wings of aeroplanes with the thin plating usual, the ribs were invariably arranged *parallel* to the direction of flight at the leading edge and in the case of welded ships the "cheque board" system of framing (i.e. combined transverse and longitudinal) would give a far superior plate support with the thinner plates welding should permit. There was a tendency in this country to belittle the direct hydrodynamic gains of welded ships and reliable scientific data was needed by shipowners to enable them to settle future policy.

In the author's last paragraph the need for greater co-operation between scientist, experimenter and operator was stressed, and there is no doubt that the N.P.L. should undertake far more research under actual sea conditions and have greater scope in actual ship design. The speaker believed that far more full size experimental work should be undertaken by the Government under a special technical non-commercial Maritime Board equivalent to that which had operated since 1936 in the U.S.A. with such striking success. It seemed that our sole chance of regaining our maritime position was by courageous and well planned technical adventure without undue regard for tradition, backed by all the scientific and practical knowledge at our command. A recent investigation by the Ministry of Labour had apparently affirmed the extraordinary lack of scientifically trained naval architects and marine engineers in this country due to years of neglect and non-appreciation by the industry. Very belatedly the vacant chairs of naval architecture might shortly be filled, but it would be ten years at least before a trickle of trained men were available for responsible research and development.

It therefore seemed imperative that the greatest possible economy be exercised of such highly trained scientists as now existed and it was submitted that for the next few years most ship research work should be centrally directed at Teddington where there was already an efficient but small organisation, and placed under the aforementioned Board. The composition of the new twin shipbuilding and marine engineering research associations mentioned, consisted essentially of the heads of industry who were directly responsible for the present regrettable position and it seemed evident that some new blood and non-commercial direction was urgently needed. The money for the proposed research work by the industry was to come from income tax rebate and therefore from public funds. The simplest and logical way of increasing short term research and development in shipbuilding was for the Government immediately to increase the financial grant to the Teddington Tank whose staff had already so greatly added to our scientific knowledge of ships. Simultaneously, it might be desirable to introduce a competitive scientific element within the industry, but this must surely be a longer term policy. The speaker strongly urged the need for a White Paper dealing with all aspects of ship and engine research, design and construction, to guide the Government on its future policy of maritime affairs on which the well being of the country so greatly depended.

The Chairman said that, speaking as a mere marine engineer who had been for some few years responsible for the powering of a large number of ships, from liners to fast cargo vessels, the paper made him feel that when one said that a ship was going to do 23 knots on a certain power, and that she required to be a certain length and a certain breadth and a certain draught, one was taking great risks. He had usually adopted Taylor as a sort of father in determining the power required.

As the author pointed out, the first power that one had to estimate was the effective horse power; after that one came to the propeller, and the question of the revolutions of the propeller, so ably brought out by Mr. Burn, was one which had to be considered in relation to the efficiency which could be obtained. He would like to say, however, though not in any spirit of egotism, that it was possible to approximate the effective horse power very nearly to that which was obtained afterwards from tank experiments.

As a superintending engineer, one had in the first place to make a specification, and one had to take the responsibility of putting in that specification what the respective builders, when they quoted for the job, were expected to accomplish. It was naturally open to the builder to say that he could not provide the speed on the power given, but in his own case that had occurred only on one occasion, and when the vessel was tried in a certain tank (not the National tank, but a Vickers tank) the superintendent of that tank tried out various forms of bossing, and, although having previously asked for a slight reduction in the speed specified, produced an inward-turning screw which showed a considerable reduction in horse power for the same speed. Seeing that it was an appreciable percentage, and that it had come from the tank, they expected to get something like half of it in practice; but when the ship was put on trial, with the inward turning screws and the bossing adopted, over the measured mile she did just over 23 knots for 1,000 less h.p. than had been given the builders to do 22½ knots, with a certain displacement. He was not advocating inward-turning screws, because the ships which were fitted with inward-turning screws were changed over to outward-turning screws afterwards. No doubt everyone was guessing what the form of drive was; it was turbo-electric, the only form in which such an arrangement was possible.

Marine engineers had sometimes to delve into the questions with which the author had dealt. They did not profess to know nearly so much about them as the learned naval architects who had spoken that evening, but they had to take the responsibility afterwards that the ship achieved the speed laid down, and they had to take the responsibility for other things in addition to speed, such as fuel consumption. On that point it was possible, working from the fundamental Ⓒ, to put the Admiralty coefficient in terms of the Ⓒ and another coefficient used in marine engineering, the fuel coefficient, and it was generally possible to prove, by the correlation of those three coefficients, whether a man who said that he was doing a certain fuel consumption per s.h.p./hour was actually speaking the truth or thought that one was foolish to believe him. He had found that very useful.

Those few remarks with regard to the shaft horse power might be considered to be outside the scope of the paper, because the author was speaking of the effective horse power, but it all led to the shaft horse power, which was what one was after, and he was sure that the various statements which the author had made with regard to angles of entrance, parallel middle body and so forth would be of very great value. Dr. Telfer had made some facetious remarks about the marine engineer, but it must be remembered that the marine engineer had to work to precision limits, and be certain about everything that he put into his engines, while, as Dr. Telfer had remarked, the naval architect was still not certain about this and not sure about that.

BY CORRESPONDENCE.

Sir Amos L. Ayre, O.B.E. (Director of Merchant Shipbuilding): The author is to be congratulated on so ably overcoming the difficulty to which he refers in his introductory paragraph. He has more than overcome it; he has, in fact, enriched the TRANSACTIONS of the Institute with what is really an up-to-date condensed text book on the subject of ship resistance.

It may be that the speed function Ⓟ appears with some predominance, and in my view, unnecessarily so, having regard to the very great majority of practitioners who have no use for it, if only for the reason that there is available the entirely satisfactory and simpler function $\frac{V}{\sqrt{L}}$. I often wonder why the few supporters of Ⓟ do not realise that $\frac{V}{\sqrt{L}}$ is a perfectly reliable function in the determination of the positions of the "humps" and "hollows" for any normal ship form, and in fact, most that may be termed abnormal. Humps occur very near to values of ·78, ·98 and 1·46, whilst the "hollows" lie very near to ·72, ·86 and 1·15. At lower values, the phenomenon is of little importance in its effect, unless in the very exceptional case of a vessel which for some reason may require to be given a speed at which she is overdriven relative to the block coefficient. In the ordinary or general case the first definite instance of the phenomenon is experienced at $\frac{V}{\sqrt{L}}=\cdot 78$.

It is pleasing to note the two occasions on which the author refers to radius of bilge, and particularly his view that the bad feature of making this too small has been lost sight of in the past. But it did not apply to the whole of the past; it is only during the past thirty or forty years that there has been a trend towards very sharp bilges.

The author's recognition of there being subjects, other than resistance, with which the ship designer is concerned, is also to the good, as Tank Authorities would not always seem to have done so. Successful ship design involves successful compromise within a variety of subjects. There is an important reference to this in the concluding paragraph of Section 14 of the paper; an example which, alone, concerns the two principal features of Experimental Tank work.

