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SMALL SHIPS

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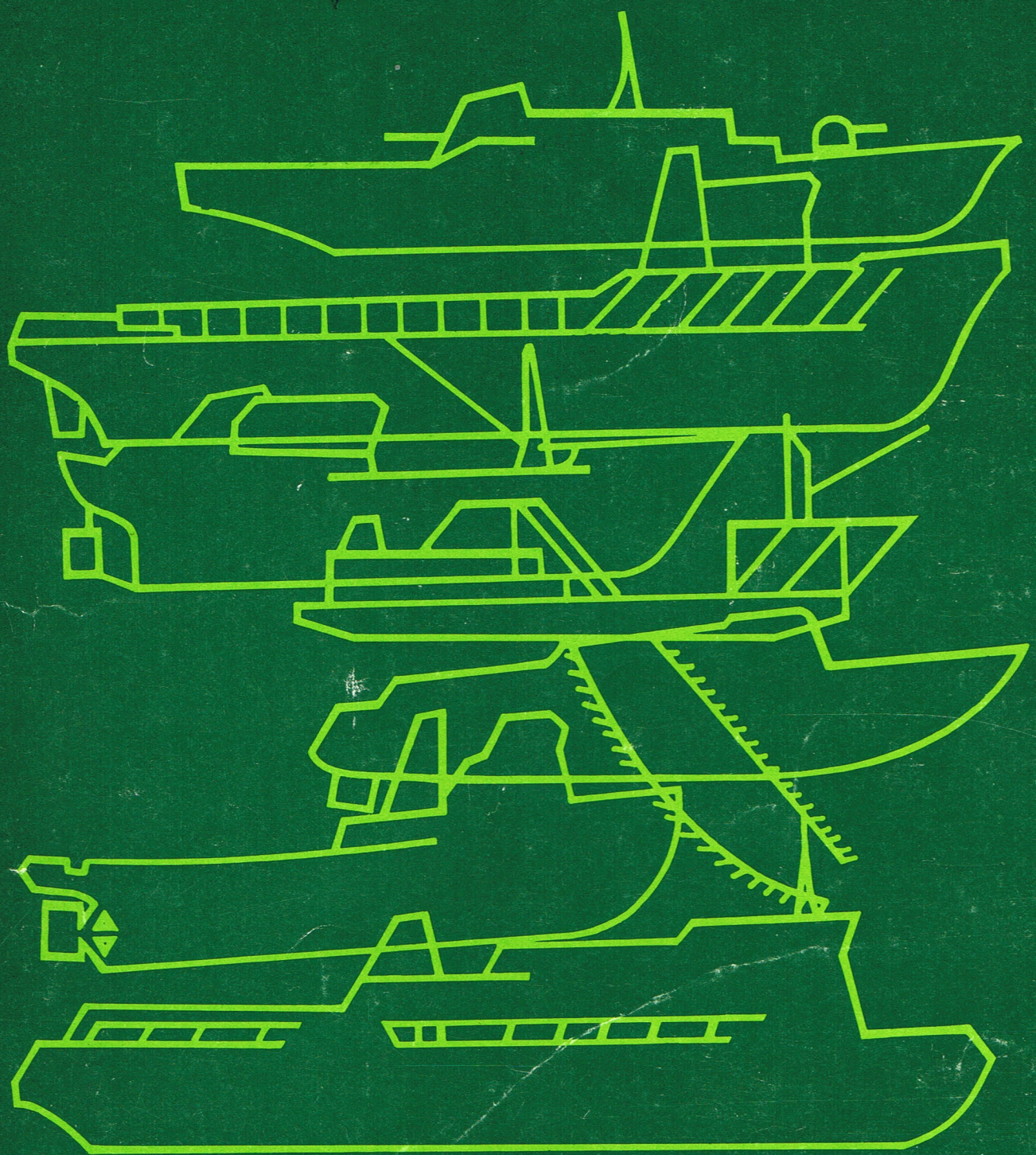


THE AUSTRALIAN SYMPOSIUM ON SMALL SHIPS

THE ROYAL INSTITUTION OF NAVAL ARCHITECTS,
AUSTRALIAN BRANCH

THE INSTITUTE OF MARINE ENGINEERS,
AUSTRALIA/NEW ZEALAND DIVISION

AUSTRALIAN GOVERNMENT DEPARTMENT OF TRANSPORT

THE UNIVERSITY OF NEW SOUTH WALES

at the University of New South Wales
4th-5th November 1975

C O N T E N T S

		PAGE
I	UNIFORMITY IN AUSTRALIA OF SMALL SHIP RULES	
	Uniform Requirements for Australian Small Ships, N.L. ETHERTON	I-1
	New Zealand Experience in Implementing Regulations for Small Ships, D.J. EYRES	I-37
II	ROLE OF SMALL SHIPS IN THE AUSTRALIAN SCENE	
	Small Ships of the Australian Defence Forces, a Review of their Role and Acquisition, K.S. BROWN	II-1
	An Outline of Dredging and the Role of Dredgers in the Australian Environs, J.H. KNIGHT and R.F. FRY	II-11
	Servicing the Offshore Oil Exploration and Production Industry, J.C. NEEDHAM	II-17
	Fishing Boats in the Australian Scene, H.E. ROGERS	II-29
	Can the Murray-Darling River Trade Occur Again?, G.S. HACKWORTH	II-57
III	FINANCIAL BASIS FOR A SMALL SHIP INDUSTRY IN AUSTRALIA	
	Some Aspects of Financial Planning in the Small Ship Industry, N.D. CHIDGEY	III-1
	A Solution to the Added Costs Imposed on the Small Ship Industry by Government Assistance, L.B. GLOVER	III-9
	Government Assistance for Small Ship Construction - Analysis of Costs and Subsidies, June 1972-May 1975, W.E. SHEPPARD	III-24
	Ship Construction Bounty Act - 1975, from the Department of Manufacturing Industry and the Department of Transport, Canberra.	III-31
	Some Financial Aspects of Fishing Boat Investment, M.A.Q. STURMAN	**Distributed separately**

ISBN 0 9599829-7-3

IV THE DESIGN OF SMALL SHIPS, THEIR MACHINERY AND EQUIPMENT

Refrigerants in Fishing Vessels - Their Influence on Design, J.C.R. SUNDERCOMBE IV-1

The Fisheries Research Vessel - A Complex Small Ship, G.C. TROUT IV-21

Aluminium Construction - Can it Improve the Safety of Fishing Vessels?, C.E. BODEN IV-32

Development of a Class of Oil Rig Supply, Anchor Handling and Towing Vessels, M.J. DOHERTY IV-46

Performance and Manoeuvrability of Modern Towing Vessels, R.P. DUMMETT IV-72

Some Observations on the Stability Characteristics of Small Ships, J.R. PAULLING IV-86

V THE BUILDING OF SMALL SHIPS IN AUSTRALIA

Ferrocement Construction: Some Points to Watch, G.L. BOWEN and I.C. BAUGH V-1

The Economic Necessity for the Construction of "Production Line" Ships in Australia, D.P. VERBOON V-11

Development of a Modern Shipyard for Small Vessels, J. LAVERICK and J. LAMB V-23

GRP Hulls - Construction and Technical Standards, C.G. DOVE V-35

Wooden Commercial Vessels - Virtues and Faults, A.N. SWINFIELD V-60

The Design and Construction of Fast Aluminium Alloy Patrol Boats, R.M. SIMMONDS and J.A. LUND V-65

VI OPERATIONAL EXPERIENCES IN AUSTRALIA

Attack Class Patrol Vessel: Extended Operating Experience with Naval Reserve Crew, G. EDWARDS VI-1

Operation and Maintenance of Passenger Ferries on Sydney Harbour, W. HEADING VI-12

VII RESEARCH IN THE SMALL SHIP FIELD

Research on the Fluid Dynamics of Air-Cushion Vehicles, L.J. DOCTORS VII-1

The Small Ship Model Tank: A Useful Facility or an Expensive Toy?, R.F. HALLIDAY VII-17

The Need for Research on Fishing Vessels in Australia, F. MISTREE VII-26

Some Aspects of Patrol Craft Development in Australia, S.S. SCHAETZEL VII-34

NOTE: Participants in A.S.O.S.S. are reminded that the papers printed here will *not* be given oral presentation by authors at the symposium. Instead, a panel of authors will be available for *discussion* of the papers in each session. Readers are therefore urged to make a careful study of papers of particular interest to them and to be ready with questions or contributions to discussion at the meeting. It is intended to publish summaries of the discussions in the final symposium volume.

SESSION CO-ORDINATORS' INTRODUCTORY REMARKS

I. UNIFORMITY IN AUSTRALIA OF SMALL SHIP RULES

Co-ordinator: R.J. Herd, Naval Architect, Marine Standards Division, Department of Transport

In introducing the first session of the Australian Symposium on Small Ships, I will attempt to set the patterns for subsequent sessions.

I believe that the basic philosophy of our meeting has been aptly expressed by Lord Macauley -

"Men are never so likely to settle a question rightly, as when they discuss it freely".

The later sessions dealing with design, construction and operation of small ships must treat their subjects against the background of compliance with safety standards established by the appropriate governmental marine authorities.

As Session I sets out to open for public discussion the approach to regulations for small ships adopted by the seven Australian marine authorities and by their opposite number in New Zealand, questions about the need for special requirements for small ships arise.

Are more onerous requirements than for larger vessels necessary? Are small ships more liable to hazard than large?

Let us look at some figures. The number of ships over 100 tons tonnage increased from 32,358 in 1954 to 61,194 in 1974, an increase of nearly ninety per cent. In 1974 almost half the ships were under 500 tons gross tonnage and of these 47 per cent were under 10 years old.

In the fourteen year period 1960-1973, there were over 4000 vessels lost by all causes, 26 per cent being lost by either fire or collision.

Of the total losses almost 53 per cent were vessels under 500 tons gross tonnage. Vessels under 500 tons gross tonnage lost by collision formed about 54 per cent of those lost by that means and the corresponding figure for fire was almost 42 per cent.

It is submitted that on the basis of these figures no claim can be made for relaxing the standards of safety on small ships.

Before opening the session for questions and discussion, there is one topic which I feel, deserves special mention.

A difficulty experienced regularly in drawing up standards of safety is the determination of an appropriate parameter on which to base equipment scales, manning etc. The New Zealand experience with registered length is recounted in the second paper while the A.A.P.M.A. Committee whose activities are detailed in the first paper have derived a new reference called "measured length" which for many vessels will be almost equal to length over all. It remains to be seen how this definition works and whether it will produce design anomalies.

In inviting your questions and discussion on the two papers we have before us, I commend for your reflection a quotation from Oscar Wilde - "the man who sees both sides of a question is a man who sees absolutely nothing at all".

II. ROLE OF SMALL SHIPS IN THE AUSTRALIAN SCENE

Co-ordinator: Mr. R. Campbell, Controller of Design, Shipbulding Division, Department of Transport.

In simple terms 'role' can be defined as function expected of or undertaken by a person or object. For the purposes of this session of the Symposium, the intention is essentially that - to explore the various functions or duties expected of small ships and by analyses suggest future trends and developments which may be undertaken to fulfil these roles.

In planning this Symposium, it was considered appropriate that an introductory session be assigned for the purpose of considering the functions and changing roles of small ships, thus setting the theme for subsequent sessions dealing with more specific areas of the small ship business - finance, design, construction, operation and research. However, in so doing, it is inevitable that aspects relating to some of these areas such as design and operation will be touched on by authors in this session. It is hoped the discussion generated by these papers can be contained to general aspects of ship functions and activities and how these may affect the Australian scene, rather than intruding into a consideration of detailed aspects of ship operations.

At this stage, and by way of introduction, it would seem appropriate to list briefly the principal small ship types and identify them by way of their traditional roles. The multitude of diverse activities which are increasing being requested of small ships to meet the expanding industrial and commercial interests of Australia make this no easy matter, and the following summary should not be looked upon as exhaustive or in too categorical terms.

Ship Type		Duties
Tugs and Workboats	-	Towage, salvage, general service.
Barges and Lighters	-	Local and restricted usage for carriage of cargo.
Dredgers	-	Harbour and channel dredging, reclamation and transportation of spoil.
Fishing Vessels	-	Vessels 15-60 metres engaged in fishing industry.
Offshore Supply Vessels	-	Servicing the offshore oil rigs by supply of stores, equipment and personnel.
Small Naval Craft	-	Wide variety, including patrol and survey craft, tugs, landing craft, lighters, inshore mine sweepers etc.
Research Vessels	-	Fishery research, hydrographic and oceanographic work, survey work etc.
Ferries	-	Restricted harbour, channel, river estuary operations - passenger and/or vehicle transportation.

Ship Type	Duties
Coasters	- General cargo on restricted coastal operations.
Special Purpose Craft	- Floating cranes, pollution control, fire floats etc.
Small Craft, Launches	- Multitude of activities, mostly of a general nature.

As general background to a consideration of ship functions and future trends, analyses have been made of the existing Australian small ship fleets in terms of type, geographical location, size and age, and presented in tabular form - see page v . The data contained in the Australian Shipping and Shipbuilding June 1974, published by the Department of Transport has been used as the basis for these analyses. It is not presumed that this publication necessarily provides a comprehensive, complete or up to date statistical record of all small ships operating on the Australian coast, but rather that analyses of the data can provide a general picture of the existing scene and may provide an indication of future trends. Gross tonnage has been used as a uniform index for size of ship, although it is fully realised this may not necessarily be the most appropriate factor in all cases.

It has been said that statistics can prove everything and/or indicate nothing. A first glance at the tabular analyses would appear to confirm the latter view. However, a closer inspection does indicate some broad patterns and general trends.

Apart from showing the obvious tendencies, such as a general trend to larger size vessels, specialised types and the heavy concentrations along the seaboard of the eastern states, the statistics do indicate the quite significant proportion of relatively small tugs, dredges, ferries and lighters in service, which because of their size are presumably mainly engaged within sheltered harbours.

The fairly high proportion of 'aged' ships - built prior to 1940 - particularly in respect of ferries and to a lesser degree barges, dredges and tugs, is somewhat surprising. If these ships are still fulfilling useful functions, it might indicate that the roles of such craft do not vary extensively over the years. It is suggested this is not necessarily so, rather that their replacement is unwarranted on grounds of limited usage or that high cost of new construction prohibits their replacement.

The influence of Governmental policy might also be inferred by the increase in number of new vessels of certain types or sizes over certain periods of time e.g. the high proportion of tugs built since 1960 and more recently other types of small ships, particularly fishing vessels.

Other aspects influencing the role of small ships on the Australian Coast which may not be so readily deduced from the outline analyses, include

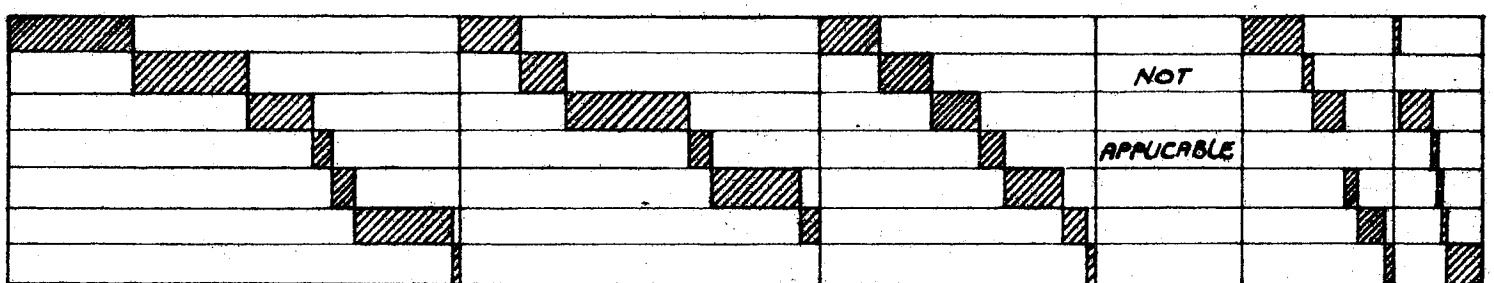
- emergence of the offshore oil and gas business, leading to building of supply vessels, derrick and pipe laying barges and higher bollard pull tugs.
- development of ports and terminals to meet expanding trade, and to berth larger vessels, requiring heavy dredging effort.

- larger bulk carriers to be handled, again requiring larger size and capacity tugs.
- extension of offshore territorial claims leading to a need to investigate ocean and sea bed, requiring increased number of specialised research vessels.
- economic and technological factors, such as developments in machinery and equipment, manning requirements, financial aspects, etc.

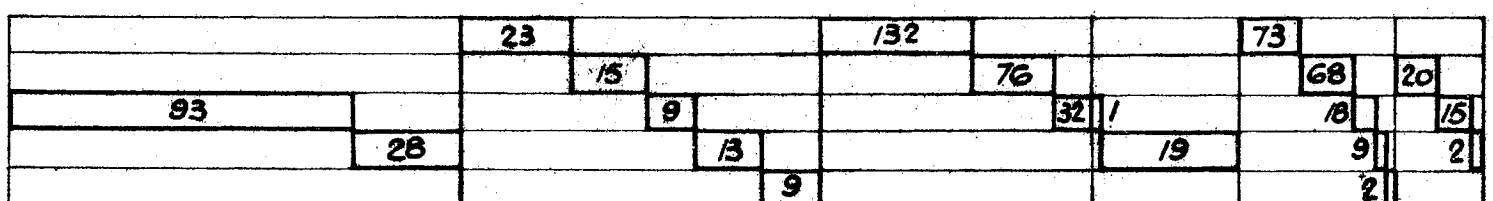
It will be appreciated that circumstances do not enable a comprehensive review of the roles of all the types of small craft operating on the Australian coastal scene to be covered in detail at such a symposium. It is hoped, however, that this brief and outline review may generate thoughts and promote general discussion relating to the roles and functions of all small ships, rather than restricting it to those which are the subjects of papers to this session of the Symposium.

	BARGES AND LIGHTERS*	DREDGERS	TUGS	RIG* SUPPLY	FERRIES (over 50 Passengers)	FISHING*	TOTAL
GROSS TONS	47400	37000	29800	15200	15000	10000	154400
Nº OF VESSELS	121	69	240	20	170	37	659

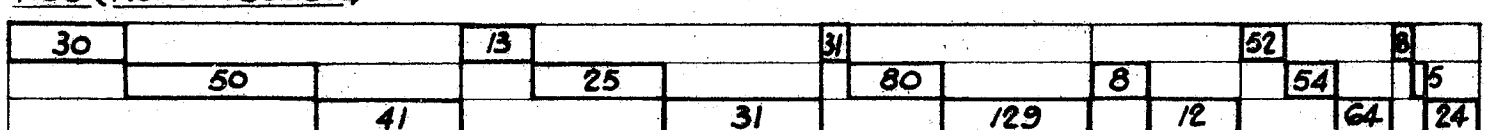
STATE. GEOGRAPHICAL (GROSS TONS)



GROSS TONS SIZE (No. OF VESSELS)



PERIOD AGE (No. OF VESSELS)



* N.B. VESSELS IN EXCESS OF 200 GROSS TONS ONLY.

III. FINANCIAL BASIS FOR A SMALL SHIP INDUSTRY IN AUSTRALIA

Co-ordinator: Dr. J.H. Taplin, Director, Bureau of Transport Economics, Canberra.

The question implied by the title of this section of the Symposium is whether there is a financial basis for a small ship industry in Australia. The answer is obviously unclear. To me, it would be important to ask whether there is an economic basis for such an industry and, in that case, one would consider the critical factors such as the special skills that have been developed in Australia and the reservoir of skilled manpower.

However, the businessman who is operating in this field or contemplating setting up in it can presumably command both the skills and the necessary supply of skilled manpower. Therefore he will see the vital question as being the extent to which he can command the necessary capital equipment and working capital. The relevant considerations in facing up to this problem are dealt with in Mr. Chidgey's paper. This paper rightly lays great stress on the gearing ratio, i.e. the ratio of borrowed to equity capital. This is relevant to both the financing of the ship by the shipowner and the financing of his business by the shipbuilder. The paper reviews the various sources of borrowed funds and goes on to deal with aspects of corporate planning and the particular problem of funding working capital in an inflationary period. Mr. Sturman's paper then takes us into the consideration of the more special area of fishing boat investment.

Another aspect of financing the small ship industry is that of the ship construction bounty. We now operate under the Ship Construction Bounty Act 1975 and the Second Reading Speech by the Minister for Manufacturing Industry is given here together with details. Possible inefficiencies arising from bureaucratic controls are dealt with in Mr. Glover's paper which also presents his suggestion for an alternative scheme for administering subsidies. Mr. Sheppard's paper provides us with a rare insight into the facts relating to recent Australian government disbursements for subsidy and bounty for small ships.

IV. THE DESIGN OF SMALL SHIPS, THEIR MACHINERY AND EQUIPMENT

Co-ordinator: C.E. Boden, Consulting Naval Architect.

The designing of small ships requires a broad knowledge of all facets of the total finished vessel. Now, more than ever, the designer must have knowledge of various types of vessels, each of which have their own peculiar features and service capabilities.

The papers here presented, reveal the breadth of the field of knowledge from which the naval architect must reap his experience.

One paper explores the theory and practice of refrigeration systems, necessary for the preservation of the fisherman's catch.

Another surveys the design problem associated with the development of an important fisheries research vessel, involving ultra-modern electronic devices for oceanographic survey and fish detection.