The Alexander formula quoted by the author as

$$C_B = 1\cdot 04 - \frac{V}{2\sqrt{L}}$$

should, I think, be accepted as applying to vessels of low speed, say about $\frac{V}{\sqrt{L}}=\cdot 5/\cdot 6$, and in respect of service conditions. If it is written as

$$C_B = 1\cdot 08 - \frac{V}{2\sqrt{L}}$$

it will correspond to the speed at which Ⓒ begins rapidly to increase, and can be accepted as the speed and block coefficient relationship beyond which the model is overdriven, i.e. in the smooth water of the Experimental Tank. In determining this relationship from curves of Ⓒ, care must be taken to sort out any other reason for rapid advance, such as the approach to a "hump" speed. Whilst the formula using 1·08 will usually apply to the Tank condition up to a speed equal to $\frac{V}{\sqrt{L}}=1\cdot 0$, it is not necessary to reduce to 1·04 for the service condition at the higher speeds. For service conditions the formula can, in the normal case, be used to determine the maximum block coefficient that should be used, as follows:—

$$1\cdot 04 - \frac{V}{2\sqrt{L}} \text{ at } \frac{V}{\sqrt{L}} = \cdot 50$$

1·045 –	„	„	„	= ·60
1·05 –	„	„	„	= ·70
1·06 –	„	„	„	= ·80
1·07 –	„	„	„	= ·90
1·08 –	„	„	„	= 1·00

As a rule, the effect of a "hump" speed can be eased somewhat by a reduction in the block coefficient. In the case of a normal vessel which, because of length limitation, must be run at the "hump" speed of $\frac{V}{\sqrt{L}}=\cdot 78$, a reduction of ·02 in the block coefficient as determined by the formula, will usually meet the "hump" effect, and produce a smooth curve of Ⓒ in that vicinity. The more powerful "hump" effect at $\frac{V}{\sqrt{L}}=\cdot 98$ cannot, however, be so met.

The Wigley experiments, summarised in Table 3, are most interesting, but are, of course, abnormal in the range of location of L.C.B. A range of 2 per cent. of L. forward, and the same amount aft, will usually cover all vessels from very low to very high speeds. Even at 4·08 per cent., forward and aft, we have abnormal instances. Ordinary cross curves drawn through the curves given in Fig. 17 indicate that, for these models, the best positions for L.C.B. is at about 5 per cent. of L aft of midships for $\frac{V}{\sqrt{L}}=\cdot 70$ and varying to 2 per cent. L aft of midships for $\frac{V}{\sqrt{L}}=1\cdot 00$. This could not, of course, be accepted for ordinary ship design, even with regard to the subject of resistance.

There is a great deal of valuable information and guidance in Table 5, and the only comments I would make thereon concerns the midship section coefficients that are given. For medium speed cargo ships, it might be emphasised that 0·98 should be looked upon as a maximum. In the case of the cargo liners, I believe 0·975 is a preferable maximum, the same applying to intermediate liners.

The references to rudders and sternposts are important, but the saving of 7 per cent. as the result of streamlining these appendages, together with the addition of a fin is, perhaps, put somewhat modestly. I believe that savings of much higher magnitude are possible. But I do not think that any more than a small proportion of the total saving arises out of the reduced resistance; the improvement in propeller efficiency arising out of the fin effect is by far the greater. No doubt, owing to scale effect, it is not possible to determine exactly what the reduced resistance amounts to.

I agree with the author that our knowledge of the subject is still far from complete but, with closer co-operation between the experimenter in this particular branch of our science and those who design and build ships, we should learn much more. The condition of weather, use of helm, etc., during the course of full scale tests, usually makes strict comparison difficult, but there should be much more opportunity given to the experimenter to participate in these, as well as when the vessel is in service, to enable full correlation of the model and full size condition to be produced.

Mr. B. P. Fielden (Member): Dr. Todd has done good service to the shipping industry by his work. One fundamental he does not mention is the necessity of having personnel who know their job in designing and running ships and are given the position to which their brains and work entitle them. It is doubtful whether the public realises what has been done by those out of the limelight and one can only judge the Admiralty's valuation of the Engineering Branch by the fact that there is no engineer with the rank of Admiral and only one Vice-Admiral on the Active List. There are a few Rear-Admirals, and as for Naval Constructors, are there any? The Mercantile Marine is a bit ahead of them in this matter, but not much.

Another fundamental which might be discussed is the breadth to length ratio; a common one for all vessels is not suitable. On the North Atlantic trade, ships coming eastwards are generally laden but going westwards, owing to U.S.A. tariff laws, they are generally light and a ship with a comparatively low $\frac{L}{B}$ ratio will slow up in bad weather and pound which no one likes, with the possible exception of ship repairers.

A beamy ship may be all right for a passenger type where little cargo is carried and the forward end is kept fine, but for cargo carriers the ideal to the shipowner is one in which all the holds can be discharged and loaded at the same time; in other words, all the holds should be as nearly equal in capacity as possible.

In my opinion, the finest cargo ships carrying a few passengers that have ever been on the North Atlantic trade were the "Minneapolis" class of ships owned by the Atlantic Transport Company, Ltd. They were 600·7ft. between perpendiculars, 65·5ft. extreme breadth and 43·3ft. moulded depth with a loaded block coefficient of ·72. In detail around the sterns they could have been improved, as advocated in Dr. Todd's paper, but they had good constitutions and did a lot of work until in the last war the Germans sank the lot.

Another ship of similar length but with 80ft. beam, which was more fashionable but less hardy, pounded badly. Ships have to be built to suit the trade they are employed on.

Dr. A. M. Robb (University of Glasgow): Dr. Todd has presented a valuable summary of knowledge as it is to-day. In recent years that knowledge has, so far as the fundamentals are concerned, developed rapidly, in large measure because of the development of aeronautics. The development has answered some questions, but it has raised others. A possible question is whether the accepted practice of classifying the elements of resistance into four categories is now adequate. The grouping in category (3) on page 1 is common, but there is ground for suggesting that the resistance due to the formation of eddies at local regions of a hull, or at the whole after end of a hull should be separated from the resistance due to eddies around details of stern gear. The latter source of resistance, the only eddy making resistance recognised in the older text books, seems to obey Froude's Law of Comparison. That is a reasonable conclusion from Dr. Todd's work published in 1934 and from some much criticised trial trip records which, published nearly four years before, anticipated Dr. Todd's conclusions. There is doubt, however, whether the other eddy making resistance, the resistance generated by excessive fullness of after body, also follows the Froude Law. If the two forms of eddy making resistance follow different laws they should not be grouped together, and they should receive individual recognition. The evidence on the matter in doubt is far from complete. Nevertheless, it seems permissible to relate a series of seemingly separate considerations in case the action should lead to further investigation. In 1913, the existence of serious "hull" eddy making was first brought to light by Baker, who published photographs of the disturbance. In 1919, Semple published some results of experiments on cargo ship models which showed that undue fullness of after body resulted in a resistance increased by 80 per cent. beyond that of the more common form. Since such an increase represented, roughly, a five-fold increase in residuary resistance and there was no comment on excessive waves being created, it seems reasonable to associate the excess with the formation of the "hull" eddies brought to notice by Baker six years before. Doubts have been expressed whether the resistance of the full size ship would be increased by the whole of the 80 per cent.; but there was an obvious difficulty in the way of obtaining full size confirmation or contradiction. The doubt seems, however, to receive justification from some remarks by Mr. E. Wilding in the course of the discussion of a paper by Mr. M. P. Payne in 1934. Mr. Payne had expressed scepticism regarding the application of the ordinary law of comparison to shallow water experiments, and Mr. Wilding supported him by instancing cases in which tank prediction and trial trip result were widely divergent, the resistance measured in the tank being relatively much in excess of that experienced by the ship. It is possible that these records from 1913, 1919 and 1934 should all be associated. Moreover, it is possible that some shallow water experiments by Taylor should also be taken into consideration. Taylor found that it was impossible to obtain consistent results at speeds *above* three knots with a 20ft. model; in other words, at speed-length products much higher than those normally associated with instability of result. Further evidence is afforded by a record of shallow water experiments in the Dumbarton Tank, published in "Design and Construction of Ships", Vol. II, p. 238. The record shows instability of result over a range of the higher speeds and not over the low speed range. The instability of result suggests eddy making. The occurrence at the higher rather than the lower speeds suggests "hull" eddy making, as does the occurrence in shallow water, which has the advantage, from one point of view, of exaggerating phenomena. If the association of all these seemingly separate considerations is reasonable, it suggests that there is another element of resistance which does not follow Froude's Law, and which, to borrow from the realm of aeronautics, may be termed "form drag", and which is distinct from both the "form resistance" noted on page 11 and the eddy making resistance developed behind details of stern gear. It is not suggested that "form drag", if it is indeed a separate element, is a considerable factor; it is suggested that there may be a need for further investigation as a step towards fuller understanding.