Another considers the development and effects of the use of new material upon the design of fishing boats with particular reference to stability with the light weight aluminium alloys.

A fourth paper reaches out into the exciting field of oil search, with its exacting demands upon the service craft necessary to maintain the operation of the oil rigs. The paper traces the evolution of these designs in Australia.

The fifth paper is concerned with tugs and the ever increasing need for higher powers for greater bollard pull and faster performance and shows the benefits to be derived from new rudder configuration in association with propeller nozzle devices.

The sixth and last paper is a most welcome one from Professor Paulling of California, who has taken his study of safety into the realities of stability of small vessels in various conditions of the sea state.

A brief summary of the scope of the individual papers for discussion follows:-

1. Refrigerants in Fishing Vessels: Their Influence on Design, J.R.C. Sundercombe

In this paper, we have a review of the merits of various primary refrigerants as available and suited to use on fishing vessels.

The theoretical basis for the evaluation of a particular refrigerant is discussed.

A comprehensive table of the physical properties of four principal primary refrigerants is given together with a similar table of the properties of the secondary refrigerants.

The conclusion compares a variety of systems for different purposes on board ship, followed by a comprehensive bibliography.

2. The Fisheries Research Vessel - A Complex Small Ship, by G.D. Trout.

This paper discusses in its early pages, various modern fishing methods currently in use and shows that a fisheries research vessel, similar to the new C.S.I.R.O. Fisheries and Oceanographic Research Vessel, must provide for the use of similar methods to explore new grounds and to capture evidence of the availability of particular species in the areas explored.

The importance of careful planning both at the design stage and during the subsequent construction and fitting out is highlighted. He points to the need for careful adjustment of the priorities of fitting out, to avoid rework in the shipyard with its delay, frustration and cost.

Stress is laid upon the special requirements necessary to obtain a 'noiseless' hull, which will give the least interference to the transducers of the acoustic survey equipment.

3. Aluminium Construction - Can it Improve the Safety of Fishing Vessels?. by C.E. Boden.

This paper brings to notice the virtues of aluminium construction of fishing vessels. These are summarised and compared with some of the apparent disadvantages.

A study of the effect of the substitution of aluminium alloy for steel in a stock trawler design is described with reference to stability. The interesting fact emerges, that at least for the particular vessel considered,

the aluminium vessel would possess inbuilt margins of safety if perchance the vessel is overloaded with fish.

4. Development of a Class of Rig Supply, Anchor Handling and Towing Vessel, by M.J. Doherty.

The importance of the oil rig supply vessel to the development of oil search has been well established.

This article shows how designs have been evolved to meet the particular needs of oil search around the Australian coast. The transition from types of vessels characteristic of oil search in the Mexican Gulf, to the more recent larger and more powerful units is traced. The paper brings out very clearly the advantages that have resulted by preparing full working drawings before calling tenders, enabling the smaller shipyards to be free of the drawing office and design work.

5. Performance and Manoeuverability of Modern Towing Vessels, by R.P. Dummett.

In recent years, with the increase in size of bulk carriers and container ships, there has arisen the need for high powered tugs with greater bollard pulls and manoeuverability. In the design of new tugs it has been possible to improve these performances by the use of new Shutter Type Rudders. The system has been fitted on a number of tugs in Australia. Some of these are listed. It is also shown that this new rudder configuration can be fitted with minimal cost to existing tugs enabling them to meet the heavier demands made upon them with improved efficiency.

6. Some Observations on the Stability Characteristics of Small Ships, by J.R. Paulling.

Conventional design assumptions for stability of small ships are inadequate and examples are given to emphasize some of their idiosyncrasies. It is hoped to pass on to the design profession some experience from past mistakes.

V. THE BUILDING OF SMALL SHIPS IN AUSTRALIA

Co-ordinator: E.S. Clarke, First Assistant Secretary, Shipbuilding Division, Department of Transport.

The six papers submitted not only deal with 5 different construction materials but very helpfully adopt different approaches - multiple production, avoidable faults, virtues, construction details.

Small vessels are notable for the stimulus they have provided in recent years for the development of competing materials for their construction.

Wood continues its thousands of years of history and with the development of modern glues, marine ply, laminated construction, rot-proofing, has much to offer especially using the reliable, strong, straight-grained Australian species such as spotted gum and Queensland maple.

For sturdy work boats, tugs, trawlers etc. *steel*, a mere 100 years old is predominant. The universal use of welded construction, generally of major prefabrications away from the building berth, coupled with modern

methods of shot-blasting, prime coating and zinc-base protective paints and anti-fouling coatings have facilitated economic production and extended the periods between dockings for scraping and painting. Chine construction has simplified construction by avoiding bending of frames and curvature of shell plating with minimum penalty in hull efficiency.

Aluminium alloys have been developed which combine their salient property of lightness and minimum salt-air corrosion, and the former difficulties of achieving sound welds with adequate penetration and physical properties equal to the parent metal, have now largely been overcome. It has much to offer too in combination with other materials by its use high in a vessel, such as in deck houses, in reducing topweight which might otherwise be excessive.

The two remaining and modern materials, glass reinforced plastic and ferro-cement have one thing in common - they are cast in situ from homogeneous fluid materials each containing meshes of stress-carrying fibres - polyester resin with its micro-filaments of glass, and concrete with its steel rod "armature". The former has all but captured the pleasure boat market, small and large, dominates the life-boat scene and is extending its scope into trawlers and work boats. Ferro-cement has had a slower and more chequered development over about the same period and has yet to gain the confidence of owners through assurances that weight, strength, freedom from corrosion of reinforcement and other crucial technical details are in firm control at the building stage.

It is difficult to make first-cost comparisons between these five materials because of lack of a series of similar vessels in each of the five. Nor should first cost be considered only, because maintenance costs during the life of a vessel will vary perhaps in the opposite direction. Steel and aluminium are examples; wood and GRP have very different maintenance characteristics.

One of the heavy anchors which impedes the forward movement of productivity in the Australian shipbuilding industry is lack of multiple orders. On the other hand, and at the other end of the scale, the moulding of GRP hulls for small boats has demonstrated the cost savings of tooling up for multiple production.

Even for steel trawlers, standard lines, scantlings, fittings, machinery and outfit bring the great benefit of the steep initial descent of the learning curve as production runs rise from one or two to six or more. Owners should appreciate the cost benefits of accepting standard designs and not insist on variations to suit preferences which may be desirable from their point of view but not in any way essential.

The Papers Committee is very grateful to the four Australian and two overseas authors for these six complementary papers. I hope there will be active discussion on the virtues, promise or problems of construction in these five or other construction materials.

VI. OPERATIONAL EXPERIENCES IN AUSTRALIA

Co-ordinator: K.M. Murray, Chairman, N.S.W. Branch
Institute of Marine Engineers.

In acting as convenor for this session, I would firstly like to apologise for the small number of papers presented. This has no doubt been brought about by the current pressures in the shipping industry, particularly in the field of operation whether it be tugs, oil rig supply vessels, fishing vessels

or their many types of dredges, to mention just a few, which come within the category of small ships. I do sincerely thank the two authors of the papers now before you on your behalf. Before opening the session for general discussion on the very important subject of "Operational Experiences in Australia", I would like to briefly place before you my own feelings and opinions which I hope will stimulate thinking in this field.

Operational experiences can be divided into two categories - pleasure or work. One may be operating say, a small craft in the holiday tourist trade off the Queensland coast but we are gathered here today to examine the work and serious side of the subject, namely, the many small craft which operate in order to provide the service demanded by the general public or the many other organisations that are so dependent upon a regular and reliable service.

It is my contention that a considerable amount of cost, and therefore time, can be saved in the maintenance of any type of vessel if the designer places himself in the position of that poor person, the operator, who has to contend with many pressures. How many times have quite a number of members of this symposium complained about the inaccessibility of certain items of equipment. In some cases it almost appeared that the designer had deliberately gone out of his way to place items, some of which may invariably require the major amount of maintenance, in the most inaccessible part of the vessel. This can be particularly aggravated in the case of small craft where space is usually at a premium. I appreciate that sometimes in small craft this situation is unavoidable, but please give some thought to the poor operator who has the task of maintaining these craft in service, usually under adverse conditions. At the same time he would have to contend with his superiors, these days invariably of an accountant type, who sometimes do not fully appreciate the practical problems and who are continually complaining about the costs involved, the lack of return on capital investment because the particular craft is not earning money but costing plenty. No doubt many of you have been subjected to these pressures.

In my opinion it is therefore essential for the subject of maintenance to be given a very important place during the design stage of any craft, by firstly designing to reduce maintenance which can often be done at no extra cost. If, however, there should be an additional expenditure involved, it should be equated with the savings that may be achieved in the lifetime of the craft. We all know that there are some items which have to be maintained and surveyed, and here once again the designer can assist by arranging for those items which from experience need the most amount of attention, to be located in readily accessible positions or which can be easily removed with a minimum of fuss. The carrying out of repairs and maintenance on board a craft, and this would undoubtedly apply more so to small craft, is a most expensive procedure mainly because of lack of accessibility. So please design for simplicity, don't try and show how good you are by making for a complicated arrangement and design, but better still, demonstrate your ability in the way recommended.

It must also be considered that some of the people operating small craft are not qualified by certificates. All that these people want to do is to go about their task, whatever it may be, in a ship that is reliable and will stand up to the rigours of the sea. May I suggest that you take a leaf out of the book of the agricultural machinery designer who produces an article for operation under the most adverse conditions. In fact, some of the most successful marine propulsion or auxiliary units have had their Genesis in the agricultural field.

It must also be remembered that the operation of small craft, probably more than any other, is subject to stresses and strains beyond the normal.

Mr. W. Heading's paper quotes the operation of hydrofoils on Sydney Harbour - this could also apply to tugs, where one minute the main propulsion unit or units are idling and the next are expected to develop full power. I do not know of any other industry where this severe loading occurs.

I hope that these comments will engender your thoughts and provoke the necessary discussion through which we will all learn something and therefore achieve the desire of those who have organised this symposium.

VII. RESEARCH IN THE SMALL SHIP FIELD

Co-ordinator: Professor P.T. Fink, Dean,
Faculty of Engineering,
University of New South Wales.

Neither of the thoughts behind this session lend themselves to crisp definition - research is many things to many people and no one can define the limits of the small ship field by logic alone. I tried to analyse our appalling contempt for research in a paper* for the Symposium which was held here in 1973 to celebrate the 25th Anniversary of the Australia/New Zealand Division of the Institute of Marine Engineers. The recommendations of that paper are still in the queue for consideration with numerous others relating to technological research in this country. In the meantime many tomorrows have become yesterdays and all phases of the ship industry have become that much more vulnerable. This is because research is not a luxury for academics, something to keep them from idleness! It is the detailed work associated with one's forward thinking and is neglected at one's peril, whatever one's calling might be. Research is therefore appropriate to the matter of every one of the six preceding sessions. It includes all non-immediate predictive activity to support planning and technical work in an organisation, including the digestion of research information from others if one's technological and scientific literacy is 'up to it'.

Thus we could pick out numerous research areas of vital concern in our discussions:

> Operation of small ships tends to be a highly fragmented activity, but is it really nobody's business to perform research on the state of the sea, on operations, on maintenance, on ship management, on vibration and noise, on soundproofing, on in-port performance, on .... ?
>
> Manufacturing industry in Australia has seen declining profits for a decade. How and why is this? Can a small ship-building industry do better than the rest? Is our market research of adequate level? Who is analysing the balance of capital and labour inputs and are conclusions being drawn? Where is our research on construction?
>
> Industrial relations in Australia are largely based on British industrial structures of the nineteenth century. What does research offer to employers and unions?

---

* Ship Research in Australia?, Proc. Symposium on Design, Construction and Operation of Australian Ships, University of New South Wales, August 1973, pp 102-122.

> Design is an obvious field for research - and research collaboration since consultants claim that they cannot afford to gather high-technology know-how which they cannot afford to be without ..... Stability, sea-kindliness, manoeuvrability are obvious areas of difficulty for vessels which are small in relation to the elements and they constitute obvious areas of research - but what of ship machinery and systems and, especially for the uncomfortable objects of our attention, ergonomics and all appropriate aspects of man-machine interaction? What of structures and materials, cargo-handling and the rest?

The four papers in this Session have been prepared for us by busy authors - sometimes under duress - and they only touch on some of the above topics. However each is written by an expert with considerable expertise in his own area and they are supplemented by some papers in other sessions such as Professor Paulling's in Session IV. I believe that between them, they illustrate enough of the points listed above to enable us to discuss these more general matters. Let us try to isolate the areas of greatest need, to decide how the job might be done, who is to pay for it and in which areas do we need to maintain world standards of technological literacy in order at least to be able to understand what enterprising people are up to elsewhere. We can continue to remain aloof and slide further downhill or we can decide to back some small ship industry research in this country!

UNIFORM REQUIREMENTS FOR AUSTRALIAN SMALL SHIPS

by

L.N. ETHERTON

Assistant Secretary
Marine Crews and Services Branch

Convenor
Committee for Uniform Requirements for the
Survey and Manning of Commercial Vessels
Department of Transport
Melbourne

SUMMARY

The paper outlines the history, work programme and progress of the Committee for Uniform Requirements for the Survey and Manning of Commercial Vessels. This Committee was formed in 1971 with the approval of the Association of Australian Port and Marine Authorities to lay down a set of basic requirements on which both Australian and State legislation could be modelled.

Because of the far ranging scope of the topics to be covered, the work of the Committee has been entrusted to five working Groups, each responsible to the Committee.

The paper prepared by the Convenor of the Committee is supplemented by Seven appendices. The Chairman of each Group has been responsible for an appendix dealing with the work of that Group. Appendix VI outlines proposals for the training and qualification of small ship personnel which are developing parallel with the uniform survey requirements. Appendix VII has been prepared by the Chairman of Standards Association of Australia Committee MS/22 Shipbuilding. This Appendix elaborates on the work of standardisation in shipbuilding which is a most useful adjunct to the uniform survey requirements.

UNIFORM REQUIREMENTS FOR AUSTRALIAN SMALL SHIPS

Background

For some years, principally through the Australian Transport Advisory Council, discussions have taken place between Australian and State Government Officials about the lack of uniformity in marine law and the inadequacies in the provisions for certain classes of vessels. Examples of particular classes of vessels in this context are vessels on delivery voyages to overseas or interstate destinations without passengers or cargo, vessels that are normally engaged in intrastate trade, non-trading vessels which make occasional interstate or overseas voyages without passengers or cargo, pleasure yachts, and similar vessels which proceed on non-commercial voyages beyond port limits.

In 1963-1964 detailed discussions also took place between Australian and State Government Officials on the possibility of introducing uniform manning requirements for both interstate and intrastate vessels.

The importance of uniformity in marine legislation in Australia was stressed during the inquiry into the loss of the dredge 'W.D. Atlas' when Mr Justice Spicer in his findings stated that 'navigation and shipping does seem to be a field in which uniform legislation, if not a common code, applicable to all aspects of navigation and shipping in Australian waters, is desirable.'

The Australian Transport Advisory Council subsequently established a Working Committee to look into the question of uniformity of Australian and State Government marine legislation and at the same time to propose a scheme for the allocation of control of shipping administration in Australia. This Committee met on two occasions and, although it occupied itself largely with shipping administration matters, at its second meeting drew attention to the fact that the Australian Port Authorities' Association, later to be known as the Association of Australian Port and Marine Authorities (A.A.P.M.A.) had already done a considerable amount of work in connection with uniformity of survey requirements. It was agreed therefore that the Department of Transport (then Shipping and Transport) should refer the question to the AAPMA.

The matter was considered by the Permanent Committee, which recommended to the 22nd Biennial Conference of A.A.P.M.A. that the question of uniformity of Australian and State Government marine legislation be considered by a Committee representative of the Australian Government and the States - with the representative of the Australian Government acting as convener. This was approved by the Biennial Conference at its meeting in February 1971.

It was decided to lay down a set of basic requirements on which both the Australian and State legislation could be modelled. Australian legislation gives effect inter alia to the International Convention for the Safety of Life at Sea 1960 and the International Convention on Load Lines 1966, in addition to various other Conventions dealing with qualifications, protection measures and the like in relation to maritime employment. Although the provisions of most of these Conventions are expressed to apply to ships on international voyages, it is customary for the conference which adopts such a Convention to recommend that each contracting country should apply the conditions of the Convention, so far as practicable, to all ships flying its flag.

For some decades it has been the practice of the Australian Government to extend the provisions of such Conventions to interstate shipping. It seemed therefore, that, subject to suitable modification in the light of the size and nature of the craft being dealt with, it would be possible to apply them in a modified way to small ships, and to ships on comparatively short voyages. The provisions of the Conventions were thus used as a basis on which to establish a set of uniform requirements covering the safe operation and seaworthiness of all Australian vessels.

The terms of reference of the Committee covered a wide range of subjects, and it was considered to be quite impractical to carry out the task in any detail in a single Committee.

In order to facilitate working, therefore, it was decided to establish a number of groups or working parties to cover different aspects of the technical field of marine legislation. Each of these groups reports back regularly to the Committee, which watches the overall legal aspects including the application of the proposed requirements.

Working Groups

Five groups were formed to consider the technical requirements. These were supplemented by a drafting group to oversight the presentation of documents. Each group is chaired by an officer of the Department of Transport.

The principal subjects allotted to each group are:

GROUP (1) - HULL SURVEY AND EQUIPMENT

Cargo hazards prevention
Compasses
Dangerous Goods
Deck Cargo and Livestock
Direction Finders
Fire Appliances (in conjunction with Group (2))
Grain
Life Saving Appliances
Loading and Unloading Safety Measures
Miscellaneous Equipment
Pig-Iron, Coal and Ballast
Radio Equipment
Surveys and Survey Certificates (in conjunction with Group (2))

GROUP (2) - ENGINEERING SURVEY, EQUIPMENT AND QUALIFICATIONS

Certificate of Service (in conjunction with Group (4))
Construction (in conjunction with Group (3))
Examination of Engineers
Fire Appliances (in conjunction with Group (1)
Machinery and Electrical
Surveys and Survey Certificates (in conjunction with Group (1))

GROUP (3) - CONSTRUCTION, STABILITY, LOAD LINES

*Construction (in conjunction with Group (2))
Load Lines
Metrication
Stability and Subdivision

* Apart from general construction requirements, to include structural requirements for five materials, viz. aluminium, ferro cement, glass reinforced plastic, steel and timber.

GROUP (4) - NAVIGATION AND QUALIFICATIONS

Certificate of Service (in conjunction with Group (2))
Collision Regulations
Courts of Marine Inquiry
Crew Accommodation
Examination of Masters and Mates
Hospital Accommodation
Manning
Musters and Drills
Passengers
River Murray Traffic Regulations
Signals of Distress, Urgency Signals and Danger Messages
Wrecks and Salvage

GROUP (5) - MERCANTILE MARINE REQUIREMENTS

Distressed Seamen
Health
Log Book
Master and Seamen
Rating of Seamen

Presentation of Requirements

Members have discussed the possible presentation of the uniform requirements in legislative form. Consideration was given to referring all completed Sections to the Standing Committee of Attorneys-General in order to achieve complete uniformity of legislation. However, it was decided that implementation of uniform technical requirements was urgent and each Authority will apply the requirements in its own jurisdiction in a manner decided upon by the Government concerned. It was considered by members that from a technical viewpoint the best legislative form that uniform requirements could take would be to have the enabling provisions in an Act, the machinery provisions in Regulations and the technical content in code form. This would allow maximum flexibility for amending the technical requirements to keep abreast of technological developments in a particular field.

To assist in the usage and up-dating of the Requirements they are divided into convenient Sections, each devoted to one main topic.

In an endeavour to ensure that the deliberations of the Committee were representative not only of the views of the Authorities but also of those of Industry a system was implemented whereby members discuss with Industry contentious points raised during the generation of each Section. Each completed Section is then referred to Industry for comment after both the Group and the Committee have accepted its contents. The Committee later reviews each Section in the light of Industry comments before referring the Section to a second but smaller Committee, appointed by the Council of the A.A.P.M.A. to review the work. When this second Committee, the Council Review Committee, has completed its work the Section is forwarded to the Council of the A.A.P.M.A. for endorsement. Agreed Sections are forwarded by the Council to meetings of Ministers for Port Development and Marine Affairs for final endorsement and action by the authorities concerned to give effect to them.

Each Group meets in rotation on a monthly basis, usually for the five days of the first full week in a month. The Committee meets approximately each four months or on a needs basis. Similarly the Drafting Group meets on a needs basis as the Groups require its services. In the event of one of the Groups requiring technical assistance, appropriate technical experts are called in to assist members in their deliberations e.g. from the Australian Post Office and the Overseas Telecommunications Corporation for Radio Equipment, and from Fisheries Divsion of the Department of Agriculture on matters pertaining particularly to the Fishing Industry.

Progress to Date

Up to the present time the following Sections have been submitted to and endorsed by the Council of the A.A.P.M.A., and are now in the hands of the Australian and State Government Marine Authorities for their action:

- Introduction, Definitions and General Requirements Section
- Life-Saving Appliances Section
- Collision Regulations Section

The following Sections are with the Council Review Committee (June 1975) for final consideration before submission to the A.A.P.M.A. Council for their endorsement:

- Amendments to the Introduction, Definitions and General Requirements Section
- Ferro-Cement Construction Sub-Section
- Fire Appliances Section
- Load Lines Section
- Miscellaneous Equipment Section
- Radio Equipment Section

Several Sections are at present in an advanced stage of preparation by the Groups. Information on these and other topics being considered by the Groups is contained in Appendices I to VI.

Completion of Work

It is hoped that this aspect of the work of the Groups and the Committee will be completed by the end of 1977. However, it will be necessary for each Group to meet at approximately annual intervals to review any problems experienced in the application of the Requirements and to up-date Sections of the Requirements in the light of that experience and of advances in marine technology, new Conventions, etc. (A conference will be held in the northern autumn of 1976 to draw up an International Convention for the Safety of Fishing Vessels, for example).

Shipbuilding Standards

Concurrently with the work of the Committee, Standards Association of Australia (S.A.A.) Committee MS/22, Shipbuilding together with its Sub-Committees has been working towards the development of shipbuilding standards. The Committee was set up to meet a need expressed by Australian shipbuilders for uniform practice in various aspects of shipbuilding. The history of this work is outlined in Appendix VII.

The A.A.P.M.A. and S.A.A. Committees are complementary in their activities. The S.A.A. Committee's function is to develop standard methods of construction, fitting out, equipment design, etc. to meet the relevant legislative requirements where appropriate, or good shipbuilding practice where there are no requirements. The aim as with all standards is to cheapen construction through better design, use of standardised components etc.

APPENDIX I

SUMMARY OF WORK OF GROUP 1

Preparatory Measures

The area of responsibility of Group 1 is Surveys and Equipment. Early in the proceedings of the group the following order of priority of subjects was agreed to:

1. Life-saving Appliances;
2. Miscellaneous Equipment;
3. Navigational Equipment;
4. Radio Equipment;
5. Surveys and Certificates;
6. Towage Requirements;
7. Cargo Gear and Handling Safety Requirements;
8. Deck Cargo;
9. Livestock; and
10. Special Type Vessels.

The initial meeting of the group, together with Group 2, in September 1971, first adopted the classification of vessels. After minor amendments, that classification is now as follows:

Passenger Vessels

1A Unlimited Sea-going
1B Limited Sea-going
1C Restricted Sea-going
1D Partially Smooth Water
1E Smooth Water

Non-Passenger Vessels

2A Unlimited Sea-going
2B Limited Sea-going
2C Restricted Sea-going
2D Partially Smooth Water
2E Smooth Water

Fishing Vessels

3A Unlimited Sea-going
3B Limited Sea-going
3C Restricted Sea-going
3D Partially Smooth Water
3E Smooth Water

Special Vessels

4A Unlimited Sea-going
4B Limited Sea-going
4C Restricted Sea-going
4D Partially Smooth Water
4E Smooth Water.

For the purpose of this classification the following terms were defined:

Smooth Water Vessel	A vessel operating in those waters within the particular geographical limits nominated by the Authority concerned as 'smooth water' (as a guideline, where the wave height, under normal conditions, does not exceed 0.5 metres from trough to crest).
Partially Smooth Water Vessel	A vessel operating in those waters within the particular geographical limits nominated by the Authority concerned as 'partially smooth water' (as a guideline, where the wave height, under normal conditions, does not exceed 1.5 metres from trough to crest).

Restricted Sea-going Vessel	A vessel operating in those waters within the particular geographical limits nominated by the Authority concerned provided that: (i) For a vessel operating out of a port or harbour the limits shall be not more than 50 nautical miles from the prescribed limits of that port; and (ii) For a vessel operating out of any place of departure other than a prescribed port - the limit shall be not more than 50 nautical miles from that place. Note: When the Authority concerned is satisfied that these limits can be extended coastwise with safety this may be done for special purposes.
Limited Sea-going Vessel	A vessel operating in those waters within the particular geographical limits nominated by the Authority in which the vessel concerned may be permitted to operate.
Unlimited Sea-going Vessel	Where not otherwise prescribed above.

Each Authority (i.e. State) to delineate its own areas in relation to smooth water vessels, partially smooth water vessels, limited sea-going vessels and restricted sea-going vessels for inclusion in this Section.

To provide a basis for the discussions on amount and type of equipment for the various classes of vessels, some other parameter was also necessary. Gross tonnage was rejected in favour of 'measured length', defined as the distance from the fore part of the hull to the after part of the hull, taken at the upperside of the uppermost weather deck or, in the case of open vessels, at the height of the gunwale at each end of the vessel.

The classification of vessels, general definitions and diagrams illustrating the concept of 'measured length' are contained in the Introduction, Definitions and General Requirements Section, which is used in conjunction with all Sections of the Uniform Requirements.

Life-saving Appliances Section

This was the first task undertaken by Group 1 and therefore set problems of arrangement as well as content. The Section consists of preliminary and general provisions, scales of equipment for each vessel of type 1, 2 and 3, and appendices containing specifications for the type of appliances.

The scales of equipment were obtained from an integration of Australian and State regulations, with each requirement being scaled down for decreasing measured length. In addition, the scales contained several options in the types or capacity of appliances required, e.g. Lifeboats or liferafts and rescue boats.

The large number of Appendices (23) was made necessary by the distinction between Australian requirements based on SOLAS 1960 Convention and requirements for 'State' vessels, labelled as 'Coastal'. Hence it was necessary to define 'Solas' and 'Coastal' liferafts, for example. The Appendices are a synthesis of information obtained from national and international sources on the construction, capacity and equipment of survival craft. New ground was broken only with the introduction of specifications for 'coastal' liferafts and 'coastal' lifejackets for State ships.

This Section was endorsed by the Council of AAPMA in March 1974.

Miscellaneous Equipment Section

For the purposes of these Uniform Requirements, Miscellaneous Equipment is defined as items of equipment which may be required for safety of navigation, safety of crew, passengers or other persons on board, in port or at sea, and which items of equipment are not required to be provided by any other Section. As such, Miscellaneous Equipment includes navigational equipment, accommodation ladders, anchors and cables, pilot ladders and hoists, provision of navigation lights and shapes and medicines and medical stores.

The format of this Section and its compilation were similar to that for the Life-saving Appliances Section. The equipment requirements are generally those that might be expected in such areas, but some appendices are worthy of a special mention, for example:

The requirements for accommodation ladders and gangways are based on the I.L.O. Code of Practice for Safety and Health in Dock Work. All vessels are required to have either an accommodation ladder or a gangway, or to make use of a fixed safe means of access. The Appendix for pilot ladders gives force to the latest IMCO requirements.

In setting requirements for anchors and cables to match in with Classification Society Tables of Equipment, it was found necessary to consider the dimensions of the most typical vessel (a fishing vessel) and to apply the formula EN = $2/3+2BH+0.1A$ as used by the Classification Societies. The end result was a table of anchor weights in terms of measured length and total height above the water, on which requirements for cables, windlasses etc. could be based.

The Miscellaneous Equipment Section has been sent to industry for comment, and will shortly go before the AAPMA Council for review and endorsement.

Radio Equipment Section

This Section is concerned only with the provision and use of radio equipment for safety purposes, although the same equipment will be used for general communications on other frequencies.

The preparation of the Section was dominated by resolutions of the World Administrative Radio Conference made in Geneva in 1967 for the change from the Double Sideband mode of emission to the Single Sideband mode. This change was being introduced as a means of relieving the congestion in the radio frequency bands below 30 MHz as in simple terms, the Single Sideband (S.S.B.) mode only takes up half the frequency band space of Double Sideband (D.S.B.).

The dates laid down for the change-over to S.S.B. mode were:

(i) From 1 January 1974, new and replacement installations to be in SSB mode;

(ii) From 1 January 1978, all ship stations using frequencies above 4 MHz to be equipped for SSB operations; and

(iii) From 1 January 1982, all ship stations using frequencies below 4 MHz to use only SSB mode.

Hence the Radio Equipment Section had to be drawn up, insofar as scales of equipment and appendices were concerned, in terms of 'existing installations' using D.S.B. mode, and 'new or replacement installations' using S.S.B. mode. (This duplication will cease with the demise of the D.S.B. mode.) It was also necessary to take account of the varying reception of the distress frequencies in different parts of Australia and the specifications of the Post Office as the licensing Authority.

The Section is mainly concerned with the provision of radiotelephone equipment on those smaller vessels under the Authority of the States. Larger vessels to be taken as over 300 tons gross, will meet the requirements of the Australian Department of Transport's regulations.

Because of the expense of S.S.B. equipment, the Section has also made allowance for the use of V.H.F. radiotelephone installations, where vessels operate exclusively within suitable range of stations maintaining constant watch on V.H.F. Channel 16, which has recently been established as a recognized distress frequency. Talks are proceeding on the possible installation of a coastal chain of V.H.F. slave stations for the use of inshore vessels, which would therefore not require S.S.B. installations.

As well as the scales of equipment and appendices, the Section contains general provisions for the location and siting of the equipment, the documents required, miscellaneous items, spare components, qualifications of operators and the keeping of a radio watch.

In drawing up this Section, the group was assisted by technical advisors from the Australian Post Office and O.T.C. to whom thanks are due. This Section has also been sent to the shipping and fishing industry for comment, and will shortly go before the AAPMA Council for review and endorsement.

Surveys and Certificates Section

This Section applies to all vessels under the jurisdiction of an Authority which are required to be surveyed at intervals and to carry on board evidence of meeting survey requirements.

Under 'Survey Requirements' all new vessels, or vessels coming under survey for the first time, are to have a major 'Initial Survey' to satisfy the Authority that they comply with its laws and regulations. Appropriate arrangements are made for application, survey and declaration by surveyors.

After the Initial Survey, vessels are to undergo periodic surveys or inspections. The requirements are basically that:

(i) a vessel's hull is inspected annually, but surveyed out of the water at intervals not exceeding 2 years;

(ii) a vessel's machinery is surveyed at intervals not exceeding 1 year; and

(iii) a vessel's equipment is surveyed at intervals not exceeding 1 year.

Allowance is made for survey programmes to be approved and followed, giving owners the chance to adopt planned maintenance and docking programmes. Arrangement is also made for surveys or inspections where vessels have been damaged, altered, laid up or changed to other trades.

Under 'Certificate Requirements' a Certificate of Survey is to be issued to the owner of a vessel passing the Initial Survey. Every vessel under survey is to carry evidence on board that it complies with survey requirements, which evidence may be a copy of the Certificate of Survey, or some other form of evidence such as a sticker or metal plate bearing brief details of the vessel, its class, size, limit of operations and the number of persons to be carried.

After each subsequent survey, either a new copy of such evidence, or an attachment indicating revalidation of the evidence on board, shall be issued. Allowance is also made for the extension of certificates, etc. for periods up to 3 months, or for their Suspension or Cancellation.

This Section also makes provision for the transfer of vessels from one Authority to another, without re-survey and re-certification being necessary, at the approval of the second Authority.

This Section has been passed to Group 2 for their comment before releasing it to the industry.

Outstanding Work

At present Group 1 is involved in producing uniform requirements for 'hire and drive' vessels.

Outstanding are two subjects, for which the level of Group 1 involvement has not yet been established. These subjects are:

(a) Cargoes, covering Livestock, Deck Cargo, Dangerous Goods and safety measures in Loading and Unloading, which will, at most, apply to only a small proportion of State vessels; and

(b) Special Vessels, for which only brief guide-lines have been established. It is likely that Special vessels will include dredges, hydrofoils, multi hull vessels, and vessels of unusual design or construction, but no decision has yet been made on whether these will be incorporated into a special Section, or whether they will be included in the Sections described above.

APPENDIX II

SUMMARY OF WORK OF GROUP 2

Preparatory Measures

Group 2 was created with the prime purpose of dealing with those matters which are normally handled by marine surveyors with marine engineering skills.

Fire Appliances Section

The first Section undertaken was that of Fire Appliances. This was essentially an editorial exercise - the requirements for small ships were developed from the various State requirements existing at the time and the rules of the U.K. Department of Trade.

Examination of Engineers Section

The next Section considered was that of Examination of Engineers. It was decided to evolve requirements which would allow for a career structure and link up with the requirements already existing for 2nd Class Certificates of Imperial Validity - this would enable a person commencing at the bottom of the ladder (e.g. a boatman) to finish up as the holder of a 1st Class Certificate of Imperial Validity. The types of certificates considered necessary for the industry were then decided and syllabuses and required qualifying service established. On this general information the Principal Examiner of Engineers was able to produce a draft and the requirements were then developed. After Group 2 had commenced this exercise, Group 4 commenced work on an Examination Section for 'Deck' personnel and it soon became evident that:

(a) a number of clauses were equally applicable to 'Deck' and 'Engineering' Examination Requirements; and

(b) there was a small but undesirable difference in approach to that adopted in the Engineering Section in that Group 4 had decided that the requirements should cover the various vessel types collectively i.e. there would not be separate requirements for each of the passengers, cargo and fishing vessels.
Group 4 also decided that the water limits specified throughout other sections were unsuitable for Examination purposes and evolved a more appropriate set of geographic limits.

It was subsequently decided to combine the Deck and Engineering Examination Requirements into a single Section and the Engineering requirements were amended as necessary to ensure consistency existed throughout the document.

Manning Section

A Section devoted to Manning is in preparation by Group 4. After completing the Examination requirements for Engineers, Group 2 was in a position to meet a request from Group 4 for an appendix to their Manning Section covering engineers required for vessels of all classes up to 80 metres in length.

Surveys and Certificates Section

A Section on Surveys and Certificates has been prepared by Group 1. The final draft of this Section will be completed on receipt from Group 2 of clauses and appendices specifying the survey periods of various hull and machinery items.

Machinery Section

A Machinery Section is presently in the early stages of development - its basis has been essentially the various State requirements presently existing and has so far been limited to vessels less than 35 metres in length. The Section will cover matters such as electrical arrangements, bilge systems, propulsion shafting, LP gas installations, exhaust systems, fuel systems, gearboxes, instrumentation, engines, pressure vessels, steering gear, ventilation and windlasses.

APPENDIX III

SUMMARY OF WORK OF GROUP 3

Background

On 17 June 1969, the Acting Premier of Victoria wrote to the Prime Minister suggesting that a meeting of Commonwealth and State Officials be held to consider whether the provisions of the International Convention on Load Lines 1966 might be applied to intrastate ships and, if so, to make recommendations which should ensure that uniform requirements are introduced by each State.

As a result a meeting was held in Melbourne on 5-6 May 1970 which agreed after considerable discussion to recommend that the technical provisions of the 1966 Convention as expressed in the Navigation Act 1912-1970 and the Navigation (Load Lines) Regulations 1968 made under that Act should be applied to all vessels under State jurisdiction with some few exceptions.

It was further agreed that because of the experience of the officers of the then Department of Shipping and Transport in load line assignment, further meetings would be held to guide the States in the principles involved and the application of the Convention to smaller vessels. One or two States were to develop draft Regulations which would then after consideration form the basis for uniform Load Lines Regulations.

The establishment of the Committee for Uniform Survey and Manning Requirements for Commercial Vessels in 1971 was described in the main body of this paper. When the workload of Group 3 was determined it was seen that the appropriate State and Australian Government officials were already meeting as the Load Lines Committee.

Consequently the fifth Load Lines Committee meeting in December 1971 became the first meeting of Group 3, which has been meeting at approximately 5 monthly intervals since.

Group 3 is responsible for drawing up uniform requirements or uniform practices with respect to:

- Load Lines assignment
- Intact stability for all types of vessels, e.g.:
  - passenger vessels
  - cargo ships
  - dredges
  - barges (dumb and self-propelled)
  - oil rig supply vessels
  - fishing vessels
  - tugs
  - landing barges
- Subdivision and damaged stability

- Construction requirements and material testing procedures for hulls of:
  - aluminium
  - ferro cement
  - glass reinforced plastic
  - steel
  - timber
- Structural fire protection
- Metric conversion

Approach

The Group makes use of published material in each field of interest, whether codes of practice, test results, theoretical investigations, casualty reports. These are examined, compared and discussed in the light of the experience of members. Where there are 'grey' areas or information is lacking the Group has no hesitation in conducting its own researches.

For example, it is proposed to initiate some basic research to establish 'yardstick' test data for the assessment of design drawings for ferro cement and glass reinforced plastic hulls.

In this way it is hoped to develop Sections of the Requirements which will be up-to-date and appropriate for use in Australian conditions.

Load Lines Section

This Section has been developed in two ways.

In order to finalise the commission to prepare a set of draft Regulations which should form the basis of uniform State legislation, draft Regulations developed by Western Australia and agreed by the other States, were transmitted by the Prime Minister to the Premiers for incorporation into States' legislation.

In order to make the Uniform Requirements complete, a Load Lines Section became necessary.

The draft Regulations which had been transmitted to the States were then revised and presented in a format uniform with the other Sections. The Load Lines Section is now with the Council Review Committee for examination prior to transmission to the Council for endorsement.

The requirements generally follow those of the International Convention for vessels of 24 metres and over with appropriate modifications for vessels below 24 metres and for vessels operating within restricted limits. The lower length of vessel for assignment of a computed freeboard is 16 metres measured length.

Construction Section

1. General

The Group agreed that it was necessary to develop requirements for all five materials currently in use in Australia, viz, aluminium, ferro-cement, glass reinforced plastic, steel and timber. It was also agreed that the appropriate Section of the existing A.P.A.A. Model Code of Recommended Practice for The Construction and Survey of Fishing Vessels would serve as a useful starting point for the work.

The following order of priority was agreed:

1. Glass reinforced plastic
2. Ferro-cement
3. Aluminium
4. Steel
5. Timber

The method of approach to the development of the Sub-Sections and to the presentation of the requirements received extensive consideration.

The needs of the builder unskilled in the application of formulae were considered and it was decided that where appropriate both tabulated scantlings and formulae should be presented. On deriving the formulae the need for uniform design loadings was recognised, particularly for light planing or semi-planing types of vessels.

It is envisaged that the Construction Section will include a Sub-Section itemising the standard loadings which the Group has taken into account in developing the formulae.

In this way it is hoped that the Construction Section will be of equal value both to the designer who wants to develop his own optimum structural arrangement and to the builder who wants his scantlings clearly laid down.

In conjunction with the study of design loadings the question of probabilistic versus deterministic hull design was considered. That is to say, the Group considered whether the requirements should be based on the traditional (deterministic) approach of using ultimate proof, or yield strengths of materials in association with fixed factors of safety to establish permissible working loads. The alternative (probabilistic) approach of allowing for the probable variability in loadings and in strength of material had appeal as being closer to reality. This latter approach is being used increasingly in other fields of structural design.

The Group agreed that for the present, the data available to it was not sufficient to justify a radical change in approach. The question will be kept under review and at some future date when probabilistic design methods are better established, the opportunity can then be taken to amend the presentation of the Construction Section.

2. Glass Reinforced Plastic (G.R.P.) Sub-section

Development of this Sub-section is well advanced and it is hoped to have it finalised subject to editorial amendment at the Group meeting scheduled for September 1975.

Because the material is cast in situ, even with the aid of simultaneously prepared test pieces, the strength of a hull must remain largely conjectural. Use of standard proved lay ups and materials will provide guidance as to the likely strength of the result in hull but only time will tell whether that hull is adequate for its task.

Availability of co-ordinated test data is limited and it will probably be necessary to carry out some 'benchmark' tests to obtain data suitable for checking the construction of proposed vessels.

Because the materials, operator skills and shop conditions play such a major part in determining the inherent merit of a hull, the Sub-section will include provisions for these aspects of G.R.P. construction.

Material specifications and requirements for storage and handling are being drawn up. Proficiency tests for G.R.P. laminators have been established and will be included in the completed Sub-section. As the production of a G.R.P. hull is a chemical process, dependent on ambient temperature, humidity, dust content of the air etc., for its success, special attention is being paid to these factors.

A major problem with all G.R.P. hulls is fire. Two approaches to developing fire resistance of G.R.P. hulls are common viz: the use of fire retardant resins in the layup and the application of intumescent paint.

Experience throughout the world with both these methods of protection has been mixed and the matter is being actively pursued by the Group.

The provision of escape routes and lifesaving appliances in vessels of conventional material such as steel is based on the premise that the hull life in the event of fire is in excess of 60 minutes. With the best expertise available no such figure can be achieved with G.R.P. Consequently the question of the fire resistance of a G.R.P. hull cannot be considered in isolation from other aspects of the vessel's construction and equipment.

3. Ferro-Cement Sub-Section

This material too is cast in situ and despite the simultaneous preparation of test pieces, the actual strength of the completed hull will remain to some extent unknown.

To an even greater extent than with G.R.P., co-ordinated research into the strength characteristics of ferro-cement hulls is scarce. The Group is arranging to carry out a test programme to derive basic data for use in assessing design proposals submitted to an Authority for ferro-cement vessels to be built under survey.

The Ferro-Cement Sub-section has been submitted to the A.A.P.M.A. Council for endorsement prior to its application throughout Australia. This Sub-section was developed using the best data and experience available and the Group are now anxious for it to be tried in practice. After some experience has been gained in its application, it will be reviewed and amended where necessary in the light of that experience.

4. Aluminium Sub-section

This Sub-section has been based on the materials suitable for marine usage which are currently available and on welding techniques which are the present good practice. Particular advantage was gained by the issue earlier this year of the draft Australian Standard 'Rules for Welding of Aluminium Structures' which when issued as an Australian Standard will be used by all the Authorities.

The Sub-section will include provisions for workmanship, inspection procedures, factory standards and weather protection. All these aspects of aluminium construction are considered by the Group to be of major significance in the successful production of aluminium hulls.