In the same connection, it might be a help if all published tank records could be presented in the manner shown by Fig. 13, with the Ⓒ curve continued below the lowest speed at which consistency of result is possible, and with the "scatter" at low speeds indicated. Comparison of such records might assist towards a fuller understanding of form drag and form resistance, assuming this distinction, and might also cause uncertainty as to whether wave making is entirely negligible at the lowest speeds of tank tests. Consideration of the last point arises from watching a coaster rather less than 200ft. long approaching a berth on the Manchester Canal. The ship was at an angle of 30–40° to the berth, well away from it, and only the forward draught marks could be seen. She was barely moving but there was an appreciable "hump" on the water at the stem, which by comparison of draughts before and after berthing amounted to about three inches. The extent of the local elevation of the water with almost imperceptible motion raised a doubt as to whether commonly accepted beliefs are fully valid.

This doubt leads one to question whether wave making resistance has been as closely studied as it deserves. Close study involves careful investigation of records of wave profiles, and there are grounds for suggesting that there are not nearly enough records and the few that have been published have not been properly analysed. The records made by Froude in the course of his parallel-body experiments were brought to light only recently, fully 60 years after the experiments, and the only others available are those published by Kent in 1915. The latter records show some remarkable features which have been ignored, and an incomplete examination suggests that there is a link between them and a feature of the Froude parallel-body experiments which has also been ignored. It is not necessary to recapitulate the considerations which suggest that the Ⓟ criterion is based on inadequate investigation. The "entrance wave" criterion noted on page 11, $V = 1{\cdot}09\sqrt{L_E}$, is also based on inadequate consideration. It was developed from two sets of experiments. A summary of the results of one set shows the impropriety of the criterion. The five lengths of entrance ranged from 129·4ft. to 221·7ft. According to the criterion, the speeds at which there should be excessive resistance should range from 12·4 to 16·23 knots. The actual "hump" speeds ranged from 12·7 knots to 15·85 knots. The point for criticism is that the difference between criterion and actuality is in one direction at one end of the range and in the other direction at the other end of the range, criterion 12·4 knots and actual 12·7 knots at 129·4ft. as compared with criterion 16·23 knots and actual 15·85 knots at 221·7ft. When there is a definite trend of difference, it is not proper to take an average value and use it as a basis for a physical explanation. The other set of experiments shows the same characteristic variation. Incidentally, too, some experiments carried out by McEntee on the most suitable position of parallel body showed that the best result for a speed of 11 knots was attained when the length of the entrance was 105·3ft. According to the entrance wave "law", that length of entrance should give a bad result at 11·2 knots. Hence, there is no "law". The consideration here is that presentation of criteria such as Ⓟ and Ⓥ based on inadequate examination of available data, is a hindrance the development of fuller understanding since it has a deterrent effect on investigation. In spite of all the progress that has been made, or possibly because of it, there is ample scope for further, and fuller, investigation.

Dr. R. A. Collacott, B.Sc., Ph.D. (Associate Member of Council): While it has obviously been impossible for the author to include in his paper an account of all the aspects involved in the selection of a ship form, I would be interested to learn whether he has carried out any work on the relationship between ship form as represented by its propulsive efficiency (in the manner outlined in this paper) and its general manœuvrability, both from a steerage point of view for turning and in its reversibility.

For turning, there is a certain amount of "way making" and the rate of turn will depend initially on the turning moment (applied via the ship's propellers and rudder) and on the ship's form. It would be interesting to receive the author's comments on this feature of ship form and propulsion.

Furthermore, the economy of operation of many small vessels depends not simply upon their propulsive forward efficiency, but also their efficiency when operated "in reverse". This is a particularly important factor with tugs, and as the propellers do not themselves possess such a high efficiency when operated in reverse as when in the forward direction, it would follow that the ship form for these vessels should have the highest possible general efficiency for both directions of motion.

In conclusion, I would like to suggest that the susceptibility of a ship's structure to vibration is also an important factor in its ultimate selection, and that some model experiments should also analyse this feature as well as the hydrodynamic aspect treated by the author. Ships which vibrate badly are uncomfortable for the crew or passengers, and may be rendered structurally unsound.

Nevertheless, I would like to congratulate the author on having presented an exceedingly interesting paper.

Mr. A. M. Riddell (Member): Dr. Todd is to be complimented on the mass of information he has been able to put forward in such a short paper.

In view of the complexity of the problems raised in arriving at the best hull form for given service conditions, I feel that if the paper has brought home to engineer superintendents and their like the need for having expert advice, it has fulfilled an important and useful function. In these days of specialists I feel that most members, after reading the paper, will fully appreciate that form design is a matter for someone who has not only a thorough knowledge of the underlying principles, but also a vast fund of experience.

I notice that in section 2 of the paper headed "The Elements of Ship Resistance", Dr. Todd does not mention form resistance, although in Fig. 13 and under section 9 form resistance is mentioned and approximate figures are furnished showing the relationship between skin friction (as calculated for a plank of the same length and surface area as the hull) and form resistance. I presume there are under water appendages and fittings which have little or no effect on wave making resistance and, if properly designed, do not create eddy resistance, although these both have skin friction and form resistance.

In section 14, propulsive efficiency, wake and thrust deduction are all mentioned. I think the value of the paper would be considerably enhanced if Dr. Todd were to give a clear definition of wake and thrust deduction and, by quoting examples, enlarge on the interplay between these two factors. This would demonstrate the undesirability of reducing hull and propeller efficiency to a greater extent than the benefit obtained by a reduction in hull resistance. In dealing with wake, Dr. Todd might also deal with the balance which has to be arrived at in ensuring that any fining down of the lines immediately in front of the propeller does not so reduce the beneficial effect of wake as to make the net result less efficient than would be the case with somewhat bluffer lines.

Although the paper does not deal with the propeller, I think a clear definition of the term "Quasi-propulsive coefficient" would be of value.

I feel that collaboration between the staffs of the various Tanks and the personnel who are running the ship, would be extremely valuable. The amassing of data covering performance under different conditions of displacement and weather, if furnished to experts, could go a long way towards bridging the gap between the purely scientific and the practical aspects of the subject. In this connection, I would suggest that with correctly calibrated torsionmeters the registering of s.h.p. would be extremely simple and free from error. Furthermore, a Walker's or other patent log, correctly calibrated, would facilitate a true reading of speed through the water. This would obviate those errors which are bound to occur if the speed of tide or current have to be assumed. Data regarding direction and velocity of wind and state of weather should also be furnished, this being obtained from "the Bridge".