In writing the structural requirements, the aim of the Group has been to make full use of the innate characteristics of aluminium rather than to approach the question by treating aluminium as a substitute for steel as is commonly done.

The economics of aluminium construction are becoming such that an increasing number of Australian vessels built of this material seems likely. The Group hope to encourage this trend by what they hope will be realistic structural requirements.

The development of that Aluminium Sub-Section should be well advanced following the Group's next meeting in September 1975, with anticipated completion about mid 1976.

5. Steel Sub-Section

It is intended that the Steel Sub-Section should be soundly based on structural theory, experimental results and service experience - as well of course as on the materials available for use.

The Sub-section will be in two parts, one for the heavier commercial vessel and the other for the lighter, faster vessel. In accordance with the Group's agreed practice but, particularly for the latter vessels, formulae for use in conjunction with standard loadings will be presented, as well as scantling tables. Both transverse and longitudinal construction will be provided for.

To date no problems have been experienced, probably because of the extensive documentation and experience available. The Group expects to complete its work on this Sub-section by mid 1976.

6. Timber Sub-section

No work has yet been done in this Sub-section. It is expected to commence its preparation early in 1976.

Provision for other materials?

STABILITY SECTION

1. Intact Stability

The range of vessels which operate in and around the ports and along the coast of Australia is diverse. To provide for this the Department of Transport is developing criteria for individual types of ships to be applied over and above the IMCO criteria for passenger, cargo and fishing vessels which have been adopted for general use. These criteria are based on analysis of those used in other parts of the world.

The criteria, though as yet in draft, have been studied by the Group for adoption in the Stability Section. The range of vessels will be extended to include vessels operating solely in intra-state service. Until the work on the Section is completed provision is made in the Load Lines Section for stability requirements for the following types of vessel:

- Seagoing vessels of 24 m length and over
- Seagoing vessels of less than 24 m length
- Vessels operating within smooth and partially smooth waters
- Barges, lighters, and similar vessels operating within partially smooth waters
- Barges, lighters, and similar vessels operating within smooth water limits.

Regard is paid to conclusions to be drawn and lessons learned from casualties as well as the documents which result from the deliberations of IMCO Sub-Committees. It is evident that some types of vessel which are numerous in Australian waters are not so common overseas, and these require special consideration.

A good example is the landing barge which has played so significant a part in Australian mining and oil exploration activities. Overseas this is regarded as a special type of vessel, a view with which we do not concur.

A problem of considerable significance which has not been fully resolved is, for the smaller vessel, the quantity, presentation and detail necessary in stability data to ensure that the ship's personnel have all the information necessary for them to be fully apprised of the condition of their ship at all times. Where the officers do not hold qualifications which necessitate a wide knowledge of stability, and especially where the design of a ship is somewhat complex necessitating detailed operating instructions and prohibitions (as for example limiting slack tanks to two or three), the best mode of presentation is a problem of great importance.

The Group considered that the following classes of vessels would be specially provided for:

- Tugs
- Off-shore service vessels
- Barges
- Dredges (Hopper)

- Dredges (Bucket)
- Dredges (Tin)
- Floating Cranes
- Grain Elevators
- Fishing vessels which carry cargo
- Hydrofoils
- Multi-hulled craft
- Passenger vessels
- Sailing vessels
- Sea angling vessels

The development of requirements for intact stability of small passenger vessels was considered to be of major importance. The diversity of vessels existing in the various States and of the experience gained from them over the years has led to some divergence of views as to the form that the requirements should take. One factor which is being fully explored because of its influence especially in the lighter vessels is 'passenger load factor' (the ratio between the weight of the maximum permitted number of passengers and the load displacement).

Stability for fishing vessels will be influenced by the requirements contained in the International Convention for the Safety of Fishing Vessels. The views of the I.M.C.O. Sub-Committee who are presently drafting the Convention are that freeboard will be determined not by geometrical calculation but by the stability associated with the maximum intended loading. Account will be taken inter alia of wind, waves and bow height.

Requirements for the other types of vessel will probably be in line with international standards where they exist, and the best analysis of national standards in other cases.

2. Subdivision and Damaged Stability

It was considered by some States that for the smaller vessel, the complete calculation was not warranted and that a more approximate approach such as that adopted by the U.S. Coast Guard for small passenger vessels would do all that was necessary.

Advice as to the background and philosophy of the Coast Guard approach was obtained in order that the method would be fully understood by the Group before a definite decision was reached.

Comparisons were made using existing vessels for which complete direct calculations had been carried out.

Following examination by a small working group requirements for Subdivision and Watertight Integrity for Small ($\leqslant$ 35m) Passenger Vessels should be agreed at the next meeting of the Group.

These requirements provide for the number, construction and spacing of watertight bulkheads, standard damage and damaged stability limits, drainage, hatches, coamings, hull penetrations and shell connections.

Structural Fire Protection Sub-Section

At an early meeting, the question of the need for structural fire protection for the smaller vessels was discussed, particularly in relation to the statistics of loss of or severe damage to vessels caused by fire. The Group was of the opinion that structural fire protection was needed, but to develop standards appropriate to particular classes of vessels would require close investigation.

Structural fire protection for passenger vessels has been a requirement for some decades. Structural fire protection for Australian interstate and overseas non-passenger vessels was introduced in 1968 when Australia gave effect to the International Convention for the Safety of Life at Sea 1960. As a result some years of experience in the provision of structural fire protection in ships is available to the Group.

Additionally, the International Convention for the Safety of Life at Sea 1974, which extended the provisions of the 1960 Convention, a new part to the Convention now being finalised and dealing in detail with the structural fire protection of cargo ships, and the draft International Convention for the Safety of Fishing Vessels all contain provisions for structural fire protection of which account must be taken in developing uniform Requirements.

As a basis, documents relating to the provision of structural fire protection in accordance with the Navigation (Construction) Regulations were circulated for discussion. One State produced a base paper elaborating ideas on the approach to be adopted for smaller vessels and other States have presented their views on the subject.

Two questions on which agreement is necessary in developing a philosophy on the subject are the evacuation time necessary for passnegers and crew to leave a vessel, and the advantage of passengers and crew remaining aboard a stricken vessel from the point of view of speedy rescue. The latter approach requires steps to be taken to limit the spread of fire and at the same time to bring maximum extinguishing capacity to bear.

Preparation of the Sub-section is well advanced with estimated completion in early 1976. When the new U.K. Construction of Fishing Vessel Regulations become available, these will be examined in the light of the latest development of the Group's proposals, though the structural fire protection requirements contained in the draft International Convention for the Safety of Fishing Vessels will be more significant in influencing the Group's thinking.

Metric Conversion

The Group has followed the introduction of metric conversion into both shipping and shipbuilding and has drafted its requirements in the appropriate S.I. units wherever possible. (Some portions of the Ferro-Cement Sub-Section remain in imperial units because of material availability).

No problems of any magnitude have been found so far.

APPENDIX IV

SUMMARY OF WORK OF GROUP 4

Preparatory Measures

The Group first met on 9 September 1971. From the outset it was apparent that the State Authorities had very little legislative cover in the topics set for consideration by this Group. It was decided to use existing International Conventions and Department of Transport Regulations as a basis for consideration.

Collision Regulations Section

The first Section completed by the Group was the Collision Regulations Section. In the main this Section calls up the Convention on International Regulations for Preventing Collisions at Sea 1972. This Section has since been endorsed by the Council of the Association of Australian Port and Marine Authorities (A.A.P.M.A.).

Examinations and Certificates of Competency Section

On a time consumption basis the Examinations and Certificates of Competency Section has absorbed the greatest amount of time so far. Several drafts were prepared before Group 4 and Group 2, who contributed the engineer provisions, put their document to Committee. The Section is now with industry for comment.

Manning Section

A Manning Section was prepared at the same time as the related Examinations and Certificates of Competency Section. It was once again prepared with the assistance of Group 2. The Section provides the structure of and conditions for Manning Committees and it sets out suggested manning scales for vessels of less than 80 metres measured length for use by the Manning Committee. Fishing vessels of less than 35 metres (measured length) will have their manning prescribed by regulations but there will be appeal provisions to the manning committee for variation from the prescription.

Signals of Distress, Urgency Signals and Danger Messages Section

Members deliberated on the production of a Section on Signals of Distress, Urgency Signals and Danger Messages, but because of uniform current practice based on the Department of Transport's existing regulations, decided against publishing such a Section. This decision was taken in collaboration with a representative of the Department's Marine Operation Centre, Canberra.

Crew Accommodation Section

A Crew Accommodation Section is currently under consideration. The Section contains the latest requirements of the International Labour Organisation convention No. 126, and Conventions Concerning Accommodation on Fishing Vessels. The Section will apply mainly to non-Convention vessels and simply call up for Convention vessels I.L.O. Convention Nos 92 and 133, Convention Concerning Crew Accommodation on Board Ship.

River Murray Traffic Regulations Section

Shortly the River Murray Traffic Regulations Section will go forward for endorsement by Council. This Section was prepared in the main by representatives of the Authorities involved, viz, Victoria, New South Wales, South Australia and the Department of Transport. A great deal of assistance was also rendered by the State Rivers and Water Supply Commission of Victoria, Engineering and Water Supply Department of South Australia and State Public Works Department New South Wales, who are all members of the River Murray Commission.

Outstanding Work

Other Sections which have been looked at and briefly discussed but are yet to have drafts prepared are:

Courts of Marine Inquiry
Hospital Accommodation
Musters and Drills
Passengers
Wrecks and Salvage

APPENDIX V

SUMMARY OF WORK OF GROUP 5

This Group is concerned with administrative controls relating to maritime employment. Wit h the exception of Victoria, all States and the Australian legislation in this field is based upon the Imperial Acts of 1894 and 1906, modified in some instances to meet local requirements.

The first meeting of the Group on 6 October 1971 had for discussion a document prepared by a Marine Consultant dealing with all aspects of employment and protection provisions of the Australian Navigation Act, the first critical evaluation of the appropriateness of those provisions since the Act was proclaimed. A companion paper prepared in the Department of Transport analysing the document was also introduced.

Since then the following subjects have been dealt with by the Group:

Articles of Agreement
Apprenticeships
Discipline
Foreign seamen
Log books
Seamen's Wages
Employment of crew on cargo
Protection of seamen, their rights and property
Seamen distressed abroad
Health
Provisions
Master's duties
Administration

Agreement in principle with the terms of the discussion papers was reached, but at this stage only in respect of vessels of Class 1A, 2A (limitless), and 1B, 2B of 35 metres and over.

Progress on particular application of the above subjects is being made but only in respect to the classes of vessels mentioned.

When the exercise in regard to these vessels is complete it is intended to turn then to the other classes of vessels scaling down the controls appropriately. Small vessels, as a group, will be dealt with in that second exercise.

APPENDIX VI

TRAINING AND QUALIFICATIONS OF SMALL SHIP PERSONNEL

INTRODUCTION

A proposal for a new structure of certificates of competency for masters, mates and engineers has been developed by the Department of Transport in collaboration with the State Marine Authorities. It covers all sizes of Australian commercial vessels - including fishing vessels - and all modes of operation. It seeks to introduce, for the first time, a set of uniform requirements throughout the country.

Concurrently with this, proposals for a substantial upgrading of marine training facilities are being developed. These proposals are centred on the establishment of an Australian Maritime College to serve what might be considered the 'national' elements of the shipping and fishing industries; and on the establishment of supplementary training facilities around the country to service 'local' requirements.

This paper seeks to highlight and discuss certain new philosophies and approaches to the training and qualifications required for small ship operation. In particular, a case is made for a more practical approach, than hitherto, to the requirements for the master and chief engineer of small vessels operating on extended, or unlimited, voyages.

GENERAL

The proposed new structure of certificates of competency has been developed within the framework of the uniform shipping laws machinery: Group 4 having prepared the requirements for masters and mates, and Group 2 those for engineers. The certificate structures are shown in Attachment A to this paper.

The proposals represent a significant restructuring of the present requirements, and one of the reasons for this is the need for a more realistic approach to the certificates of competency for personnel on small trading vessels and fishing vessels. Associated with this is the realisation that for the sophisticated vessels now in service there is a greater need for formal practical training than there was in previous times, when experience covered all the training that was necessary.

This latter factor - which is aggravated by the current lack of practical training facilities in Australia - applies to all sizes of ships. It has now been recognised and, hopefully, will be remedied by the establishment of the Australian Maritime College together with supplementary provision throughout the country to serve local requirements. The proposed new certificate structures have been developed with the new training requirements very much in mind. Indeed, it would not be too much to say that without the provision of the necessary training facilities the new certificate requirements would have a very limited achievement.

SOME MAJOR FEATURES OF THE NEW CERTIFICATES

Inevitably much of the following applies to ships of all sizes, but the emphasis is placed on small ships wherever possible.

1. Greater Integration: In developing the certificate structure, the necessity to provide for transfer or mobility of personnel - both vertically, i.e. upward through the various grades of certificates, and horizontally i.e. across from one area of the industry to another - was kept very much in mind.

Attachment B illustrates the provision for vertical mobility inherent in the certificate structure as the person in charge of a vessel less than 20 metres in length (Coxswain) can rise through the various grades to the highest 'command' qualification (Master Cl.I) while a Deckwatchkeeper who would normally progress to Master Class I or Master Class II may, by performing the necessary service in small vessels, attain a qualification for command of small craft.

In the case of horizontal mobility, perhaps the most significant example is the provision for ease of transfer between the fishing and shipping industries. Traditionally the certificates for commercial fishermen have been quite separate for those for merchant seafarers. However, there are indications that the situation where fishermen remained in fairly closed social communities and did not transfer to merchant ships is changing. For example, a number of fishermen are employed in various sectors of the off-shore industry: often initially through the charter of a fishing boat for hydrographic or seismic survey work.

The new structure of certificates for engineers applies equally to fishing vessels and to small trading vessels. For masters and mates there is a common core of work which is the same for both industries i.e. navigation, meteorology, seamanship etc. and only the additional specialist papers such as 'cargo work', on the one hand, and 'safety in the handling of fishing gear', on the other hand, are different for say Master Class IV and Master Class IV (Fishing).

2. On-going Competency Standards: At the present time, once an officer has obtained his highest grade certificate - i.e. either the master or chief engineer qualification for the appropriate category of ship - no further consideration is given to whether the level of competency, once achieved, is thereafter maintained: unless of course he is unfortunate enough to appear before a Court of Marine Inquiry.

The new proposals envisage the necessity for evalidation of certificates, or licences, at periods not exceeding five years. This would not necessarily involve the officer concerned in further examinations. Rather, the emphasis would be on encouraging personnel to update their knowledge by requiring attendance at short courses. In a similar way it is proposed to require attendance at special short courses by key officers on ships carrying hazardous and noxious cargoes, i.e. whereever it is considered necessary in the interests of safety at sea or the protection of the marine environment.

3. Ship Size and Operating Area: More emphasis is now placed on ship size, than hitherto. Certificates of competency have tended to be categorised mainly by trading area - i.e. coastal and foreign-going. However, commercial practices have moved ahead of the statutory requirements in this regard. For example, large sophisticated vessels in the coastal trade normally carry officers who are qualified at the highest levels although this is not a legal requirement. The new certificate proposals include the provision that all ships over 80 metres in length (for masters and mates) and 3000 kw (for engineers) should carry officers holding the highest grades of certificate - irrespective of trading or operating area.

Conversely, it is suggested that small ships engaged on extended voyages should not require the top grade qualifications, but that a more practically-orientated certificate would be more appropriate. This argument is expanded on in the following section.

4. A more practical approach for the small-ship man: It has to be stressed that this approach in no way infers that a lesser appreciation of safety at sea is required by 'small ship' men than by those manning large vessels. The essential philosophy is that more benefit will accrue through treatment of the subject matter in a more practical way - and to a lesser depth of theoretical knowledge - than is traditional for the 'big-ship' man, who tends to have had a different background of formal education.

In navigation, for example, instead of the traditional 'watering down' of the foreign-going syllabuses for coastal (and generally 'small ship') work, much of the mathematical theory can be eliminated by the use of pre-computed tables of altitudes and azimuths, pro-forma work sheets, and plotting charts.

In such matters as stability and stresses there is considered to be room for similar improvements. But this can only be achieved within the constraints imposed by the type of stability and stress data required to be carried by law. In general, the masters and mates on small vessels are involved in different and more practical working operations than their counterparts on large vessels; and neither their working environment nor their educational background is suited to handling the type of data that is applicable to the 'big-ship' situation. A more practical approach to the understanding of the main dangers associated with the movement of a ship in a seaway is needed. But ideally this should be complemented by the supply of data and pro-forma of the type that leads to a 'go - no go' situation. This type of approach is already being implemented in at least one other country.

5. Dual Qualifications: A final element of the new proposals which is perhaps worth mentioning is the provision for the combined nautical/ engineering qualificiations for very small craft. The Coxswain and Boatman certificates cover both nautical and mechancial knowledge, as it is envisaged that generally one man would perform the dual-function involved.

It was not considered realistic, at this time, to propose an extension of the dual qualification to larger classes of ships - although, of course, the holder of the proposed Coxswain certificate would be able to progress to a higher level certificate in either the nautical or engineering disciplines. He would not however serve in a dual capacity on a ship greater than 20 metres.

CONCLUSION

In conclusion, it should be emphasised that the new certificate structures only have the status of a proposal at this stage. They are currently with the Industry for consideration and comment. Whatever the merits or demerits of the various new suggestions, however, it is suggested that there is one general factor which should gain universal approval - that is, the aim to achieve a single uniform structure of certificates for the whole country. The benefits to the industry, and to the individual, must be substantial.

Any comments and questions which you may have regarding these proposals will be welcomed.

Benefits to industry?

Industry involved in Government bought?

ATTACHMENT A

Certificate Requirements, by Vessel Size and Operating Area:

The following table indicates the lowest grade of certificate which is normally acceptable for each master and mate position:

LIMIT OF OPERATIONS	MASTER	1ST MATE	2ND MATE	3RD MATE	4TH MATE
- All seagoing vessels of 80 metres and over in length:					
Unlimited (i.e. irrespective of range of operations)	Master Cl.I	Master Cl.I	Dk/Wkr	Dk/Wkr	Master Cl.III (if carried)
- Seagoing vessels of 35 metres and over but less than 80 metres in length:					
Unlimited	Master Cl.II	Master Cl.II	Master Cl.III	Master Cl.III (if carried)	
Regional Australian & Middle Water	Master Cl.III	Master Cl.III	Master Cl.IV (if carried)	Master Cl.IV (if carried)	
Offshore	Master Cl.III	Master Cl.IV	Master Cl.IV (if carried	Master Cl.IV (if carried)	
Inshore	Master Cl.IV	Coxswain			
- Seagoing vessels of less than 35 metres in length:					
Unlimited	Master Cl.III	Master Cl.IV	Coxswain (if carried)		
Regional Australian & Middle Water	Master Cl.IV	Coxswain	Coxswain (if carried)		
Offshore					
20-35 metres	Master Cl.IV	Coxswain (if carried)			
less than 20 metres	Coxswain				
Inshore					
20-35 metres	Master Cl.IV	Coxswain (if carried)			
10-20 metres	Coxswain				
less than 10 metres	Boatman				

NOTE: 1. The Coxswain and Boatman Certificates are dual-role (i.e. nautical and mechanical) qualifications

- Vessels which ply exclusively in harbours and inland waters

As for vessels in 'Inshore' operations, except that the syllabus content may be amended by the Authority to meet local requirements; in which case the certificate titles (Master Cl.IV, Coxswain and Boatman) shall be qualified accordingly (e.g. by the addition of Harbours and Inland Waters); and the syllabus subjects shall be listed at the back of the certificate.

The following table indicates the lowest grade of certificate which is normally acceptable for each engineer position:

LIMIT OF OPERATIONS	CHIEF ENGINEER	2ND ENGINEER	3RD ENGINEER	4TH ENGINEER
- Vessels of 3000 kW and over				
Unlimited	Engineer Cl.I	Engineer Cl.I	Engineer Cl.III	Engineer Cl.III
Regional Australian and Middle Water	Engineer Cl.I	Engineer Cl.I	Engineer Cl.III	Engineer Cl.III
Offshore	Engineer Cl.I	Engineer Cl.II	Engineer Cl.III	
Inshore	Engineer Cl.I	Engineer Cl.II		
- Vessels of 1500 kW and over, but less than 3000 kW				
Unlimited	Engineer Cl.II	Engineer Cl.II	Engineer Cl.III	Engineer Cl.III (if carried)
Regional Australian and Middle Water	Engineer Cl.II	Engineer Cl.II	Engineer Cl.III (if carried)	
Offshore	Engineer Cl.III	Engineer Cl.III		
Inshore	Engineer Cl.III	Engineer Cl.III (if carried)		
- Vessels of 50 QN and over, but less than 1500 kW				
Unlimited	Engineer Cl.II	Engineer Cl.II	Engineer Cl.III	
Regional Australian and Middle Water	Engineer Cl.III	Engineer Cl.III	Engine-driver Gr.I (if carried)	
Offshore	Engineer Cl.III	Engine-driver Gr.I (if carried)		
Inshore	Engine-driver Gr.I			
- Vessels of 35 QN and over, but less than 50 QN				
Unlimited	Engineer Cl.III	Engineer Cl.III		
Regional Australian and Middle Water	Engine-driver Gr.I	Engine-driver Gr.I		
Offshore	Engine-driver Gr.I	Engine-driver Gr.II (if carried)		
Inshore	Engine-driver Gr.I			
- Vessels of 20 QN and over, but less than 35 QN				
Unlimited	Engine-driver Gr.I	Engine-driver Gr.I		
Regional Australian and Middle Water	Engine-driver Gr.I	Engine-driver Gr.II		
Offshore	Engine-driver Gr.II	Engine-driver Gr.II (if carried)		
Inshore	Engine-driver Gr.II			

- Vessels 15 QN and over, but less than 20 QN

Unlimited	Engine-driver Gr.I
Regional Australian and Middle Water	Engine-driver Gr.II
Offshore	Engine-driver Gr.II
Irshore	Coxswain

- Vessels of less than 15 QN

Unlimited	Engine-driver Gr.I
Regional Australian and Middle Water	Engine-driver Gr.II
Offshore	Coxswain
Inshore	Boatman

- Vessels which ply exclusively in harbour and inland waters

As for vessels in 'Inshore' operations.

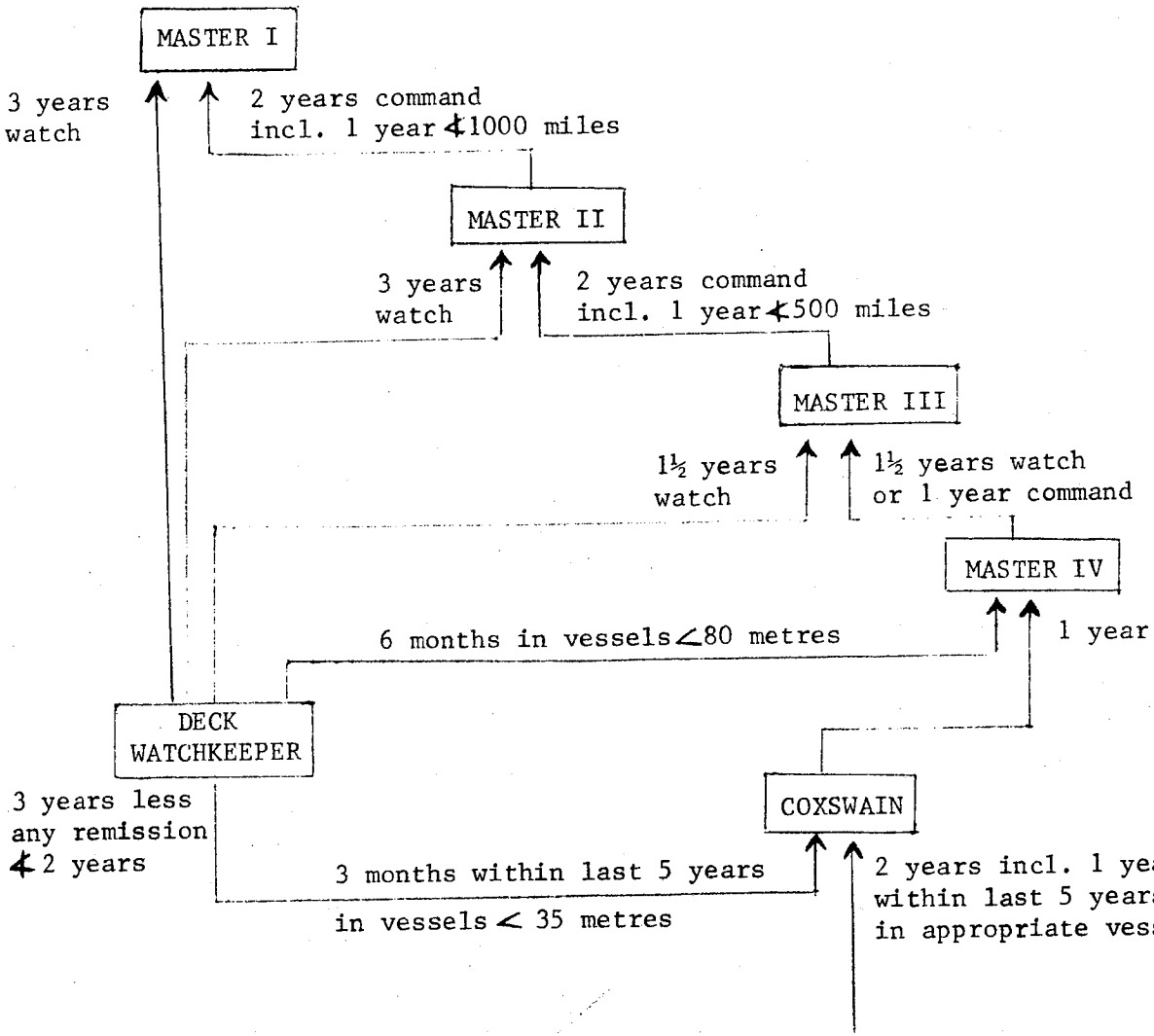
QN - Qualifying Numeral means

(a) measured length; or

(b) the maximum continuous brake power of the propulsion machinery in kilowatts divided by 15

whichever is the greater.

FLOW DIAGRAM OF PROPOSED CERTIFICATE STRUCTURE



Endorsement requirements for trading or fishing service in vessels to which endorsement applies.

1 year including 6 months in vessels ≮ 20 metres with Master III

6 months including 3 months with Master IV.

APPENDIX VII

STANDARDISATION IN SHIPBUILDING

NOTE ON WORK OF STANDARDS ASSOCIATION OF AUSTRALIA

During the Shipbuilding Conference held in Sydney in 1966 there was a discussion on the contribution to shipyard productivity and reduced costs which could be expected from standardisation of components and, in the long run, ship design. It was agreed that action should be initiated with the Standards Association of Australia towards a programme of preparation of appropriate standards.

A Steering Committee - SAA Code No. MS 22: Shipbuilding - was set up with representatives from major shipyards and shipowners, the Shipbuilding and Marine Standards Divisions of the Department of Transport, Classification Societies, the Department of Defence (Navy Office) and the Standards Association. This Committee listed a number of components and other aspects suitable for standardisation, assigned priorities and appointed working groups to study each.

The following sub-committees were established:

S.A.A. Code No.	Subject
MS/22/1	Electrical
*MS/22/2	Hull and Outfit
MS/22/4	Machinery and Piping
MS/22/5	Terminology and Trials
MS/22/6	Air Conditioning

* Originally MS/22/2 was Hull Structures and MS/22/3 Hull Outfit - Subsequently amalgamated as a result of operational experience of sub-committee work.

In addition to the above, a sub-committee AK/7/1 - which is a sub-section of the Acoustics Committee - has been considering the subject of noise emission and control.

The sub-committees meet at approximately 3 month intervals depending on the progress of the preparation of standards and the main committee meets once a year to review progress and forward work.

Progress is inevitably slow because of the need for detailed study of the components concerned and the proposed standard itself but a number of standards have been published and others are at advanced stages. It is interesting that one of the first metric standards issued in Australia was the one dealing with steel plates for shipbuilding.

In preparing standards it is essential to ensure that the standard does not conflict with statutory requirements e.g. the Navigation Act and Regulations, and if possible is not at variance with established standards overseas e.g. ISO standards.

As with most of the work of the Standards Association of Australia and other standards organisations, this work in the preparation of Australian shipbuilding standards will achieve nothing unless the standards are quoted by owners in ship specifications and in orders by shipbuilders for material or components, adopted by component manufacturers, and used in other ways to reduce the cost involved in a multiplicity of designs, materials and methods. It is to be hoped therefore that Australian shipowners and shipbuilders will acquaint themselves with the standards and make increasing use of them.

Attached are lists of published Australian shipbuilding standards and those approaching publication.

AUSTRALIAN SHIPBUILDING STANDARDS

Published

AS 1002	Nominal Thicknesses of Steel Plate for Shipbuilding Purposes
1016	Manholes for Ships
1035	Vertical Steel Ladders for Ships
1036	Inclined Steel Ladders for Ships Machinery Spaces
1037	Inclined Steel Ladders for Use in other than Ships Machinery Spaces
1101 (Part 2)	Graphical Symbols for General Engineering - Ventilation Systems in Ships
1149	Rotating Electrical Machinery in Ships
1150	Artificial Illumination in Ships
1168	Elastomer-Insulated Electric Cables for Fixed Wiring in Ships
1267	Ships Pilot and Embarkation Ladders
1322	Fluid Velocities in Pipes
1345	The Identification of Piping, Conduits and Ducts
1395	Docking Plugs and Associated Bodies
1695	PVC Insulated Fixed Electrical Cables for Ships
F5	Graphical Symbols for Ships' Pipelines

AUSTRALIAN SHIPBUILDING STANDARDS

Drafts Prepared or for Public Review

Rational Series of Diameters and Thicknesses for Copper Pipes

Rational Series of Diameters and Thicknesses for Copper Alloy Pipes

Rational Series of Steel Pipes for Shipbuilding Purposes

Small Square Weathertight Hatches

Seawater Temperatures for Cooling of Ships' Machinery

Measurement of Noise on Board Ships

Noise Emitted by Vessels on Waterways and in Ports and Harbours

Special Requirements for Electrically Operated Cooking and Heating Appliances for Marine Use

Guard Rails and Stanchions

Ventilation Closing Devices

Salt Water Piping Systems

Hydraulic Fluid Contamination Levels

Air Conditioning

Fire Control Plans on Ships

Dimensional Co-ordination in Shipbuilding

Ships' Windows

Ship Specification Index

NEW ZEALAND EXPERIENCE IN IMPLEMENTING REGULATIONS FOR SMALL SHIPS

by

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SUMMARY

The introduction to the paper briefly outlines the development of legislation in New Zealand relating to shipping from the Colonial period to the present legislation embodied in the Shipping and Seaman Act 1952. The extent to which small ships are subject to this legislation is outlined.

Classification of small ships into categories for international voyages, home trade and restricted limits is discussed and the problems that arise in classing certain vessels e.g. charter yachts is raised. Categorisation of fishing vessels into deep sea, coastal and inshore classes is dealt with.

Information on and the origins of the construction requirements published by the Ministry for steel and aluminium vessels, wood vessels and ferro-cement vessels from 7 metres to 30 metres in length is included. Also included are the Ministry's requirements for tonnage measurement, subdivision, and stability of smaller vessels. Load Line requirements relating to these craft and submersion lines required for certain craft not subject to load line requirements are indicated.

Regulations relating to equipment particularly fire appliances, lifesaving appliances and radio requirements is covered, and the problems experienced in enforcing these regulations on smaller craft is considered.

Manning of New Zealand vessels and the undesirable influence the regulations can have on the design of small ships is outlined in the paper.

The paper concludes with a consideration of possible future legislation and trends both national and international.

Footnote:

Any opinions expressed in this paper are the authors and not those of the Ministry.

INTRODUCTION

The survey of ships in the colony began with the passage of the Steam Navigation Act 1862. Survey was restricted to coastal steamships and it is understood that this Act was almost identical with Acts in the Colonies of New South Wales and Victoria.

Two classes of ship were provided for in the modified Steam Navigation Act 1866 'sea-going' and 'river service' which proved difficult to implement and led to the then permanent head of the department introducing 'extended river' certificates for steamships plying along the coast within defined limits. In questioning the legality of this course of action he stressed that powers of classification should be conferred on the Government by law and 'Instructions' issued so that surveyors could be guided in their duties and shipowners informed of their obligations, a policy followed to this day.

In the period between 1862 and 1904 legislation was enacted to bring sailing ships and motor ships within the departments jurisdiction and the term 'sea-going' was replaced on survey certificates by 'foreign going', 'intercolonial' (no longer in use), or 'home trade'.

Marine laws in force in New Zealand were embodied in the main into one Act with the passage of the Shipping and Seamens Act 1877. This being based to a large extent on the Imperial Merchant Shipping Act of 1854 and many of its sections being the basis of the provisions in the present Shipping and Seamen Act 1952. With the introduction of the Imperial Merchant Shipping Act of 1894 New Zealand found it necessary to revise its shipping laws and the Shipping and Seaman Act 1903 was passed. Because of conflict between the proposals of this Act and those of similar Australian legislation (both of which were scrutinised by the Imperial authorities) on the one hand and British legislation on the other hand a Colonial Merchant Shipping Conference was called to bring about some uniformity. The present Act incorporates International Conventions and gives effect to the provisions of the British Commonwealth Merchant Shipping Agreement 1929 which clauses it would have in common with Australian shipping legislation.

Survey requirements in New Zealand appear to have been more far reaching than those of many countries, even in the early 1920's every ship, except a pleasure yacht or launch or a fishing boat under 10 tons gross had to be surveyed annually. Today all ships are subject to annual survey with the exception of -

(a) pleasure yachts not exceeding 50 tons register.

(b) passenger launches not exceeding 16 feet which are not ferries.

(c) fishing boats not exceeding 35 feet.

(d) unmanned barges, lighters etc.

(e) vessels engaged in agricultural and pastorial pursuits not exceeding 50 feet.

Plan approval for ships built in New Zealand was first required in 1909 and applied to those vessels exceeding 25 tons gross. Today this requirement applies to all vessels except -

(a) pleasure yachts not exceeding 30 metres.

(b) passenger launches not exceeding 16 feet which are not ferries.

(c) fishing boats not exceeding 20 feet.

(d) unmanned barges, lighters etc. not exceeding 50 feet.

SERVICE CLASSIFICATION OF SHIPS

The service classification of ships determines in the main their equipment and manning and to a lesser extent their scantlings.

New Zealand ships of less than 60 metres in length other than a few tugs equipped for salvage work are not found in the foreign going classifications. Home trade classification embraces tugs and cargo ships of various type, also passenger ships which fall into two categories those unrestricted and those making daylight excursions only. (Home trade is within 150 miles of the coast).

Passenger launches and ships, tugs and other workboats and a few smaller cargo ship types are found in the restricted limits classifications of 'extended river limits' and 'river limits'. A special extension of extended river limits are gazetted in New Zealand for 'deep sea sports fishing vessels' which operate in designated zones often outside normal extended river limits. These vessels which must exceed 30 feet in length operate in fine weather and favourable conditions only, are limited to 6 passengers and are manned as extended river limit passenger vessels but require additional equipment.

Charter vessels principally charter yachts have posed problems particularly in the manning area, here the vessel is to be equipped for the service limits requested. If the vessel is manned by the owner or crew employed for that purpose manning is in accordance with the scale and qualifications for the limits of operation. However, if a sailing yacht is manned by the hirer and his party the owner is to be satisfied as to the competency of the hirer to handle the yacht.

Fishing boats are placed in three categories 'Deep Sea', 'Coastal', and 'Inshore'. Deep Sea vessels are unrestricted, Coastal operate up to 75 miles from the coast, and Inshore vessels within 12 miles of the coast. The latter are restricted to vessels not exceeding 50 feet of hard chine construction with a minimum stipulated power and are not trawlers.

CONSTRUCTION REQUIREMENTS FOR SMALL SHIPS

At the present time the Marine Division have publications covering construction requirements for Steel and Aluminium Fishing Vessels (30 feet to 100 feet), Wood Fishing Vessels (30 feet to 75 feet), Wood Inshore Fishing Vessels (20 feet to 45 feet) and Small Ferro-Cement Boats.

The scantlings and other requirements for Wood Fishing Vessels were first published in 1965 and cover the traditional form of construction with planked hull on steam bent frames principally found in coastal operation. Following legislation reducing the size of craft surveyed and

representations from boatbuilders in 1970 concerning provision for separate construction requirements for a lighter, higher speed, type of craft engaged in coastal crayfishing and long lining fisheries the Wood Inshore Fishing Vessel requirements were introduced in 1972. Scantlings of these boats of hard chine configuration are based on a ply or diagonally planked hull with sawn frames and closely spaced stringers, a form of construction popular in New Zealand for planing or semi-displacement craft both in the commercial and pleasure fields. Operating within 12 miles of the coast the lighter scantlings contained in the requirements are permitted on the basis of the vessels ability to reach safe harbour quickly and for this reason a minimum installed continuous horse power against length is stipulated. The vessels are normally diesel powered with conventional screw drive, jet units and outboards are restricted to 3 miles from the coast.

The Steel and Aluminium Fishing Boat requirements are fairly comprehensive setting out scantlings, machinery and piping, outfit, and electrical installation of vessels up to 100 feet. These may be used as a basis for assessing scantlings etc. of other types of craft in steel or aluminium requiring survey. For larger vessels reference is made to published rules of the major classification societies.

Various types of small craft in ferro-cement are built in accordance with our requirements principally charter yachts, a number of fishing vessels and some passenger launches (passenger ships by definition carrying more than 12 passengers are not permitted at this time in ferro-cement).

GRP construction is extensive in the pleasure boat industry but few commercial craft are produced in this material. Where they are required to meet survey standards, such vessels are often a stock pleasure craft hull outfitted and equipped to comply with the regulations. Lay up of these hulls in the main is of layers of gunstock and woven rovings and workshops often fall short of ideal conditions making it difficult to apply rules published by classification societies. Each hull must be assessed on its merits, although there is provision for 'prototype' approval for a run of stock hulls. The longest hulls moulded in New Zealand would be in the 53 - 55 foot range.

Survey by a classification society of a vessel built in New Zealand does not exempt that vessel from any of the mandatory requirements for plan approval and construction survey by the Marine Division.

In framing construction and other requirements for small ships close liaison is maintained with the New Zealand Ship and Boat Builders Federation and Fishermans and Shipowners Associations. In introducing the above construction requirements one of the more difficult areas of disagreement with owners and builders arose over the provision of freeing ports in fishing vessels. We have now arrived at the position where vessels over 80 feet comply with the IMCO recommendations and vessels of less than 50 feet have a freeing area of 5% of the bulwark area in the after two-thirds and 2% of the bulwark area in the forward third of the deck length. For intermediate lengths of vessel the freeing area is derived from an interpolated scale between the requirements at 80 feet and 50 feet. One must be careful not to legislate for too great a freeing area which will probably encourage, in our experience, the small boat fisherman to block off the freeing area during fishing operations and defeat the object.

MEASUREMENT OF SMALL SHIPS

The tonnage of New Zealand registered ships are ascertained in accordance with the Shipping Tonnage Regulations 1969. These incorporate the IMCO recommendations of 1964.

With the exception of home trade ships of less than 24 metres, fishing boats, pleasure yachts, and barges, lighters etc. load lines are assigned in accordance with the Load Line Rules 1970 which give effect to the International Convention on Load Lines 1966. Mandatory submersion lines are assigned to a range of vessels which are not load line ships. These include vessels under 24 metres which are home trade or restricted limit cargo ships, and both bona-fide workboats and restricted limits passenger ships provided they exceed 100 tons gross. Unmanned barges, lighters etc. exceeding 50 feet and sailing ships which are not pleasure yachts are also included. The onus for determining the minimum freeboard for a submersion line ship rests with the Surveyor carrying out the survey but to maintain conformity the requirements of Load Line Rules 1970 are used as a guide, for barges a standard procedure has been adopted, and all freeboard assignments are submitted and checked by Head Office.

The Passenger Ship Construction and Survey Rules 1972 require all foreign going and home trade passenger ships to have a standard of watertight subdivision in common with the SOLAS convention. Restricted limit passenger ships are required to be provided with a collision bulkhead and such other bulkheads as are considered necessary. It is usual practice to require flooding calculations for at least a one compartment standard of subdivision for vessels carrying more than 50 passengers. Fishing vessels over 30 feet are required to have a collision bulkhead and over 50 feet are to have the machinery space enclosed by watertight bulkheads.

No stability criterion for small ships have been drawn up other than the standard conditions laid down for load line ships and an initial inclining test for passenger vessels.

EQUIPMENT FOR SMALL SHIPS

Regulations concerning Lifesaving Appliances, Fire Appliances, Radio, and Compasses covering all classes of vessel are published by the Ministry.

The Lifesaving and Fire Appliance requirements are in line with SOLAS provisions and also outline the equipment to be provided on smaller restricted limit ships and fishing boats. Implementing these regulations in the smaller passenger launches, workboats and fishing boats has prompted much discussion in the past and consideration is being given to easing the requirements for fire appliances in the smaller surveyed fishing craft and workboats as a result of these discussions.

The provision of radiotelephone installations on surveyed vessels with the change to single side band equipment probably provoked more controversy than any legislation concerning small ships of recent times. This was caused in the main by the inability of the manufacturers to make available in New Zealand type approved sets at the time of commencement of the regulations and latterly owners particularly fishermens resistance to the substantially increased costs involved. As a result of the former problem temporary permits for the carriage of double side band sets had to be

issued for new construction and replacement sets. The Shipping Radio Rules 1967 implement the SOLAS requirements and relate to foreign going and home trade ships and require radiotelephones on extended river limit ship carrying more than 50 passengers and deep sea sports fishing vessels. Provision of radio telephones on fishing vessels is covered by the Fishing Boat Radio Rules 1971.

MANNING REQUIREMENTS FOR SMALL SHIPS

Minimum manning scales for New Zealand ships are laid down in the Shipping and Seaman Act 1952 and these indicate the certificates of competency required by the officers of each ship. The actual manning scales whilst meeting the minimum requirements of the Act are usually negotiated with the seafarers official organisations.