Some of the technical officers of the William Froude Laboratory travel from time to time in the actual ships which have been designed from the results of model trials. They have thereby gained a very valuable fund of experience of the actual service conditions. I feel it is only correct to mention this as there are still a few "diehard" critics who contend that Tank Authorities in general are too pedantic. I remember hearing Mr. Kent, the present Superintendent of the William Froude Laboratory, state in a broadcast that he was slung over the stern in bad weather in order to study the working of the propeller and rudder. This, I think, supplies the complete answer to any criticism that Tank Authorities do not make every endeavour to gain as much practical experience as possible!

As the paper deals only with the fundamentals of ship form, I appreciate that propeller performance was entirely beyond its scope, but I do think it would be an advantage if Dr. Todd would read another paper dealing with the fundamentals of propeller performance, such paper to be an extension or complement to the present one, since on account of their mutual interaction, it is impossible to divorce hull form from propeller performance.

Mr. C. Wigley (Ship Division, N.P.L.): I must congratulate Dr. Todd on a very readable and informative paper. I think it should serve very well its purpose of giving the marine engineer some insight into the problem of hull design.

I should like to emphasise that the chief difficulty at present in the calculation of wave resistance for ships of ordinary speeds is the correct assessment of the effects of viscosity on the wave resistance. As Dr. Todd mentions in sections 2 and 8 of the paper, the division of the resistance into separate items is only a rough approximation and at low and moderate speeds the effect of viscosity on the wave resistance cannot be neglected. The present method of assessing this effect is empirical and, as I think, capable of improvement. There is no great difficulty in extending the present methods of calculation to ordinary ship forms (in contrast to forms derived from algebraic equations); the lines to be followed were laid down by Havelock in 1943[1]. In the same paper Havelock also gave the mathematical expression for the wave resistance of a source and an equal sink at distance pL apart and in the line of motion; he also showed that this combination is the first approximation to the wave resistance of a form which takes account of its length when the strength of the source is correctly chosen. It is possible from this expression to deduce the position of the maxima and minima of Ⓒ$_W$ on a base of Ⓟ; the maxima occur at approximately Ⓟ$=1{\cdot}50$, $0{\cdot}86$, $0{\cdot}67$, and the minima at Ⓟ$=1{\cdot}14$, $0{\cdot}74$, $0{\cdot}61$. These values may be compared with those given by the Ⓟ theory, in equation 12 of the paper, and, allowing for the misplacement of the first maximum, the reason for which is given by Dr. Todd, it will be seen that this simple approximation gives maxima and minima in very nearly the places prescribed by the Ⓟ theory. It follows that the theoretical explanation of what has been known for years as the Ⓟ theory is in fact the possible approximation to a form by replacing it by a source and a sink.

(1) "The Approximate Calculation of Wave Resistance at High Speed", by T. H. Havelock, F.R.S., N.E.C.I. of E. and S., Vol. 60 (1943).

The Author's Reply to the Discussion.

The Chairman's remarks about the merits of inward and outward turning screws on twin screw ships are most interesting. It has been found at Teddington that inward turning screws give a higher propulsive efficiency, but the best results can only be achieved with either type when it is associated with the correct shape of bossing. If this is done, and the direction of turning afterwards changed, it follows that the screws will then not be working under the best possible conditions, and some unnecessary loss is being incurred. In the past, inward turning screws have usually been rejected because a ship with them was said to be less easy to manœuvre, but it is believed that this fault has been considerably exaggerated, and that with a little experience the small drawbacks could be overcome or accepted in face of the reduction in horse-power. Mr. Smith has had considerable experience in this question, and in stating that the direction of turning was subsequently changed from inward to outward, he has aroused our curiosity as to the reasons for the change. It would be most interesting if he could give the whole of the facts some day, including the comparison of ship and model figures, since here is a case in which a Tank prediction going contrary to accepted practice was vindicated in the full scale trials.

Mr. Smith is quite correct, of course, in saying that one can approximate very closely to the effective horse power, and Taylor's Standard Series is doubtless a very good guide in the case of the types of ship with which he is generally concerned. But it must not be forgotten that Taylor's and all other series have been derived from model experiments, so that the latter form the true basis for all reliable estimates. Standard series, too, are usually developed from a single parent form, and this cannot be the least resistful at all speeds, so that a little improvement can usually be looked for when experiments are made upon models specially designed for particular conditions.

Dr. Telfer has raised many controversial questions, which cannot be adequately dealt with in the reply to a discussion on this paper —indeed, any one of them might easily form the basis for another paper.

The Ⓟ "theory" was evolved in the first instance solely on empirical grounds to explain the variation of wave making resistance with speed, brought about by interference between the different wave systems created by a ship. In this field it has proved both illuminating and useful, and although it had originally no theoretical basis, the subsequent work of Wigley with a wedge shaped form showed that for such a simple shape the assumed wave making length of pL was actually true except at the highest speeds. More recently, Havelock has shown that the mathematical conception of replacing a ship's form by a source and an equal sink requires that they should be situated a distance pL apart, as clearly brought out by Mr. Wigley in his contribution to this discussion. It is evident that the Ⓟ theory has, in fact, a real theoretical basis, and can be extremely useful in discussions on wave making resistance and interference phenomena.

It is probable that Dr. Telfer's idea of substituting the load water line coefficient for the prismatic coefficient would give a nearer approximation to the truth, but I regret that under the present pressure of work at the Ship Division, it has been quite impossible to go further with this matter.

I find myself in complete agreement with Dr. Telfer over the present lack of fundamental knowledge of roughness effects, and in Section 6 of the paper have already made a similar plea for a complete reconsideration of the methods of dealing with skin friction resistance, which must of course include the effect of roughness. To-day we are using coefficients of friction for ship surfaces derived by some method unknown from model experiments (made 75 years ago), and apparently including an unknown allowance for the effects of butts, laps, rivets, paint, etc.—surely not a satisfactory state in this year, 1945?

Dr. Telfer has rightly called attention to the differences between local and total roughness effects, but the figures to which he takes exception have been exceeded in practice, as for example, in the cases cited in Section 12 for American warships, where the additional resistance due to fouling was as much as $3{\cdot}62\times10^{-3}$, agreeing very closely with Kempf's values in Table 2.

Certain conclusions have been drawn in this paper from results of model experiments made by Mr. Wigley at Teddington. Dr. Telfer says that these models were suffering promiscuously from laminar flow and that the conclusions are in consequence not valid. None of these models were tried with any device for inducing turbulence. On the other hand they were large models and moreover had not bluff, rounded bows but were all finished sharp, the maximum angle of entrance on the waterline in the fullest model being only 18°, which would fall away rapidly at lower levels, whilst in the finest model this L.W.L. angle was only 2·7°. In the past various models have been run at Teddington with roughened bows (made so by the use of a Kempf scraper) and in no case of models of fineness and proportions similar to those in question has any appreciable effect been observed. The only time when a change was found was in the case of models of extreme fullness, in which the resistance values at low speeds were very erratic, and were stabilised by the artificial roughening at the higher values. The results of the analysis into form resistance also show a progressive change with angle of entrance, and this does not look like a fortuitous feature, whilst the general conclusion that full entrances lead to decreased resistance at low speeds has been known to be true in practice for many years. For these reasons I am not satisfied that Dr. Telfer's criticism is a sound one, but obviously the matter could only be settled by resort to experiment, and this cannot be done at the moment, involving as it would the reconstruction of some of these models and their running again with and without artificial roughening. Perhaps when the press of commercial work at the Laboratory abates, it may be possible to include an investigation of this question in our programme with future models of the series.

Mr. Burn raises a very interesting question when he mentions the shape of the hull above water. This is an aspect of seakindliness which has not received sufficient consideration in the past, due principally to a lack of reliable information as to the behaviour of ships in different types of weather. Analysis of service logs seldom leads to clear-cut conclusions and a great deal of work will eventually have to be done on board ships by trained personnel before this problem can be seen correctly and the solution found. In connection with above-water resistance, we must also remember air resistance and the accumulation of gun platforms, life rafts, heaving derricks and so on in the present day war time vessels must, taken together, increase this resistance quite materially. A complete clean-up of the upper works will be necessary in these and in new ships after the war.

It is assumed that the vessels referred to by Mr. Burn as being less expensive when built with fine lines and short parallel body than when having long parallel and bluffer ends were all of the same displacement so that the former had greater beam. This does not seem logical, but in reply to Mr. Burn's request the following figures have been prepared showing comparative resistances for a number of vessels of different proportions.

Taking his length of 500ft. overall as corresponding to 480ft. b.p., and assuming a constant displacement of 14,000 tons, the e.h.p. values would be as given in Table 6.

TABLE 6.

Length b.p. = 480ft.
Length overall = 500ft.

Beam in ft.	Draft in ft.	Block coefft.	Prismatic coefft.	Naked e.h.p. at 17·5 knots ($\frac{V}{\sqrt{L}}$=0·80)	Naked e.h.p. at 18·6 knots ($\frac{V}{\sqrt{L}}$=0·85)
62	23·8	0·692	0·710	5905	7760
64	,,	0·670	0·687	5625	7330
66	,,	0·650	0·667	5430	7040
68	,,	0·631	0·647	5310	6780
70	,,	0·613	0·629	5200	6595

These show that the increase in beam when accompanied by a corresponding decrease in block coefficient reduces the e.h.p., but the reduction does not go in proportion to the beam increase, the saving becoming less as the beam approaches 70ft. Thus at 17½ knots the reduction in power for an increase in beam from 62 to 64ft. is some 4·8 per cent., whereas an increase from 68 to 70ft. only results in a saving of 2 per cent. The suggestion of using a narrow watertight deck forward with a bridge designed to act as a breakwater might give improved performance in a smooth sea but if it resulted in the vessel shipping more green seas this would be unlikely in rough weather, and moreover might lead to structural damage and perhaps serious flooding. There would also be great difficulties in arranging cargo hatches, derricks and ventilation to the holds.

Any substantial increase in propeller revolutions for the same power absorption and speed of advance will normally result in a decrease in propeller efficiency and also in the quasi-propulsive coefficient. In the case where the faster running propeller is also of smaller diameter, some advantage can be derived in resistance by adopting a deeper cruiser stern. I have no comparative figures covering any wide range of revolutions for cargo liner types, but have published many such comparisons for coasters. One of these is reproduced in part in Table 7.

The revolutions per minute for 11 knots vary from 106 to 338. As a consequence the open propeller efficiency falls from 0·68 to

TABLE 7.

Coaster 200·0ft. × 33·4ft. × 11·43ft. draft at 11 knots.

Model No.	1945A		1945B		1945C	
Stern	Raised counter.		Cruiser.		Deeper cruiser.*	
Displacement in tons	1315		1317		1317	
Naked e.h.p.	297		290		285	
Propeller diameter, ft.	10·66		8·00		6·66	
„ pitch ratio	1·0	0·6	0·8	0·6	0·8	0·5
R.p.m.	106·3	150·6	196	236	257	338
Open propeller efficiency	0·68	0·62	0·59	0·57	0·50	0·48
Quasi-propulsive coefficient	0·70	0·635	0·685	0·635	0·64	0·60
Delivered horsepower at propeller†	530	585	530	572	557	595
Thrust deduction fraction	0·29	0·29	0·21	0·21	0·18	0·17
Hull efficiency	1·02	1·02	1·14	1·13	1·18	1·21
Loss in propeller efficiency	—	9%	13%	16%	26%	29%
Loss in q.p.c.	—	9%	2%	9%	9%	14%
Gain in e.h.p.	—	—	2½%	2½%	4%	4%
Overall increase in delivered horsepower	—	10%	nil	8%	5%	12%

* Lowest point of propeller disc kept in same vertical position and shaft centre lowered for smaller diameters.

† Includes 25 per cent. for appendage and weather resistance in average fine weather at sea.

0·48, but the reduction in quasi-propulsive coefficient is only from 0·70 to 0·60—i.e. 14 per cent. instead of 29 per cent. This recovery is mainly due to the smaller thrust deduction fraction realised with the smaller screws. These screws, being lower down on the hull, have progressively finer lines ahead of them, with the result that each reduction in diameter is accompanied by a quite large improvement in thrust deduction fraction (see Table 7). There is also a small improvement in the resistance of the hull due to the cruiser stern—2½ and 4 per cent. with the two types tried. As a result, the final overall increase in power needed is only 12 per cent. for an increase in r.p.m. from 106 to 338, and up to 250 r.p.m. the penalty is no more than 6 or 7 per cent.

Whilst these figures apply quantitatively only to the coaster in question, the trend would be exactly the same in the larger ship, and they may be taken as a guide to what could be achieved with fast running engines. Thus, for a 400ft. ship, the range of revolutions would be from 75 to 240, which would cover most of the likely range suggested by Mr. Burn.

The elimination of deadwood aft would reduce the skin friction resistance a very small amount, but would also reduce the effective wake, and so lead to somewhat lower propeller efficiency. It would also decrease the directional stability of the ship and so call for the use of larger helm angles to keep her on her course.

I am not aware of any experiments made to measure the resistance of welded plating as distinct from riveted. A great deal of work has been done in aeronautical research on the effect of relative smoothness in aircraft wings and the effect of rivets, lap joints, etc. Truscott and Parkinson, for example*, tested surfaces in water with rivet heads of various types, and found the following increases in resistance over that for the smooth surface.

TABLE 8.

Rivet diameter	5/32″
Spacing of rivets in fore and aft rows	2″
Spacing of rivets in transverse rows	1″
Spacing of transverse rows	10″
Speeds up to 40 m.p.h.	

Type of rivet head.	Height above smooth surface.	Percentage increase in drag over smooth surface.
Counter sunk in dimpled plating	Level with surface outside dimple	11
Brazier in head 25/64″ dia.	5/64″	24
Round in head 5/16″ dia.	0·117″	30

*The increase in frictional resistance caused by various types of rivet heads. N.A.C.A. Technical Note No. 648 (1938).

Some figures for the effect of other surface irregularities have been given by Hood†. Joggled plating joints transverse to the flow gave an increase of 4 per cent. in drag, whilst lapped joints caused twice this increase. When the latter were chamfered off over a length of three times the thickness of plating, the increase was 5 per cent. instead of 8 per cent. Experiments made with a wing section showed that the commercial product had a resistance some 8 per cent. higher than that of the more carefully made specimen used in the tunnel tests, an increase attributed to sheet waviness between the wing frame members.

All or most of this extra resistance should be recoverable by the use of welding in place of riveting if the joints were ground as Mr. Burn suggests and if the plating were not wavy between frames. If the latter is to some extent unavoidable, longitudinal framing would have some advantage.

Mr. Burn's views on the methods which should be pursued in research in the future are most interesting, and it is hoped that the Institute's representatives on the various bodies and committees which will in future have the direction of the work will put them forward in the right quarters.

Sir Amos Ayre has raised the question of the suitability of Ⓟ as a parameter for comparing Ⓒ curves for different hull forms, and makes a plea for the use of the simpler function $V/\sqrt{L}$.