The manning scales within classes of vessel are based on physical dimensions of the ship, i.e. registered length for deck officers, continuous horse power for engineers and nett tonnage for seamen. This can result in potential owners requesting designs which offer minimum crew numbers in the smaller home trade and restricted limits ships where wages and other crew costs can be the largest single operating cost. We have two proposals before us at the time of preparing this paper for home trade vessels of about 100 feet with a registered length of 89' - 11½" (90' or more two mates, under 90' one mate), an installed horse power of 560 (565 or more one second engineer, under 565 no second engineer), and nett tonnage just under 100 tons (100 tons or more four able seamen plus boy, under 100 two able seamen plus boy). The net result of taking these factors into consideration in preparing the design is a minimum crew of six instead of ten. This same practice has arisen in the design of restricted limit passenger launches in the tourist trade where more and more passengers were being carried on a registered length of less than 50 feet (50 feet or more a master of greater experience and higher qualification required than the local launchmans licence). The registered length being measured to the centre line of the rudder stock meant that the rudders were creeping forward to the stage where some boats experienced steering problems. Design approval of such craft was tightened up and new regulations covering manning of restricted limit ships shortly to come into force relate to the registered length or 95% of the overall length whichever is greater.

CONCLUSIONS

At present and for the future the existing regulations will remain subject to review and new legislation will be enacted as required. IMCO intend to organise an International Convention on the Safety of Fishing Vessels in late 1976 and it is anticipated that our requirements for this class of vessel (over 24 metres) will be brought into line with the Convention. Under consideration for smaller fishing boats is some relaxation in the requirement for annual docking survey and an investigation of vessels to which this relaxation might apply is underway. At some stage a common length for plan approval and survey of fishing boats has to be agreed. Expected to come into force this year are the Cargo Ship Construction Rules incorporating SOLAS requirements and containing provisions for all classes of cargo ship.

It is important in framing regulations for small ships that joint consultation with owners, builders and seafarers takes place when these are in the draft stage, and that they are made aware of forthcoming legislation. This has proved beneficial in our relationship with these people in the past in implementing the regulations. Regulations which are considered too onerous in small vessels may encourage the operator to utilise a smaller vessel to avoid survey and this is often not in the interests of safety.

It is difficult to avoid using physical dimensions of vessels in regulations and to some extent these will be taken into account in the design, if not for manning as illustrated above then for example to obtain minimum scantlings. However, in introducing them into regulations the legislators must take care to ensure that they do not encourage unsafe designs.

ACKNOWLEDGEMENTS

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SMALL SHIPS OF THE AUSTRALIAN DEFENCE FORCES,

A REVIEW OF THEIR ROLE AND ACQUISITION

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Note: the views expressed in this paper are the author's and may not be strictly those of the Department of Defence.

SUMMARY.

The Department of Defence is well involved in the small ship field. Due to the classified nature of Defence plans it is, unfortunately, impossible to be other than vague about future intentions as they affect the Australian shipbuilding industry. In this paper some attempt is made to give the reader a feeling for the nature and extent of Defence marine vehicles and equipment.

More is said, however, about policies and attitudes within Defence which have been expounded to the limits of propriety by the author, in an effort to give the shipbuilding industry some indication of future developments.

It is stressed that any one Defence area is incapable of representing the total situation or forecasting with accuracy and that the author's views are his own and probably narrow. However, he concludes, optimistically, that the Defence forces are badly in need of new and further equipment in the field and that, despite the attitude of some areas of Government and Defence it is inevitable that, in the years to come, most building, equipping, maintaining and modernising will be carried out in-country. If done well and with a will this can attract an export market. An exhortation to design in-country is also included.

INTRODUCTION.

Although relatively small in numbers the R.A.N. is a sophisticated navy whose units cover a broad spectrum of functions ranging from very complex combatant ships down to small training sailing dinghies.

The paper aims, firstly, at developing a conception of the nature and significance of the military sector and, secondly, at indicating future developments by examining Government and Defence policies, changing technology and the shaping of resources in the public sector.

It has been constrained to deal only with aspects which, it is believed, have some relationship with the Australian shipbuilding industry. The reader must appreciate the restraints which apply to a public servant in a very large, diverse Government department and security limitations.

The paper progresses from publishable statements defining the present composition of relevant Defence equipment to an examination of known and predicted trends which will affect the future composition of such equipment. During this exposition it is hoped that a clearer picture is gained of the special nature of and requirements for most small ships of the Defence Services.

Perhaps most important, in regard to the future of small service ships, are the rapid developments in technology. These have steadily increased the cost of ownership of modern warships to the extent where they are rapidly becoming beyond the resources of even affluent countries to acquire in the numbers and of the capabilities they require. On the other side of the coin, however, these developments are offering the small ship an enhanced potential previously considered the province of large ships, which has resulted in a completely new range of concepts including missile armed patrol boats, hydrofoils, surface effect craft and SWATH ships.

FUNCTIONS REQUIRED OF SMALL DEFENCE VESSELS.

Ships for Australia should be designed for Australian conditions. Experience has shown that this statement is particularly true for small ships. In fact, small ships are often much more specialised and need to be tailored for a discrete service. (This adds great weight to the case for having them designed locally where the designer can talk to the users and be familiar with local parameters).

While the scope of this symposium appears to be narrow there is an enormous difference between the functions and standards for a 15 m. boat and a 60 m. ship. For this reason the following summary has been divided as shown. It is indicative rather than exhaustive.

Seaward.

a. Patrol and Interdiction - fishery, customs, health, sovereignty protection, surveillance, interrogation, arrest.

b. Oceanographic and Hydrographic Support - survey of coastal masses, underwater and scientific survey, fishery and ocean bed resources measurement, military oceanography, meteorology.

c. Search and Rescue - service and civilian surface, underwater or air occurances.

d. Training - Fleet, Army and Reserve seamanship, Fleet/R.A.A.F. and coastal co-operation.

e. Fleet Support - targets and target controlling or towing, torpedo/missile/aerial target and buoy recovery, calibration, minesweeping, lower level offensive support.

f. Defence Support - short sea transport, lower level offence and defence, convoy protection, mine-laying, minesweeping, towing, helo replenishment, Defence research and development.

Coastal and Estuarine.

a. Assault - Army embark/Transport/disembark; and wharves, alongside and beaches.

b. Minecountermeasures - minehunting, sweeping and clearance.

c. Harbour Support - towing, berthing, moorings, firefighting, lighterage, replenishment, reception of liquids, disaster relief.

d. Riverine - survey, patrol, transport.

TYPES OF SMALL SHIP FOR DEFENCE SERVICES.

The Defence area has been through a lengthy, low-key/low-decision period for ship acquisition. It is ten years since a combatant surface ship was laid down for the R.A.N., anywhere. It is the author's opinion that changes of government, too rapid cycling of decision makers and a new-look, in-depth methodology for new projects in Defence Central has not speeded matters recently. (Paralysis through analysis/costs and not values?). However, there has been some activity in the small ship sector. The following summary of the present register of small ships, is, therefore, likely to be less than it might have been.

List of Ship Types Currently in Service.

Type	Numbers	L.W.L.(m.)
"Attack" Class Patrol Boats	11	31
Torpedo Recovery Vessels	3	25
H.M.A.S. Flinders (Hydrographic Ship)	1	46
H.M.A.S. Bass and Banks (Survey Ships)	2	29
H.M.A.S. Kimbla (Research Ship)	1	49
M.C.M.V.s	5	45
H.M.A.S. Paluma	1	37
Bronzewing (Tug)	1	29
L.C.H.s	6	40
Seal, Otter, Tortoise (Diving Tenders)	3	34
Fresh Water Lighters	3	36
Motor Stores Lighters	2	24
L.C.M. 6	3	17
L.C.M. 8	18	21
Army Tugs	2	16
Army Wooden Cargo Vessel	1	28

Possible New Construction

Type	Numbers	Approx.L.W.L.
Patrol Craft (more than one class ?)	- -	40 m.-60 m.
Small Coastal Tanker (Fuel/Water)	5	60 m.
Mine Counter-Measures Vessels	- -	-
Torpedo (etc.) Recovery Vessels	1	25 m.
Harbour Tugs	2	25 m.
Submarine (Training/Special Operations)	1	40 m.
Submarine (Oceanography)	1	30 m.
Submersible (Continental Shelf Research)	1	15 m.
Army Craft (Survey & Riverine Transport)	-	-
Army Landing Craft	-	-

SPECIAL FACTORS WHICH INFLUENCE REQUIREMENTS AND TYPE OF SHIP.

This section should prove of benefit to those unfamiliar with Service ships. The aspects are obviously not treated in any depth, the object being to draw attention only to the special factors which dictate the requirements and standards of Service vessels. Virtually all aspects apply to the more sophisticated types such as patrol boats while fewer are appropriate to supporting or special Service vessels, the latter having other, particular features not dealt with here.

Ship Design - It is not claimed that the higher performance, small military ships constitute a greater challenge to designers than do their specialised counterparts in the commercial sphere. However, Defence ships do tend to be more complex and at the same time have less room for the additional crew, equipment, fuel, etc. which needs to be carried. The Defence designer is faced with a 'committee' of customers whereas the commercial designer, hopefully, has only one. While a Tuna Boat, for example, is a challenge in its precision and compromise of conditions, a Service ship usually tests the designer just as much in other directions. However, construction and maintenance of Service vessels is often more difficult with their increased complexity and more advanced equipment/systems fitted into a smaller space.

Ship Performance - Australian Defence ships frequently need a combination of relatively high top speed, great range at elevated cruising speeds, ability to maintain good speeds in adverse sea conditions but be sufficiently sea kindly to remain fully operational without undue crew fatigue or equipment failure. Have sufficient reserves of stability and subdivision to withstand severe damage. Keep accelerations from seas and shock from underwater explosions as they affect crew, equipment and machinery, within prescribed limits. Be completely reliable at all times. Operate efficiently at low speeds, be self-berthing and highly manoeuvrable at sea. Keep habitability noise and vibration within set limits and, at times, radiated underwater noise. Achieve good echo-sounding and, if applicable, sonar performance in the worst conditions.

Human Support - To achieve high performance, both hydro-dynamically and operationally means penalties with regard to space, weight, power-generation and consumables but at the same time crew numbers are inescapably higher than for a commercial vessel. Accommodation standards and habitability will be the subject of close scrutiny for pruning. However, when a ship must stay at sea for many weeks the crew expects conditions to be not too different from home. The same can be said for most working spaces. The solution to this problem is always as popular as a national wage judgement. However, in an effort to break the deadlock and to keep ships as small and as cheap as they might be some novel approaches are now being investigated.

Structure, Machinery & Outfit - Structurely, Defence vessels are often designed to one's own standards and not to a classification society's rules. The hull must usually be lightweight but must still last for 15-20 years and be driven hard. It necessarily follows that design margins will be lower. As a greater risk is unacceptable, the 'ignorance-factor' must be cut down and quality assurance stepped up. Modern methods of relating structure to sea states and reducing structural redundance must be used.

Machinery, equipment and outfit must be completely reliable and designed to withstand the rigors of hard driving, extended tropical operation, sailors, underwater shock, blast, extended periods between refits, etc. Techniques of on-board maintenance, vibration analysis duplicating systems and equipments, special mountings, planned maintenance are just some of the methods used.

Optimisation - This aspect, while being no more important than for a commercially competing vessel, seems to be taken more seriously for Defence craft. Where several vessels are to be built from the one design the pay-off from greater design effort will be magnified. There is at present a greater awareness and consequent effort being applied to staff development, design management and techniques for system designing, systems integration, operations research, value engineering, cost/weight/space planning and monitoring, through-life costing, developability, maintainability, etc. during the design phase. Lateral thinking, decision processes and justification are being applied more methodically with a view to not only optimising the design but providing documentary evidence of how this was achieved.

Such methods call for a greater number of technologists who are better trained and developed than their predecessors and who have fresh minds and a new approach to ship design, construction and repair.

Operations - It has already been stated that small Defence ships are often expected to operate in demanding conditions. Sustained tropical usage, operations in areas populated by coral reefs, obstructions and shallow bottoms are common hazards. The ability to get to sea quickly is important. However the special nature of small Service vessels is often more noticeable in their equipments. Many special equipments are often fitted not common to commercial vessels, eg high powered communications, armament, high-definition/long-range radar, sonar, special communications with shore, submarines and aircraft, very accurate navigation, special power supplies, special military equipment, working boats, possibly a helicopter, etc.

Support - With so many vessels and items of equipment the Department of Defence, as a large-scale owner, is naturely very interested in standardisation to simplify all elements of support particularly spares, training and documentation. The purchase of ships from different countries worsens this situation. Local design gives greater opportunity for standardisation but, more importantly, for local participation with the manufacture and supply of equipment. Local design also maximises maintainability as ships can be designed to suit local conditions, location and turn around.

FUTURE TRENDS IN REQUIREMENTS AND EFFECTS ON INDUSTRY.

Preamble. We know that invention is bread from necessity but modern technological history has shown us that frequently requirements are inspired by the availability of newer technology. It might, therefore, be useful to speculate on the areas of new development which, in the author's opinion, show some promise in the future for Defence application as well as try to predict the directions for development which requirements will dictate.

Technological Developments.

Earlier it was suggested that technological developments could price many

of the conventional warships out of business and introduce a new era for the small ship. It may now be appropriate to outline some of these developments and speculate on how they could affect future warship design.

The most significant development as far as weapons are concerned is the guided missile which can now be launched towards ships from aircraft, other surface ships, or from submarines. This has led to a significant proportion of the cost of a surface warship being diverted from offensive capability to self defensive to the detriment of its primary function of providing protection to other ships from the aircraft, surface and submarine threats.

The second most significant development seems to be the nuclear submarine with its long range and high speed which pose a difficult problem for any conventional surface escort without airborne surveillance and attack capabilities.

Thirdly, is the problem of the mine which can be laid by aircraft, submarines or even the apparently peaceful merchant ship going about its lawful business. This can, for some time, bottle up a port or harbour until the threat has been cleared.

Now we reach the 'chicken and egg'situation:- do the advances in technology inspire invention or vice-versa? Without getting into the realms of classified information it can safely be stated that for every problem there is a solution but the options are becoming more and more expensive to achieve particularly for a small navy like the R.A.N. with a doubtful industrial backing.

Therin lies the opportunity for the 'small ship' which is relatively cheap and perhaps in war time, if we have sufficient numbers, expendable.

Both the Egyptians and the Israelis have demonstrated the capabilities of missile-armed patrol boats against larger surface vessels and, in consequence, considerable impetus has been given to the Western World to design and develop a new breed of ships ranging from conventional patrol boats, hydrofoils and surface-effect ships, all armed with surface to surface missiles to counter the surface warship threat.

Likewise, with anti-submarine warfare, the threat posed by submarines, conventional or nuclear, has led to a whole new series of underwater detection devices. Naval architects then have the problem; how does one attack and destroy a detected submarine which is faster than surface escorts? One option, of course, is aircraft. Others, which are being given serious attention by other navies and have led to developmental programmes, are the hydrofoil, surface effect ship (SES), small waterplane area twin hull (SWATH) ship, etc.

Mine countermeasures however, present an entirely different problem. The consequences of mine warfare, as evidenced during World War 2 with the German development of the magnetic mine, has continued and we now have moored mines which can be exploded by contact or ground mines which can be activated by magnetic signature, acoustic signature, hydrostatic pressure changes, caused by ships passing over them, or combinations of any of these effects.

These threats have lead to significant technological developments, not only in mine detection and disposal methods, but in ship design to produce mine countermeasures vessels that are not only non-magnetic, resistant to explosive damage and acoustically safe but also small enough to produce a relatively safe pressure signature. One of the results of these developments is the construction of H.M.S. Wilton which is the largest GRP vessel yet built.

There will, no doubt, be more of a similar type to follow:

The Future.

The foregoing has set the scene by stating the problems and suggesting the part that small ships can play in the Australian military service. The question, obviously, is; where to from here?

A perusal of Jane's Fighting Ships, having in mind that the expected life of a small ship is 15 to 20 years, a destroyer 25 years and a large ship perhaps 30 years, will indicate that most of the R.A.N. fleet units are due for replacement between now and the next 10 to 15 years. It follows that the R.A.N. is very concerned about the replacement programme in terms of the types of ship that will be introduced and where they will be built. For small ships some idea of new construction has been given earlier. However, because of both a natural conservatism towards new concepts and present policy to procure only existing, proven designs, it is unlikely that new types of ship will be seen seen in this country for some time to come. New construction of small ships will, therefore, almost certainly cover conventional practices except for one or two interesting exceptions. Comments on where ships are likely to be built follow in the section of policies, etc.

POLICIES, ATTITUDES AND INTENTIONS

When one tries to examine Government, Defence Central and Department of Manufacturing Industry policies towards the acquisition of new marine vehicles and equipment for the Defence forces difficulty is encountered in obtaining anything in writing at the effective or implementation level. Guidance is chiefly in the form of attitudes and these, in turn, are usually transitory or veiled by politics. The author's statements are, therefore, tendered with some apology and warning.

Government Policy. This is much the same as for commercial acquisitions, viz, if it can be performed well and at a reasonable cost locally then 'let us do it locally'. This applies to all phases of ship and equipment design, construction and repair.

Defence Central Policy. Here the attitude seems to be that costs are too high in Australia and technology is too low. 'Let us do it overseas'. However, the weight of politics in relation to this has modified the policy to; buy proven overseas designs, build lead ships overseas and follow-on ships locally, repair locally except in special instances.

Department of Manufacturing Industry. This Department will be superseded by the Purchasing Commission and to some extent by the Defence branches as a part of Defence integration and streamlining. D.M.I. policy of detailed project definition and open tendering for everything (including conceptual design) has consumed a great deal of manpower and money by government and industry alike. However, this situation will not change a great deal because of Public accountability.

Army and Navy Technical Services. Superficially, the Naval Technical Services is obliged to implement Defence Central policy. Because of the long periods it takes to fully react to policy changes and because technologist development takes many times longer than project development, N.T.S. interpretation must be open to deviation, perhaps considerable deviation.

The significance of N.T.S. policy is not obvious at first. Defence Central policies, as it will be shown, are contrary to the best interests of the Australian shipbuilding industry. Likely N.T.S. modification to Defence Central policy is working in the interests of the industry.

The N.T.S. is now in the process of greatly increasing its design capability at the same time as Defence Central attitude is against local design. However, N.T.S. resources must be employed and used correctly. The most suitable area is in the field of small ship design and construction. Emphasis is being placed on developing a greater sense of professionalism in the areas of ship design, construction, research and technical management.

Adverse Side-Effects from designing overseas.

Degeneration. Non design participation locally is largely self-destroying. Unless a steady extent of in-house/in-country ship design for Defence is carried out the experts and expertise dissolve until a situation is reached in which insufficient technical know-how exists for credible task definiton, esoteric dialogue and meaningful evaluation to take place. This technological degeneration has effect on the capability of the shipbuilding and ship repairing industry and also on the general in-flow of overseas maritime knowledge. University consultative services and research potential are lost as the need for tertiary training and courses disappear.

Compromision of Requirements. It is essential, for economic reasons, to optimise each design. This not only means optimised with respect to the internal integration of the design but, as a whole, externally to the requirements and service for which it is intended. Optimisation cannot occur where requirements are vaguely defined. Users need experienced technologists to validate their requirements through iterative processes. As previously stated, small ships are usually relatively more specialised than larger ships due to having and being capable of performing fewer functions. They should be designed for a precise service and local, Australian conditions. The chances are high that procuring an off-the-shelf design will mean unpalatable compromising of requirements and less than optimum performance of real ship functions, ie less value for cost.

Re-Design. Re-design, to some extent, is inevitable for follow-on ships and, to a larger extent, at half-life modernisation. Where the ship has been designed overseas, detailed information, design data and design philosophy are imperfectly known locally. However, because of contractual difficulties and management problems local re-design is likely to be favoured. The disadvantages from not having performed the original design are obvious. Should overseas re-design be done the possibility of overseas modernisation/refit becomes greater.

Loss and Restrictions of Local Business. There are very few overseas ship design agencies. Virtually all designers of small ships are primarily shipbuilders. Shipbuilders are rarely prepared to commit their design resources unless the balance and much greater profitability from building ships is forthcoming. For this reason designing overseas will usually mean building at least the lead ship overseas. In this way, also, lies the most viable means for the designer/shipbuilder to ensure that his objectives of weight control and quality assurance, to meet his guaranteed performance are met. Overseas designing can lead to licensing arrangements which will restrict the opportunity for local yards to compete for follow-on ships.

Obsolescence. The avoidance of technical risk by buying a 'proven' design contributes to obsolescence. The procurement of existing designs which approximate one's requirements also eliminates the need for and, therefore, value from conducting some form of in-country R and D program.

Knowledge Flow. Knowledge, as a by-product of local design, would flow on to shipbuilders, ship repairers, industry, Fleet back-up organisations, educationists and overseas (where it has exchange value). This flow stems from documentation by and migration of technologists. It represents one real although less tangible means of increasing the industry's efficiency and reducing costs. These benefits are severely reduced when Australian ships are designed overseas.

Standardisation. Designing in-country assists building, operating and repairing in-country. If ships are acquired from different parts of the world a 'polyglot' situation develops with regard to sizes of fittings, use of materials, equipments fitted, standards used, documentation supplied, etc., which is an operator's and maintainer's nightmare. The supply back-up organisation and stocks held must grow greatly in size and complexity probably completely offsetting any prime cost savings in ship purchase over the life of the ship.

Having one's own standards is possible through and springs from doing one's own ship designing. In fact, once a good range of standard drawings and specifications, for basic ship sizes, is produced a great deal of the detail ship design work is already completed for all ships. Such standards already substantially exist in this country. In-house standards also mean user satisfaction as these standards are evolved from user experience under local conditions and preferences. They also mean ease of manufacture and repair as the standards are designed to suit local methods and materials and are developed with the assistance of local industry. Compatibility/interchangeability are maximised reducing ship down-time and saving costs.