I find myself largely in sympathy with this suggestion. The Ⓟ theory has considerable value when investigating wavemaking interference and in predicting fairly closely the position of the humps and hollows in the Ⓒ curves. One the other hand, the presence of the prismatic coefficient p is at times a great nuisance. Thus, when comparing two forms of the same length but slightly differing fullnesses, the same value of Ⓟ does not represent the same speed, and it is very easy to make erroneous comparisons through this change in speed scale. The trouble is that a function which is very useful in a limited field has been used in a much wider one where its claims are much less well founded. Nevertheless, the whole of the data published by the Teddington Tank uses this speed function Ⓟ, and for that reason alone it was necessary to state its derivation and usefulness. There is now a huge amount of model and ship data available on that basis, and it would be a very laborious task to convert it to any other. At the same time it would be easily possible to change the method of plotting with all future models, and adopt a new speed base. Sir Amos favours the simple $V/\sqrt{L}$, which is undoubtedly easy of use and can, in many cases, be approximately worked out mentally—it is also the basis on which American results are normally presented.

The chief criticism of this choice is that the simple $V/\sqrt{L}$ function is not non-dimensional, and would give rise to confusion when used with British and Metric systems. This can be overcome by using the function Ⓛ, given by $\frac{V}{\sqrt{L}} \times \sqrt{\frac{4\pi}{g}}$, which is non-dimensional in any consistent system of units. For V and L in knots and feet, we have

$$\textcircled{L} = 1{\cdot}0552 \frac{V}{\sqrt{L}}$$

which is not much more difficult to handle than $V/\sqrt{L}$.

Before leaving this subject, another alternative is worth attention—the old Froude speed constant Ⓚ, given by

$$\textcircled{K} = 0{\cdot}5834 \frac{V}{\Delta^{\frac{1}{6}}} \text{ with V in knots and } \Delta \text{ in tons.}$$

In many cases this is preferable to a term involving length. The

†Aircraft Engineering, September, 1939.

commonest problem the naval architect is faced with is to design a vessel of a certain deadweight (and hence to a first approximation constant displacement) to attain a certain speed, and in Ⓚ both these quantities are directly involved. In comparing a number of models a plot of Ⓒ on a base of Ⓚ is very often extremely illuminating, since for a given displacement and speed a vertical line through the relevant Ⓚ value will give Ⓒ values directly comparable with one another, even though the various models may be of different lengths, proportions and fullnesses.

At present, practitioners have to deal with data presented in all sorts of ways—Americans do not use Ⓒ, for example, but give resistance in pounds per ton of displacement—and must convert them to their own particular fancy. Before the war, biennial conferences of Tank Superintendents were held, and if these are renewed in the future Sir Amos will no doubt agree that this is one of the first items which should be discussed.

The Institute and myself are indebted to Sir Amos for giving them the benefit of his very great experience in the choice of suitable block coefficients for various speed-length ratios. His statement that the difference between service and ideal trial (or Tank) conditions grows less with increase in designed speed is borne out by experiments made in rough water.

The models run by Mr. Wigley were not, of course, of comparable form with ordinary ships—the midship section coefficient was 0·66, for example—and it was not intended that the results should be applied other than qualitatively.

As regards the gain in propulsive efficiency with fins, I am glad to have Sir Amos' confirmation that such savings are possible in ships. As regards the mechanism by which this is achieved, however, some experiments I made in 1934 showed that the majority of the improvement was due to the reduction in resistance, and not to any material improvement in propeller efficiency (31). The latter was only increased by $2\frac{1}{2}$ per cent. at 45 per cent., and unaltered at 25 per cent., real slip, whereas the total reduction in power was from 6 to 10 per cent. As an experimenter I am greatly in sympathy with Sir Amos' plea for more opportunities to be given for the collection of seagoing performance figures, and in this connection it may not be out of place to express the thanks of the Teddington Staff to him for the way in which he has, in his position as Director of Merchant Shipbuilding, enabled its members to obtain most interesting and valuable data on the trial trips of many of the vessels for which he has been responsible.

Mr. Fielden's criticism of the treatment of technical staffs has certainly been justified in the past—it is to be hoped that the war will have brought home still more forcibly our dependence on shipping, and the debt which the country owes to all engaged in the industries concerned.

Dr. Robb rightly questions the accepted practice of classifying ship resistance, in particular the inclusion in eddy-making resistance both that from appendages and from features such as unduly sharp curvature of the hull, etc. The division is, to say the least, arbitrary, and it was carefully stated in Section 2 that the separation is by no means rigid, and is more one of convenience, and a commentary on the present state of our knowledge. The eddy-making resistance from blunt appendages such as sternposts, rudder arms, etc., is not likely to suffer from scale effect, the value of $R/\frac{1}{2}\rho AV^2$ being the same for all sizes of similar objects of this type, as has been shown by many experiments. Such resistance will therefore follow Froude's Law of comparison. Resistance of other appendages, such as streamlined struts, and the resistance caused by eddies being shed from the hull will on the other hand probably depend on the Reynolds number of the flow, and will be critical in nature, and would not be expected to follow Froude's Law. This is recognised in model work, where the resistance of bossings, for example, as measured on the model, is usually halved when applied to the ship, though this is admittedly only a first approximation. This critical nature is also the explanation of the instability of resistance in shallow water to which Dr. Robb calls attention, and is also one of the causes of bad steering in many vessels in such water. It is believed that much of the discrepancy between ship and model results in shallow water to which reference is made was not due to a failure of the law of comparison but to lack of rigidity in the false bottom placed in the Tank to obtain the correct depth of water. The resulting suction between the bottom and model tended to raise the former and thus called for the expenditure of much energy. The New Tank at Teddington has a stretch of 180ft. of shallow water at one end with a concrete bottom and one of the subjects on which research will be begun as soon as war conditions permit is that of resistance in shallow water, which may throw some light on Dr. Robb's problem. We have also developed the recording of wave profiles photographically, and such records will become routine in all future research into ship form, so that the old controversy which surrounds the Ⓟ and rival theories may be finally dissolved.

Dr. Collacott. Much work has been done with models on the problems of steering, manœuvrability and backing, the results of which Dr. Collacott will find in the transactions of the technical societies—it would take up too much space to describe them here. Model work at Teddington on steering has been, and still is, greatly handicapped by the lack of a steering pond in which large models can be made to perform all the manœuvres met with in practice. Most other nations possess this facility, and it is hoped that the lack will be made good in this country before long. Vibration is not neglected in our work at Teddington, but there are many difficulties in the way of treating this problem by models. The method I have adopted has been to carry out the calculations for the natural hull frequencies and to measure the vibration on the ships themselves to verify the correctness or otherwise of the calculations. If the effect of the surrounding water is allowed for, the calculated and measured frequencies are found to be in good agreement, and the method may be applied to new vessels in the design stage with some confidence, and the necessary steps taken to avoid synchronism between one of these natural frequencies and the unbalanced forces in engines, auxiliaries or propellers.

Mr. Riddell draws attention to the fact that form resistance is not specifically mentioned among the elements of resistance listed in Section 2. The discussion has already brought out the difficulties of dividing up the total resistance into separate elements, and, in the past, form resistance has rather been relegated to the role of taking care of any resistance not otherwise to be accounted for, and treated as a troublesome part of skin friction drag. This was justified to some extent in that it was considered to be partly or wholly due to the curvature of the form increasing the length of the average path of the water along the hull, and so partaking of the nature of skin friction. For this reason it has not usually appeared as a separate item. If, however, the conclusions drawn in this paper from Wigley's work was substantiated, it is evident that this older view of form resistance does not represent anything like the whole truth, and form resistance must certainly take its own place in the elements of ship resistance.