Export Potential. Our neighbours have shown interest in our 'home-grown' small ships and have acquired some already. In-country designing and building, especially if more professionally carried out, as described earlier, will almost certainly attract export orders. It will also enhance national prestige and relations. (Values?)

Overseas illusions. Many of the advantages to be gained from overseas procurement are illusory. To quote an example: as is well known negotiations are underway to procure a proven overseas patrol boat design with a view to ship acquisition. In the author's opinion the total Government effort in this venture approximates in cost the amount of work necessary to produce an in-house design. The total time to carry out the operation is also about equal to the time it would take to complete an in-house design.

If total (World) effort is considered then the current method is consuming more resources, including costs. The cost to the Australian Government will be more when the design and building licence fees are paid not to mention the many extras which will inevitably arise.

For this we will receive a design which has few technical risks but has been optimised to someone else's requirements, perhaps de-optimised to suit some of our requirements, will be tending towards obsolesence when built, could be a maintainer's problem, etc. and the in-depth technology of which will always remain an overseas commercial secret.

Robert defence vessel - ISV defence

The "Attack" class of boat was designed in-house. Because of the above the Public must conclude that they have been less than satisfactory. However, when one considers that they were designed in 4 months, in the face of Indonesian confrontation, built without the benefit of tank testing and prototype evaluation (ie 20 boats built off the drawing board) and kept as small and simple as possible, their performance has proved to be better than satisfactory.

CONCLUSION

From the foregoing it seems safe to assume that it is in the Australian shipbuilding industry's interests for small ships to be designed in this country. In the Defence area the author predicts that, while the trend recently has been away from this, the 'pendulum' will swing back within the next five years due to strongly developing in-house capability and lessons to be learned. However, most small ship construction work will probably be undertaken in Australia at all times and this should show an increase over the level of construction which has occurred during the past 8 years. Due to licensing, consortia arrangements, etc. tendering may be limited to some extent.

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AN OUTLINE OF DREDGING AND THE ROLE OF DREDGERS IN THE AUSTRALIAN ENVIRONS

by

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Dredging projects throughout the world in general and Australia in particular tend to conjure up an image of berths and harbours but this is only really the tip of the dredging iceberg. The reclamation or improvement of foreshores, deepening of approach channels, enlargement of turning basins, widening of "tight spots", realignment of entrances are but a few of the less apparent functions of the dredge. In particular cases the changing of bottom topography is used as an aid to wave control as is illustrated in Botany Bay, N.S.W. where the creation of a relatively swell free zone has been achieved by excavating a deep zone near the entrance to the Bay. In Lyttleton, New Zealand, dredged spoil from harbour development works has been deposited in specific areas towards the seaward end of the harbour approaches with the result of diminished wave and swell effect in critical areas. Such a benefit could undoubtably have been achieved by conventional breakwater construction, but by careful dumping, improvement has taken place as a function of dredging without additional expense.

The principal task of dredging may be defined as the work of dislodging, raising, transporting and depositing materials ranging from soft silts to hard rock. Each and every one of these functions can be distinct in itself and the object of the particular excercise. Some recent Australian examples of the various prime purposes outlined are:

Dislodging

Excavation of materials from silt to basalt in Port Kembla Harbours where the materials were dislodged by suction, ripping, revolving cutter, grab bucket, plaster or surface blasting, drilling and blasting.

Raising

Again in Port Kembla materials were raised hydraulically, and mechanically.

Transporting

Dredged sand in Botany Bay and at the Gold Coast was transported as a slurry from the excavation area to the discharge point by pumping from the dredge through a pipeline. Alternative transport methods would have been

difficult and expensive by comparison. Transport of materials in hopper dredges or barges provides for medium to long distances as in the case of Weipa or Port Kembla.

Depositing

Creation of industrial land at Botany Bay, restoration of beaches at Surfers Paradise, provision of land for development at Port Hedland are some examples of successful deposition of materials.

From relatively crude implements used to shape and improve natural land/water interfaces development has emerged in a variety of ways for many different purposes. It has been usual that estuarine areas became locally used for loading and unloading of vessels where still water conditions could be expected and fresh water for the vessel was available within close proximity. As vessels increased in size and number it then became necessary to enlarge the natural facility hence the emergence of scoops, grabs, draglines, etc. The ability of such equipment to handle harder materials necessitated the introduction of machinery which could "attack" the harder materials more positively - the bucket dredge or the cutter dredge. Development of the port area with drains, effluents and the like combined with agricultural advances in the hinterland combined to increase siltation and further dredging for pure maintenance purposes.

Much more recent trends where completely artificial harbours have developed in regions where the cargo or commercial activity is centered have led to offshore dredging, often with protective construction, but necessitating robust weather safe equipment.

However, there are essentially only two basic types namely

(1) hydraulic, and
(2) mechanical

and the dredgers comprising these two groups differ vastly in character. Examples of these dredge types operating in Australian waters are as follows:

Hydraulic Type: Suction Trailer and Cutter Suction
Mechanical Type: Bucket, Grab, Dragline.

Of all those listed the Suction Trailer Dredge is the only self-propelled and self-supporting vessel and is possibly one of the most modern and radical developments the industry has produced to date. Although the remaining dredgers are all stationary vessels they have one main difference; the mechanical dredgers all require secondary means of re-handling and transporting the bulk material which has been dredged while the hydraulic cutter suction dredge fluidises the material which can then be pumped many miles to the disposal or reclamation point.

The large Australian built cutter suction dredger W.H. Kunara reclaimed all the sand one sees on the northern side of the embryo Port of Botany Bay and recently her smaller sister W.H. Karlye built at Mortlake, N.S.W. in 1972 dredged sand from the broadwater at Southport, Queensland and pumped the sand up to 6 kilometres along the sea front at Surfer's Paradise and restored the beaches which had become eroded due to the effect of weather, particularly cyclone storms.

Each of the two dredging pumps on W.H. Kunara is direct driven by a two stroke diesel engine rated at 2430 B.H.P. at 300 rpm. Both pumps in series have a capacity of 2,500 litres/sec against a discharge head of 110 metres water column.

The 276 ton cutter ladder is suspended from a gantry by wires which are used to lower and raise the ladder about its hinged connection to the fore end of the main pontoon. A maximum dredging depth of 23 metres can be attained. The cutter, cutter shaft and its geared electric drive are mounted on the top decking of the ladder whilst the suction pipe into which the cutter head feeds material is supported under the ladder. This pipe is connected to the main pontoon by a flexible rubber hose which is in turn connected to the 800 mm dia. pump suction line.

The pumping arrangement is such that a single dredge pump may be used, or two pumps in series, depending on the conditions to be satisfied. The pumps discharge through a 700 mm dia. pipeline. The floating section of this pipeline which trails directly behind the dredger must be long enough and flexible enough to enable the vessel to be manoeuvred as may be necessary. This is normally achieved by joining pontoon mounted sections of pipeline by balljoints.

Manoeuvring can be carried out on mooring spuds or on anchor wires reeved through a triple point sheave carriage known as a Xmas tree. In both cases the cutter head is pulled into the material to be dredged by side anchor wires which are connected to each side of the ladder at its extremity. The path described by the cutter as it is moved backwards and forwards by the side wires is an arc centred on the spud or the Xmas tree depending upon which one is in use at the time. When working on spuds a closer control of the operation can be maintained. This is made possible by having one large spud housed in a travelling spud carriage and a smaller auxiliary spud secured directly to the main pontoon. The spud carriage is mounted on rollers and is connected to the main pontoon by a hydraulic ram. By dropping the main spud the spud carriage becomes anchored and the main pontoon can then be walked forward a distance equivalent to the stroke of the hydraulic ram (5 m.ft.) in controlled and calibrated steps. The auxiliary spud is used to hold the main pontoon in position while the spud carriage is being repositioned for another cycle.

A very large cutter suction dredger such as W.H. Kunara has the advantage of being able to utilize the momentum of heavy duty cutter heads (11 tons) and when these cutters are fitted with correctly selected and positioned points and adaptors can dredge conglomerates the majority of the sedimentary and some of the metamorphic rocks without pre-treatment of blasting.

This dredger's capability in such material depends on the capacity in relation to the quality of rock "in situ" and consequently it is difficult to describe the limit both technically and economically by reference to pressure or tensile strength of the rock itself. In Port Kembla "W.H. Kunara" performed extremely well and blasting was resorted to only when it became economically impracticable to continue unaided.

To keep the dredger in the right position and cutting at the right place on the face of the bank and at the right depth modern electronic equipment is used.

The Bucket dredger continues to play a large part in some dredging operations and like the cutter suction dredger can perform in rock and heavy material without pre-blasting. It also has one great advantage that when it completes its dredging and has dredged to grade the harbour or channel bottom is level and has fewer furrows and irregularities.

One development from the multi-bucket dredger is the grab dredger. The W.H. Goomai built by Favelle Mort of Sydney in 1970 is a good example of this non-propelled type of dredger.

The grab crane is mounted on a 150 ft. x 65 ft. pontoon which can be positioned for dredging on either mooring spuds or mooring wires. A large cylindrical superstructure constructed on deck serves the dual purpose of providing the base for the 32 ft. diameter slewing track of the crane and facilities for the crew.

The crane/dredge is capable of handling heavy duty clamshell grabs which have a weight of 25 tons and a capacity of 10 cubic metres at a line speed of 210 feet/min. Dredging can be carried out to a depth of 150 ft. and sophisticated electronic equipment shows at all times the exact position of the grab compensated for tidal variation.

The dredge can also be used with a dragline bucket of 65,000 gross load at 105 ft. radius or it can be rigged for heavy lift work, in which case it has a rating of 260,000 lbs at 48 ft. radius.

The advantage that the grab dredger has over the multi-bucket dredger is flexibility and versatility. It would be true to say that the bucket dredger would get greater production when working in suitable material but the grab dredger has a greater range of materials in which it can work and has more mobility and flexibility as to areas in which it can work.

Rock Blasting Equipment

As evidenced at Port Kembla and in future operations in Newcastle it will be necessary for a dredging contractor working in Australia to specialize in Rock Breaking and Dredging techniques. WestHam in Port Kembla called upon the assistance of one of the associated companies of the Bos Kalis Westminster Group namely Rock Fall Company of Glasgow and this company using the Drilling Rig "Seacow 17" successfully blasted the igneous basalt rock and the fragmented rock was picked up by the grab dredger W.H. Goomai loaded into the two Vuyk type split barges which in turn were towed to sea where their contents were dumped.

The drill barge needs to be a pontoon of extremely robust construction enabling operations to continue in moderately heavy weather.

It should carry a gantry running fore and aft along the pontoon or barge. The gantry supports approximately 4 drilling rigs. In principle the process of drilling and blasting the rock is that the barge is positioned, a pattern of holes is drilled. A special casing tube accompanies each drill and remains in position in order to prevent any soft overburden entering the hole when the drill is withdrawn. A pre-determined charge of explosive is lowered through the tube into the hole.

The amount of explosive depends on the local situation and upon vibration test previously carried out. With the barge moored in one position, the required number of holes are drilled and upon completion the barge is moved to a safe distance charges exploded and the cycle starts all over again. When the rock area has been blasted and the rocks fragmented the dredger be it grab, bucket, cutter suction or suction trailer comes in and dredges the broken up rock.

Trailer Dredgers

As previously mentioned the one dredging tool which has revolutionized dredging in Australia since the end of World War 2 is the suction trailer hopper dredger.

The first commercially owned trailer in Australia was W.D.53 which Westminster Dredging brought in to dredge Botany Bay to take the tankers into the area around Kurnell and later the same company imported W.D. Seven Seas. One of the conditions allowing the importation of these vessels was that replacement dredgers were to be laid down and built in Australia and once the new vessels were commissioned the imported vessels had to leave the country. This has happened and the new dredgers are W.D.A. Endeavour and W.H. Resolution.

Australian Dredging and General Works Pty. Ltd. have also built their trailer A.D. Geopotes 1 and The Queensland Government have their Sir Thomas Hiley and the Victorian Government have a hybrid dredger part trailer part cutter the second "Matthew Flinders".

These trailer type dredgers are self-propelled sea going ships complying with all the safety equipment and loadline regulations applying to sea going ships of their size and tonnage. The material is dredged up from a draghead fitted to the end of a suction pipe in the case of W.H. Resolution two suction pipes are fitted, one each side thro' which the spoil is pumped into the internal hopper. The horsepower of the machinery installed in a trailer dredger is far greater than that usually installed in other types of dredgers.

The displacement of the vessel, the horsepower of the pumps and the pull of the draghead over the sea bottom due to the thrust of the propellers; cut the material and feeds it into the draghead in such a manner that fluidization takes place for hydraulic dredging. The design of the draghead varies with the type of material being dredged. This affects the angle of a cutting blade fitted to the draghead like a bulldozer blade, size and number of teeth, and many other variations carried out locally at site usually after consultation from the Technical Department of the company.

As mentioned these dredgers are issued with an International Freeboard Certificate. The Freeboard Rules provide a loadline for a ship between A and B class and the trailer dredger is in fact a B-60 ship.

The Department of Trade and Industry will give a dispensation from this loadline for U.K. registered vessels whilst they are dredging a harbour and proceeding to sea a short distance to dump spoil providing the vessels reach certain standards. This allows the vessel to load deeper to 5/8 of the International Freeboard.

The matters considered are dynamical stability, range of statical stability, and the intact stability of the vessel taking into account the effects of free surface or liquid in the hopper and the ability to discharge quickly the spoil from the hopper.

These trailer dredgers because of their navigable qualities do not impede traffic entering or leaving a port are easily made ready for voyaging between ports, can shift enormous quantities of overburden, sand, silt, mud in a very short space of time.

They do require however generally more maintenance, bigger crews and personnel holding Certificates of Competency issued by Marine Statutory Authorities. They are usually classed by a Classification Society, and in addition to normal seagoing skills and qualifications, the personnel have to possess a knowledge of dredging which can only be acquired by experience.

Future Developments

In the case of new ports the accent is towards deep water considerations and weather protection in reasonable proximity to proposed product or industry and consequently this initially involves intense local investigation which will precede any port development and the limitations can only be properly explored by small vessels.

The use of smaller dredgers is usually not so critical in the cases where progressive deepening and enlargement can commence from the deepwater approaches and where there is relatively little traffic to be impeded. However the dredger still needs support craft to establish and maintain shore control, survey as well as to service her daily needs. These support crafts consist of tugs, survey vessels, hopper barges, anchor barges, fuel barges, A frame barges all backed up by workshops ashore manned by welders, fitters, riggers, labourers, etc.

Whilst the advent of larger dredgers, survey ships, investigation craft and barges continues, their utilization is governed by the particular work required and the economics of that work are becoming more and more critical.

The continuing use of dredgers and their ancilliary craft seems to be assured on the Australian Coast developing new ports, deepening and maintaining existing ports. However, the major problem facing the dredging contractor is the lack of continuity of work. Costly periods of inactivity can be crippling and one solution to help aleviate this problem would be the formation of a National Port Development Authority set up to rationalize the making and development of ports throughout Australia and thus hopefully able to help set programmes of progressive development with the side effect of planned utilization of dredgers.

Dredgers with 5/8 Freeboard
.6 — ashore with d = 5m.
6/5 = 12% — 88%.

SERVICING THE OFFSHORE OIL EXPLORATION AND PRODUCTION INDUSTRY

by

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SUMMARY

GENERAL

It is only in recent years that the world wide search for oil has extended from the shore to areas under water offshore, and indeed the first well offshore was drilled in the Gulf of Mexico as recently as twenty years ago.

Offshore exploration for oil initially was largely restricted to the generally fine weather area of the Gulf of Mexico, and in relatively shallow waters, however, as the technology of this new industry was developed by America, operations extended further offshore, into deeper water. Today exploration and drilling is carried out in deep water and in all weather conditions.

Exploration and drilling offshore first came to Australia in December 1964.

The positioning of floating drilling platforms offshore, and the support of the operations being conducted from these platforms required the use of tugs and cargo carrying vessels, and in the early days of the industry this is exactly what was used. Indeed, in the very early days of drilling offshore, tugs and flat topped lighters were a common method of transporting the necessary supplies from shore to the drilling platforms.

Because of the particular areas in which the industry developed, the initial type of craft was of necessity shallow draft. From the tug and lighter concept developed self propelled barge type supply vessels, to which at a later stage was added a roller over the stern and a heavy duty winch, which comparatively unsophisticated equipment enabled the anchors of the floating drilling platforms to be worked as necessary.

This type of vessel was in use for many years, but because of the square section barge type design and simple construction, free of subdivisional arrangements, many casulaties occurred, particularly with the ever increasing quantities of drill pipe and casing that were carried on deck.

With the continuing expansion of the industry, and an increasing number of marine casualties, the American Coastguard, as the Maritime Safety Regulatory Authority, stepped in, and arranged an investigation into the safety and manning of craft engaged in the offshore oil drilling industry.

From the examination of the types of vessel involved in the support operations for drilling operations in American waters, standards of stability, subdivision, tank construction, tonnage measurement rules, and related thereto manning requirements were evolved, and these standards thereafter became established minimum requirements in conformity with which a somewhat standard type of supply vessels developed. The industry is indebted to Mr. Rahola for his criteria which provided a basis for the stability requirements of the earlier vessels.

Vessels of the order of 120 ft. in length, beam perhaps 26 ft. shallow draft, and powered to give perhaps 10 knots on twin screws, for which a horse power of up to 1000 was utilised, became the type of vessel in general use in American waters until the early 1960's.

From 1960 onwards offshore exploration commenced to extend extensively outside American waters, and about 1963/64 the first of the Gulf of Mexico type of supply vessel, by now increased in size to some 165 ft. x 38 ft. with power increased to perhaps 1700 B.H.P. but still of the same basic hard chine and shallow draft configuration, came to the North Sea.

Despite the fact that these vessels did successfully work in all weathers with the earlier type of rig, it was apparent that they were too small and too lightly constructed for bad weather conditions. The British and Dutch shipbuilders, with their vast experience of European tug, coastal and dredge construction, then entered the field and designed and built larger, heavier and more powerful supply vessels intended for service in more difficult weather conditions.

Concurrently with the general progress towards more sophistication in the supply vessels, the type and size of drilling rig was also developing, particularly towards the large semi-submersible, which required large towing capacity on the attendant supply vessels, and of course, with the increase in size came an increase in the anchoring equipment required to hold these rigs on station. The handling of this equipment consequently required further capabilities in the supply vessels particularly in regard to bollard pull, anchor winch capacity, and even chain lockers for the storage of rig cable.

In general, today, it can be said there is a demand for vessels ranging in size from perhaps 120 ft. to over 200 ft. in length and with horse power in excess of 8000.

THE AUSTRALIAN SCENE

Offshore drilling came to Australia in 1964 when the small floating drillship "Glomar 111" commencing work in the Bass Strait.

This rig was self propelled and came with the small American flag supply ship "Point Coupe". This was a vessel of the Gulf type 120 ft. in length and 1700 B.H.P.

The "Point Coupe" was fitted with a special very heavy duty

winch and the most important function of this craft was the laying and picking up the anchors and cables which held the rig in position.

The associated requirement of keeping the drilling rig supplied with drill stem piping, well casing, (which varies in size from 36" to 4-5/8" and is of a standard length of 45'), cement, bayrites, fuel, and water was at times helped by local coastal vessels.

Additionally the vessels engaged in this support operation had perforce to keep the drilling rig provisioned and transport crew members as required for regular changes of personnel on the rigs.

Looking back ten years one can only admire the manner in which these unsophisticated and unspecialised vessels performed from simple bases ashore.

Thanks to these vessels, and the Global Marine rig, acting on the skilled instructions of ESSO/BHP, Australia today has the Bass Strait oil fields currently supplying a large percentage of the country's overall fuel requirements.

Following the initial discovery of the BARRACOOTA field in the Bass Strait, the Port Jackson and Manly Steamship Company, of which the writer was then Managing Director, became intensely interested in the possibility of establishing an Australian Shipping venture to build and operate specialised vessels to support the newly emerging offshore drilling developments.

The initial effort of the Port Jackson and Manly Steamship Company was a bid to build in Australia, two 4000 HP vessels for forward work with the semi-submersible rig "Ocean Digger". The company's bid was unsuccessful and instead two Dutch flag supply vessels came in from overseas for the initial stages of this project.

With further expansion ahead the Port Jackson and Manly Steamship Co., was fortunate enough to form a joint venture company with the largest and most experienced operator of offshore supply vessels in the world, namely Tidewater Marine Service Inc., of New Orleans.

With the experience of the American partner, the new company, Tidewater Port Jackson Marine Pty. Ltd., engaged the services of the local naval architects, Messrs. Eken & Doherty, and based on developments in American design, and with knowledge of the latest trends in Europe, a supply vessel design was evolved incorporating the 'work horse' features of the Gulf boats, to which was added a more sophisticated hull and propeller design, the work of Mr.J.Eken, and refinements such as bow thruster, pressure tanks for the carriage of cement and bayrites under deck, more sophisticated navigationsl equipment and auto pilots with of course, the high standard of crew accommodation, necessary to conform with Australian standards.

The general arrangement of these vessels was to the

requirements of Esso/BHP and the overall dimensions and stability were such that two 'strings' of drill stern pipe or well casing could be carried on the clear deck space of 90' x 32' to a height of 4', together with 2000 cu. ft. of cement in pressure tank below deck and a considerable quantity of fuel oil and water for the rig.