It is rather going beyond the scope of this paper to begin discussing screw propeller performance, but as certain ideas connected with it appear in the text, Mr. Riddell is clearly right in asking that they should at least be defined.

If E is the effective horse power required to tow the ship without any appendages (such as rudder, sternpost, or bilge keels) in smooth water, and with no allowance for the air resistance of hull and upper works, and S is the shaft horse power at the propeller, then the ratio E/S is defined as the quasi-propulsive coefficient (q.p.c.). The prefix "quasi" is used because it does not take any account of the mechanical efficiency of the engines or losses in shaft friction, which must be separately assessed. The shaft horse power required at the propeller of the ship will be given by

$$S = \frac{E + \text{allowance for appendage, air and weather resistance}}{\text{Quasi-propulsive coefficient.}}$$

This allowance is usually taken as 8 per cent. for air and appendage resistance in single screw ships (with an addition for bossings in twin screw ships) and another 15 per cent. is added for weather resistance in average fine weather at sea.

If R is the hull resistance when towed without propeller at speed V, and T is the propeller thrust necessary to propel the ship at this same speed, it is found that T is greater than R and the ratio R/T is called the thrust deduction factor, denoted by $(1-t)$, t being the *thrust deduction fraction.*

Again, if the propeller is run in open water, i.e. without any hull or other obstruction in front of it, it will deliver the thrust T at the same revolutions as when behind the hull at some speed V_1 lower than the speed of advance of the hull, V. This is because when it is working behind the hull it is in the frictional wake where the water has been given some forward velocity due to viscous drag and stream line pattern, so that the average feed of water to the screw is at a speed V_1, less than V.

The ratio V/V_1 is called the Froude wake factor, denoted by $(1+w)$, where w is the *wake fraction.*

The product $(1+w)(1-t)$ is called the *hull efficiency* (h) and is an integral part of the make up of the quasi-propulsive coefficient, the latter being higher (other things being equal) the greater the value of h. This would obviously be achieved by making w large and t small, but this cannot, unfortunately, be done to any marked extent. w will, broadly speaking, be greater, the fuller the after body of the ship, but there are obvious limits to this if excess resistance is not to be the result. Moreover, a full afterbody immediately ahead of the screw has the simultaneous effect of increasing t, and in consequence h is not very susceptible to control in this way. The same applies if the afterbody is made long and fine to reduce resistance. w will be less, but so will t, and h may not suffer. It is quite possible, however, to reach the stage where for a little more fining the loss in w and in h will exceed the gain in resistance and in t, and cases are on record of hulls which are easier to tow but harder to drive by a propeller due to the fining of the run being carried beyond this optimum point.

It is hoped that these few remarks will make the ideas of wake and thrust deduction clearer to members—the subject cannot be further pursued at this stage without the discussion developing into another paper!

My colleagues and myself are grateful to Mr. Riddell for his reference to their efforts to correlate model and ship data, and he may be certain that any facilities offered to us by ship owners to collect information on trials or sea voyages will be gladly accepted.

Mr. Wigley. It is extremely interesting to have Mr. Wigley's further comments on the basis of the Ⓟ theory, and to be shown how the latter has, in fact, some basis in hydrodynamic theory when the ship's hull is represented in the simplest possible way by a source and a sink at a distance pL apart. This is, in fact, the "wave-making length" as used by Baker and Kent in their original attempt to explain wave making resistance on the basis of interference effects.

In conclusion, I would like to express my thanks to all those who, by contributing to the discussion on the paper, have so much enhanced its usefulness, and raised so many points for future thought.

OBITUARY—Commander Carl E. Petersen. U.S.N.R.

News of the death on the 22nd July, 1944 of Commander C. E. Petersen, U.S.N.R., our Vice-President for San Francisco since 1938, has recently been received. He was born on the 21st January, 1897 in America, and served an apprenticeship with the Morse Dry Dock & Repair Company of Brooklyn. From 1919/20 he was engaged with the Port of New York U.S.S. Board, and then briefly as naval architect to the U.S.M.S. Company. From 1921/7 he served the United States Lines as naval architect, and was then appointed in the same capacity to the Newport News Shipbuilding & Dry Dock Company. Mr. Petersen took a prominent part in the arrangements for the reception of the foreign delegates to the International Conference of Naval Architects and Marine Engineers which was held in New York in September, 1936 under the auspices of the Society of Naval Architects and Marine Engineers. In 1938 he was engaged as Assistant Manager of Construction and Repair to the Matson Navigation Company of San Francisco. In January, 1942 he was recalled to active duty as Commander in the U.S. Navy; he had hoped to return to his work with the Matson Navigation Company after the war. He was always keenly interested in the Institute's affairs, and his death is a very real loss to the Council.

MEMBERSHIP ELECTIONS.

Date of Election, February 13th, 1945.

Members.

James Ball.
Walter Harold Blackmore.
Gordon Burnham.
Henry Corner.
Hector Frederick Henry Dolling, Lieut.(E.), R.N.R.
Douglas Cowley Emett.
Herbert Edward Hancocke.
Arthur Hood.
William Maddick.
James Henry Meredith.
John Hart Millar.
Andrew Peebles.
Ernest Walter Selby.
Alfred Smith.
John Templeton.
Edward Price Tiplady.
William Lyle Alexander Spence.
Geoffrey Stockdale.
John Alexander Walker, Sub-Lieut.(E.), R.N.R.
Andrew Eno Simpson Rilette Wilson, Sub-Lieut.(E.), R.N.R.
Walter John George Wilson.

Associates.

Mahmoud Ahmad Ismail Al-Arabi.
John Switzer Ashmore, M.A., B.A.I.
Charles Edward Barnett.
Jack Duckworth.
Francis John Everest, M.Sc.
Harry Gerrard.
Alan Carruthers Gibson, B.A.
George Samuel Henry Jarrett.
James Munro Laing.
Kenneth Robert Longes, Lieut.(E.), R.N.R.
Parviz Nowroji Rabady.
Robert Alexander Robertson.
John Stewart Smith.

Graduates.

William George Clark, B.Eng.
Harold John Coles, Sub-Lieut.(E.), R.N.
Robert William McCreery.

Students.

Antony George, Actg. Lieut.(E.), R.N.
Harold Beaton Grant, Actg. Lieut.(E.), R.N.
Arthur Derek Francis Johnson, B.Sc., Mid.(E.), R.N.V.R.
David Bryce Stables.
Bernard Leslie Watkins, Mid.(E.), R.N.V.R.
Peter Alan Lennox Watson, Sub-Lieut.(E.), R.N.

Transfer from Companion to Member.

Arthur Pollitt.

Transfer from Associate Member to Member.

George James Nicholson.

Transfer from Associate to Member.

John Anthony Hayes.
Reginald Lumb.
Henry Thompson Meadows, Lieut.-Comdr.(E.), R.N.R.
Donald Thomas Oxton.
William Drinnan Wallace.

Transfer from Graduate to Associate.

Edward Gerald James Grenfell.

Transfer from Student to Associate.

Arthur Wood.

ADDITIONS TO THE LIBRARY.

Purchased.

Merchantmen at War. H.M. Stationery Office, 1944. 144 pp., illus. 1s. 9d.

Presented by Eng'r Com'r D. Hastie Smith, R.N. (retd.).

Discoveries and Inventions of the Twentieth Century. By Edward Cressy. 3rd Edn., 1930. George Routledge & Sons, Ltd.

Saltwater Tramp. By Warren Armstrong. Jarrolds (London) Ltd. 148 pp., 16 illus.

Presented by the Publishers.

Fuel Efficiency Bulletins issued by the Ministry of Fuel and Power, as follows:—

No. 36, Creosote-Pitch Mixture (Coal Tar Fuel "200"). January, 1945.
No. 37, Small Vertical Boilers, Steam Cranes and Shunting Engines. December, 1944.

Electrodes and Processes Approved for Use in Ship Construction. The British Corporation Register of Shipping and Aircraft, January, 1945.

Solar Radiation as a Power Source. By C. G. Abbot. Smithsonian Institution, Washington, D.C. 11 pp., 3 plates.

Electric Power Stations. Vol. II, 2nd End. By T. H. Carr. Chapman & Hall, Ltd., London, 1944. 549 pp., fully illustrated and large number of tables. 32s. net.

The present reviewer had the pleasure of reviewing favourably the first volume of the second edition. This volume maintains the high standard established by the previous work and completes the subject in a most interesting manner. The two volumes merit acquisition by naval and merchant navy engineers hoping to take up civil occupation in power station work, as they form an excellent basis of study which could be supplemented by more detailed and specialised literature.

While commending both works upon grounds of general technical and engineering value, the author would do well to remove all inconsistencies and "fancy" units (e.g. "k.p.h." in one place and other means of designation in others) and use terms to which power station engineers are accustomed. The practice of following American terminology in some cases has little to commend it. It should be remembered that such works go out to all parts of the world where references may be impossible. A thorough overhaul and standardisation of terms, units and designations appears essential. Further, the works could be indexed better even if this involves the use of smaller type.

Although it is difficult to keep abreast of new technique, as stated in the previous review, reference to several new power station equipments has been omitted; a useful service would be rendered by bringing this work fully up to date by references to modern equipments.

The Steam Boiler Year Book and Manual. 3rd Edn., 1944. Edited by S. D. Scorer, A.M.I.Mech.E., M.I.Mar.E. Paul Elek, Ltd. 30s. net.

In this latest edition, Part I consists of 25 chapters, of which six are entirely new; two have been greatly extended, and the remainder revised as necessary to bring them up to date. Part II, of five chapters, deals with fuel utilisation, developments in combustion appliances, feed water, steam and fire-side problems, and modern operational practice. The publishers express the hope that in the next edition they will be able to include important and interesting information now withheld for security reasons.

The book comprises an informative and extremely full index of manufacturers' products used by the steam engineer, which are well described and illustrated by line drawings and photographs.

Of particular interest to all watertube boiler users will be the articles upon the latest methods of expanding (by rolling) tubes, and experimental investigation of tube expanding. These latter include most interesting and useful tables and graphs.

Marine Diesel Oil Engines, 2 vols. By J. W. M. Sothern. J. Munro & Co. Ltd. 1142 pp., illus. 65s. net.

The seventh edition of this work follows closely the lines of the previous editions. It is designed to cover the syllabus of the examinations in Engineering Knowledge for M.o.W.T. Certificates of Competency; the book fulfils this purpose very well. The first volume is devoted mainly to descriptions of the types of engines used in British marine practice, and the large number of drawings and photographs which accompany the text considerably assist the description.

The second volume is devoted mainly to descriptions of auxiliaries, many of which have nothing to do with oil engines particularly, such as steering gears, generators, motors, boilers, etc., but with which the sea going engineer is concerned.

In both volumes a large amount of information is given about the actual results to be expected in practice, such as cylinder wear, and the amount of lubricating oil used. Both volumes include questions and suitable answers. No attempt is made to present the theoretical thermodynamic side of the subject, and the book is of interest mainly to the engineer concerned with the actual running of oil engines.

Practical Mathematics for Marine Engineers. By H. R. Daish, W. Embleton and J. H. Sword. 6th Edn. Thomas Reed & Co. Ltd. 1,110 pp. 30s. net.

This well-known text book for marine engineers studying for M.o.W.T. examinations is intended to cover the questions requiring a mathematical solution in Parts A and B of these examinations.

Compared with the previous edition, the reviewer can find only one small addition to the text, but several new questions set in the engineering science and heat engines examinations have been added to the test papers.

From Atoms to Stars. By Martin Davidson, D.Sc., F.R.A.S. Hutchinson. 186 pp., illus., 15s. net.

Dr. Davidson has certainly justified the title of this most fascinating study, "From Atoms to Stars". He has left out of consideration nothing that exists in the universe.

His description of the structure of the atom is the generally accepted one, i.e. a heavy nucleus with the light electrons in the outer rings, but reference is made to Dr. Tutin's theory which reverses the condition by placing the heavy protons outside and the light electrons in the nucleus. To an engineer this seems to be more understandable, for what engineer would design a flywheel with a heavy boss and a cork rim? Nevertheless, we are all free to form our theories.

Readers will find many puzzles explained in the author's chapters on the earth-moon system, such as the tides and the moon's phases.

Those who are curious regarding life on other planets are answered by the author in his description of the "velocity of escape", an important factor in the life of the human race, as well as other conditions which must exist to produce and maintain life such as exists on this earth.

The chapters dealing with the stars and extra galactic parts of the universe teem with up-to-date knowledge.

The reader will find this a most absorbing book, even the appendices being a work in themselves.

Munro's Engineer's Annual, 1945. James Munro & Co., Ltd., Glasgow, 144 pp., illus., 3s. net.

In compiling the latest edition of this very well-known annual the publishers have deleted a considerable amount of material contained in the previous edition and substituted articles of higher technical nature. These include abstracts of the symposia of the Institution of Naval Architects on "Water Tube Boilers for Merchant Ships" and the Institute of Marine Engineers on "The Engining of Post War Vessels of Low Power".

The edition contains the usual mathematical and tide tables which have always been found most valuable for reference purposes.

Electrical Installation Rules and Tables. By W. S. Ibbetson, B.Sc., A.M.I.E.E., M.I.Mar.E., published by E. & F. N. Spon, Ltd. Price 6s.

This admirable little book should be of great value to wiremen, installation engineers, maintenance engineers, and all who have to deal with electrical installation work. In this, the fourth edition, every endeavour has been made to bring the contents up to date. The first part summarises those parts of the 1939 edition of the I.E.E. Regulations which it is essential that the practical man should have readily available for reference. Tables dealing with the characteristics and operation of A.C. motors have been added.

There is also a valuable section on illumination, a subject which in the past has tended to be neglected by all but a few specialists. A useful section is that dealing with the faults to which electrical machines are prone, and their appropriate remedies. Without enumerating in detail all of the matter dealt with, it may be said that it includes a wide variety of information which is not usually found within one book.

A suggestion which might be made is that in the next edition, when we may be free from paper restrictions, the size of the book might be slightly increased. This could be done while still keeping it to comfortable pocket size. In its present form the type, and more particularly fractional figures in numerical tables, are rather on the small side.

PERSONAL.

L. C. Burrill, M.Sc., Ph.D. (Member), is the inventor of The Manganese Bronze Company's propeller shaping machine described in the abstract on page *133* of the January, 1945 Transactions.

F. W. Youldon (Vice-President) retired on the 31st January from the position of a Superintendent Engineer of the Anglo-Saxon Petroleum Co., Ltd. He has been succeeded in that capacity by Alexander Logan (Member).

J. Simpson (Associate Member) holds two decorations, M.B.E. and Lloyd's War Medal, gained in December, 1942 whilst serving in the P. & O. S.N. Co.'s s.s. "Strathallan".

G. W. Turner (Associate Member) has been awarded the M.B.E.

J. S. Wells (Member) has been awarded the M.B.E. for exceptional courage and devotion to duty when his ship was torpedoed in convoy.