Tidewater Port Jackson tendered this design to Esso/BHP and was successful in obtaining a contract for the supply and operation of two such vessels for work in the Bass Strait oil fields.

The result of open tendering for the construction of these vessels was surprising in that it proved cheaper to build at private unsubsidized shipyards than at the "recognised yards" which then enjoyed a Government subsidy.

Contracts were placed with A.B.Rea & Co., of Newcastle to build one vessel "Austral Tide" at Tomago and the second vessel "Victoria Tide" was placed at Bundaberg in Queensland.

These two vessels were completed slightly behind schedule and entered service early in 1968.

Two more vessels of this type were then contracted with the same shipyards and these craft as they entered service, replaced American supply vessels of the Mexican Gulf type, then operating for the Burmah group off the North West Shelf of West Australia.

A new company San Pedro Offshore was formed in Australia by the Inchcape group with minor Australian participation and built one small vessel at Stannards shipyard in Sydney and two others of a similar class with Carrington Slipways at Newcastle.

Exploration success in the Bass Strait, some promising results in the North West Shelf areas, caused a rapid expansion in the offshore search for oil and with it the need for more supply vessels to meet the ever increasing demand for logistical support to the rigs coming into service. The result of this demand coupled with the success of the Australian vessels then entering service was such that overseas companies engaged in owning and operating oil rig supply vessels now entered the business in Australia.

The South Eastern Drilling Co., of America commenced construction of two supply vessels to service a new semi-submersible rig then building in Japan. These were, for that period, sophisticated vessels of 4400 horse power. One of these vessels the "Sedco Anne" was built at the Carrington Yard in Newcastle and the other at Bundaberg.

These two vessels for Sedco were designed by Messrs. Eken & Doherty to the requirements of Sedco and were a good deal faster than the earlier generation of such craft, though with much the same carrying capacity, the greater horse power combined with C.P. propellers providing the requisite bollard pull required for moving the large semi-submersible rig and for laying out the larger and heavier mooring gear.

About the same time the Dutch towing company Smit Lloyd bought in, under the Dutch flag, two vessels of approximately 3000 H.P. of the heavier deeper draft type by now evolved for work in bad weather area.

By 1969/1970 therefore we see emerging on the Australian coast three fairly distinct types of supply vessels i.e.,

The small 120 ft. vessel as provided by the Sam Pedro Company.

The medium 170 ft. vessel as provided by Tidewater.

The bigger horse powered vessel up to 195 ft. as provided by Sedco and the foreign flag vessels of Smit Lloyd.

The rapid developments now taking place in the search for oil offshore Australia were such that overseas shipping companies engaged in owning and operating oil rig supply vessels in the North Sea and other overseas areas now entered the business in Australia.

Offshore Marine, which was well established in the North Sea, and also had German participation, contracted a medium sized vessel "Cook Shore" with the Adelaide Ship Construction Company, and very much later a bigger vessel the "Bass Shore" which however never worked in Australia.

Australian Offshore Services, a subsidiary of the P & O Company contracted two supply vessels with the Carrington Slipways at Newcastle. These were vessels of 4000 horse power with a universal type of gantry spanning the beam of the ship and capable of moving over the whole length of the after deck. This gantry was intended for handling rig anchors.

Smit Lloyd, the well known Dutch company, placed orders with the Adelaide Ship Construction Company for the first of a series of North Sea type supply vessels to replace Dutch flag vessels, then in the country.

By 1971 the offshore supply boat business had developed to the stage where there were in excess of eighteen vessels operating on the Australian Coast.

Broadly speaking these vessels could be divided into these principal types, small, medium and large, both as to tonnage and horse power.

Developments in the drilling rigs had also moved forward significantly towards larger and heavier equipment and the supply boat operators, by now becoming increasingly conscious of changing requirements, were looking towards larger and more powerful vessels.

Tidewater Port Jackson Marine were considering vessels of 4000 H.P. with Kort nozzles and two speed gear boxes to give a bollard pull of 66 tons; two of these vessels were built, one at Adelaide and the other at Carrington and proved very satisfactory. Australian Offshore Services, through the naval

architects, Eken & Doherty, developed and commenced construction of a series of interesting larger type of vessel 185 ft. in length and of some 4000 HP with the twin screw propulsion machinery arranged with four engines per shaft into twin input, single output gear boxes, thereby enabling the vessel to operate on reduced power as required. Six of this class of vessel were eventually built by Carrington Slipways which has now emerged as the foremost shipbuilding yard in Australia for this type of vessel.

Concurrently the Smit Lloyd company contracted for the construction of two new vessels with Walkers Ltd., at Maryborough These vessels of 4000 H.P. were of the latest European design and entered service in 1974.

In June 1975 therefore we see that since the commencement of this new industry some 28 small vessels have been built in Australian shipyards to special designs for servicing the off-shore oil exploration and production industry.

Additionally two vessels for the geophysical work associated with the search for oil and gas have also been designed and built in Australia.

Late in 1972, and unfortunately coinciding with the stepped up building programme of the three major supply boat companies, a downturn commenced in the level of offshore work, both in exploration and development, and this of course became reflected in a reduced demand for offshore service vessels, to the extent that from a peak of about 23 vessels fully employed off the Australian Coast there are, in May 1975, only 8 vessels in service.

The reduction in available employment has caused Osmarine to close the Australian operation and withdraw their vessels. The San Pedro Company has reduced its fleet to one small vessel of 120 ft. in length and the Smit Lloyd Company is understood to be contemplating withdrawal from the area.

The two major companies, Tidewater Port Jackson Marine and Australian Offshore Services each have six vessels in service with, it is ~~believed, more planned~~ and one due for delivery late in 1975. When construction of more vessels will commence must perforce depend upon the future progress of the whole Australian oil exploration industry, at present in a very depressed state. Everywhere else in the world however, it is booming.

Particular Requirements

Whilst the vessel serving the offshore oil drilling rigs has emerged as a very special type of craft, the multifarious functions it performs are far from simple and the work it does is always required in a hurry. The drilling operations of the rig are paramount and must never be delayed.

The prime function of the servicing vessel of course is to keep the rig supplied with the many items consumed in the course of the drilling operation, and in order to transfer these cargoes

the supply vessel must be prepared to berth alongside or very nearly adjacent to the rig at any time of the day or night, and this in the open sea far away from land in all but the most inclement of weather conditions.

Damage to the supply vessels and sometimes the rig is not uncommon because of the open sea operations exposed to sea, swell, wind and currents.

To accomplish this requirement to berth alongside in open waters and in a restricted space, often between the anchor cables of the rig leading out in varying angled directions, the supply vessel must be extremely manoeuvrable and with adequate power quickly available.

For this today the rule is twin screw vessels, twin rudders and bridge controls. Such an arrangement, together with a transverse bow thrust unit, provides the Master with the best possible manoeuvering controls for his vessel.

Additionally many vessels are today provided with control systems on a wandering lead which the Master can take with him to the wing of the bridge. With certain types of rig, particularly jack up types and semi-submersibles, and also when working to offshore production platforms it is often necessary to manoeuvre the vessel stern first under the rig crane and to facilitate such manoeuvring an additional engine, steering, and bow thruster control position is fitted at the after end of the bridge. This facility is of course essential for use when the vessel is handling the rigs anchor.

Coupled with the facilities necessary to safely manoeuvre the vessel to the desired loading/discharging position beneath the rig crane is the absolute necessity for the supply vessel to provide the most positively stable platform possible in order that excessive rolling does not damage either the rig or the ship, and more importantly that the personnel working the cargo may do so in the safest possible conditions.

In the earlier supply vessels it was considered that a hard chine over the greater part of the vessels length contributed greatly towards a stable platform when alongside, however, as time passed, a requirement for better speed coupled with the need for more open deck space, which required greater beam, together with better steaming and sea keeping qualities in bad weather, caused the development of a different hull form, which, when designed to meet the ever increasing stability requirements of the various regulatory authorities appeared in practice to reduce somewhat the stable performance of the older type vessel, and indeed 'synchronous rolling' was not an entirely unknown feature.

To avoid these problems and to enable the vessels to work more effectively passive stabilisation systems have been fitted on many of the latest supply vessels.

The major cargo requirements for a rig when drilling is for a regular supply of the drill stem pipe, a tube of relative small diameter, and well casing which varies in

diameter down from 36" to 9-5/8". These items which come in 45 ft. lengths are perforce carried as deck cargo in the supply boats, most of which today can carry up to 400 tons of this pipe material.

The drilling operations mostly require significant quantities of fresh water, (though some systems are salt water) and supplies of cement and bayrites. The supply vessel therefore must be able to carry large quantities of fresh water for drilling and also dry cement or bayrites, and more importantly be able to discharge these materials to the rig under adverse conditions of weather by inbuilt machinery.

Large tanks extending to the main deck are built into the supply vessel for the carriage of fresh water and fuel, and the contents of these tanks can be discharged through separate systems terminating in camlock fittings on each side of the main deck of the supply vessel to which, when in position alongside the rig, flexible hoses from the rig are coupled.

The supply vessels pumps as a general rule are capable of discharging against a static head of 250 ft. through a 4" pipe at the rate of up to 750 gallons per minute.

Cement and bayrites are carried dry in pressure tanks built into the hull of the supply vessel under deck and discharged by a compressed air system forming a separate part of the vessels machinery. Here again flexible pipes from the rig are coupled to deck fittings on the supply vessel. Capacity for this type of material often exceeds 4000 cu.ft. in the larger supply vessels and the demand for this capacity appears to be increasing.

From the foregoing it will be seen that the cargo capacities of the modern supply vessel extend through the carriage of large quantities of piping on deck to fresh water for drilling, fuel for the rig machinery, drinking or portable water for rig crews and cement and bayrites for drilling operations. Additionally of course provision for the rig crew in the form of fresh supplies plus other items in deep freezer and refrigerated chambers are always carried.

Importantly, apart from the capacity to carry these various items, must be the ability to unload the items alongside the rig in the open sea far from land in weather conditions often bad.

Whilst the role of the supply vessel outlined above is paramount it must be remembered that the servicing of the rig entails much more than the mere delivery of materials, and the service role also requires that the attendant rig service vessel be able to lay and to pick up the rig anchors and cables, and be able to tow the rig, not only between adjacent drilling locations but often from field to field which often entails very long journeys.

The modern rig service vessel such as the latest types built in Australia and operated by Tidewater Port Jackson Marine and by Australian Offshore Services is not only able to carry 800-1000 tons of cargo but is capable of long distance towing and of handling the moorings of rigs anchored in over 1000 ft. of water.

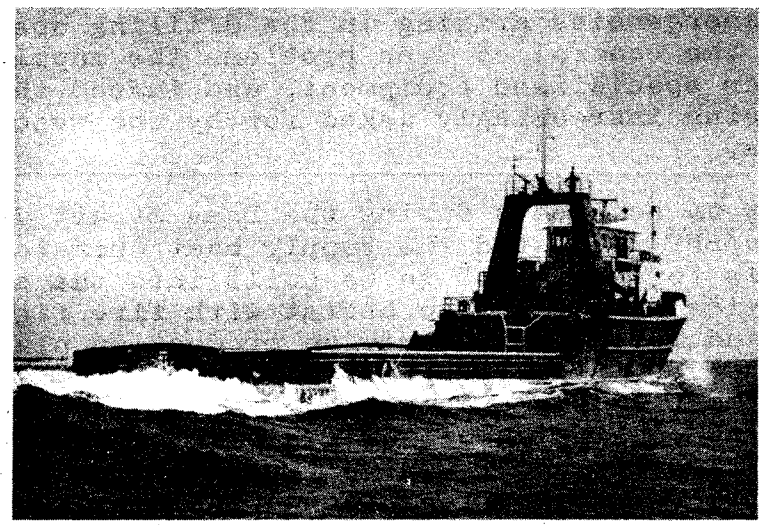
For anchor handling the vessels are equipped with large diameter (5'6") stern rollers extending over much of the width of the vessel over which the anchors are pulled onboard by a single 2" diameter wire rope from a double drum waterfall type winch capable of exerting a single line pull of 250,000 lbs. The two barrels can be operated simultaneously and to control the very heavy (30,000 lb. anchors) the vessels are fitted with two 7 ton capstans and two heavy duty deck winches capable of a 7 ton pull at almost any desired angle.

Additionally, for when it is required to bring the rigs anchor cables onboard, some of the new boats are equipped with large diameter cable lifters and cable lockers both specially sized to the rigs cables.

Some idea of the size of the mooring equipment to be handled can perhaps be gleamed from the fact that recent operations of the Tidewater vessels have involved the handling (right onboard) of rig anchors weighing 30,000 lbs. and measuring 20 ft. across the stabilising bar. To this anchor is attached cable, each of which is constructed of $2\frac{3}{4}$" diameter steel.

During recent anchoring operations in 900 ft. of water at an exposed site on the Great Australian Bight one Tidewater and one Australian Offshore Services vessel each successfully stretched the rig anchor cables out a distance of 3500 ft. to do which each vessel had to exert a bollard pull in excess of 60 tons.

Towing operations are carried out utilising a separate barrel of the vessels towing and anchor handling winch and during a recent operation one Tidewater vessel, the "Northern Tide" and one Australian Offshore Services vessel the "Lady Cynthia", without incident towed the heavy semi-submersible rig "Margie" from a location off Darwin to Sandaken in Sabah, a distance of about 2000 miles at an average speed of 4.6 knots.



4000 HP Modern Supply Vessel

In considering the requirements of the modern supply vessel for towage purposes many factors other than power have to be considered and amongst these the principal factors are:

a) Classification of vessel for towing.

b) Adequate fuel capacity.

c) Spare tow wires.

d) Stability of vessel under the most adverse towing conditions.

e) Satisfactory type of towing winch.

To ensure the maximum suitability of its latest vessels for ocean towage Tidewater Port Jackson Marine referred the specifications of its vessels to Noble Denton & Associates Ltd., a firm of Marine consultants based in London and specialising in towage work. The recommendations of this firm have been implemented and consequent thereto this vessel now figures in the international list of vessels approved for rig towage.

The requirements of the modern supply vessel have now been refined to the stage where it has become a small cargo ship with the specialised facilities of a small tanker. It is also an anchor handling vessel and tug capable of ocean towage - what more is left ?

Drilling for oil is at all times a hazardous operation and especially so offshore at sea. Dragging of anchors through uncommon, is not unknown and the rig has to be remoored - bad weather requires cessation of drilling and there is the ever present risk of blow outs and fire. For these contingencies the rigs are never left unattended and supply vessels frequently spend long periods 'standing by' the rig. This presents no problem except equipment capable of anchoring the vessel in depths of water greater than normal.

What of blow out and fire on the rig or a major oil spillage:

Here are emergencies arising in the drilling operations and to assist with the control of such problems the supply vessel requires further specialised equipment, and indeed these are capabilities being increasingly asked for by the major exploration companies.

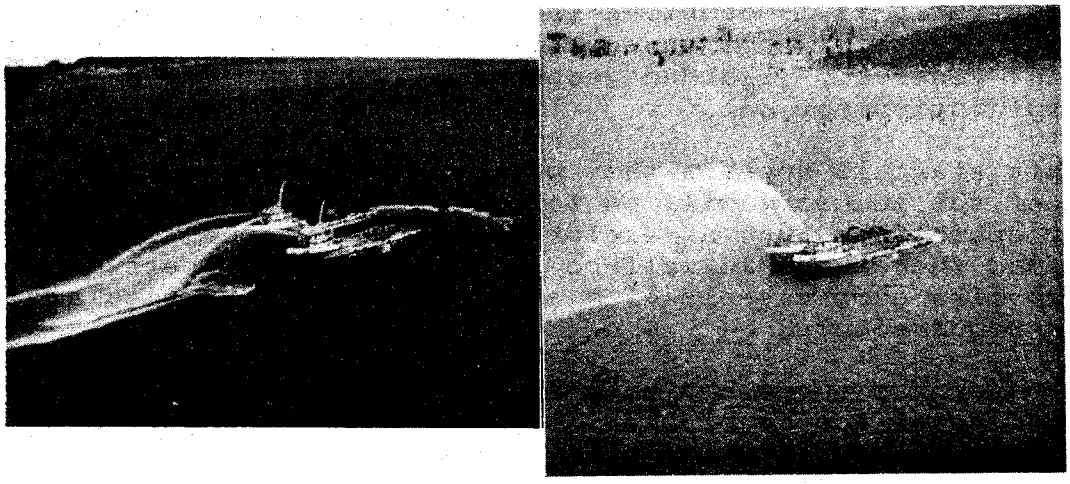
Consequent on accidents during the Bass Strait drilling operations Esso/BHP requested the supply boat operators to submit proposals for equipment to be built into the supply vessels to provide facilities to assist with fire fighting on drilling rigs and more particularly on production platforms.

The specification was exacting and called for a water system capable of cooling an oil or gas fire on the platform sufficiently to keep it under control and allow personnel to remain on the platform to perform the necessary work of shutting down the systems to actually extinguish the fire.

After design and testing Tidewater Port Jackson Marine produced a design which was accepted by Esso/BHP and built into two vessels, the "Victoria Tide" and "Austral Tide". This equipment, illustrated below in action is capable of deluging a platform at a height of 150' from a distance of about 150' with 1200 gallons of water per minute.

Similar fire fighting equipment is incorporated in all later vessels and is also combined with built in tankage capable of supplying foam to the system.

Oil dispersal equipment is now becoming a requirement but at present is in the form of portable units of a propriety nature and is not a built in feature of the vessel.



Fire Fighting Equipment in Action

Commercial Factors. The requirement in quantity and type of supply vessels for the Australian Offshore industry is of course entirely governed by the level of activity of the offshore oil exploration industry. This activity is not entirely free of political factors, prominent amongst which of course is the price a successful producer can expect from the end product.

It is not proposed to consider this aspect further except to say that at present there are supply vessels in Australia capable of meeting the different requirements of exploration, development and production. Amongst this fleet of supply vessels are craft capable of and designed for working with all types of rigs and under all conditions.

Conclusions. The designs are ready, shipyard capacity is available and the writer considers it quite certain that the two major offshore supply boat operators will readily be able to meet any expanding demand that inevitably must arise in the years ahead.

FUTURE DEVELOPMENTS

For exploration work in bad weather areas of Australia the larger semi-submersible rigs are most likely to be used, and the operators of these rigs will be looking towards larger supply vessels, but just how much larger is uncertain - perhaps the optimum in size and performance has already been reached with Tidewater Marine (U.S.A.) "Mammoth Tide" class now operating in the North Sea.

These vessels have a machinery installation of four EMD 1664542 engines giving a horse power of 8000 which on trials produced a static bollard pull in excess of 100 tons, and are representative of the largest class of supply vessels now building.

For Australia it is doubtful if such large vessels are a necessity and certainly not an economic proposition for a country which is not generally regarded geophysically as very attractive for the exploration for oil.

At this stage it appears that perhaps the next stage of expansion of the industry will be for vessels designed for particular operations such as exploration or development, and that included therein could well be some vessels in excess of 4000 HP but also some vessels of a smaller size for particular production requirements.

This paper has purposely been written in general terms to give an outline of the development of the offshore supply vessel, and to illustrate how this has been adapted to Australian requirements. More particular technical data will undoubtedly be contributed by naval architects and shipbuilders, and whilst this will undoubtedly be of great interest it would perhaps not be out of place to record that project outlines and requirements for new construction initially comes from the owners and operators who, over a very short period of less than 10 years, have brought into being an entirely new concept of coastal shipping, bringing with it work for all sections of the maritime industry.

The views expressed herein are those of the author J.C. Needham, who acknowledges with thanks the assistance of Mr.W.B. McCubbray, Operations Manager and of the staff of Tidewater Port Marine.

FISHING BOATS IN THE AUSTRALIAN SCENE

BY

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INTRODUCTION

This paper purports to review the primary sector of the Australian fishing industry with particular reference to vessels of between 15 and 60 metres in length. Within this context, an attempt has been made to tabulate the vessels, gear and methods applicable to different fisheries. In addition, management of the industry is discussed as are the major factors which affect the operation of a fishing vessel such as technology, training, safety standards and marketing.

Fishing, as in any other business, requires a reasonable rate of return on investment and desirably, the size and type of vessel is chosen accordingly. It does not follow that the bigger and more sophisticated the vessel, the greater the rate of return on investment - the result may be over - capitalisation and that situation is seldom considered worthwhile.

Once the fishing resource has been proved and the market assured it is the responsibility of management to ensure that a fishery maintains viability. In the absence of effective management, the fishery often becomes overcapitalised and the remuneration that fishermen get for their labours becomes depressed. Under these circumstances a fisherman may be forced to accept the status quo or, if circumstances permit, he may diversify his activities, make technological improvements in his vessel, replace his vessel with a larger vessel, join other fishermen to form a company or find an alternative occupation. Fishing is still a way of life for many with subsistence the reward but the comparative well-being of the man ashore is likely to destroy this romantic ideology.

MANAGEMENT

In Australia, the Australian and State Governments are the fisheries managers. The Australian Government has the power to legislate for fisheries in Australian waters beyond territorial limits and within Federal territories; the States have similar powers within territorial limits. This legislative power is generally used to maximise the number of fishermen in a fishery given that they may achieve a reasonable rate of return on investment. Aims of management may however be redirected towards other objectives such as maximising profitability, catch, employment or simply to limit entry to the fishery.

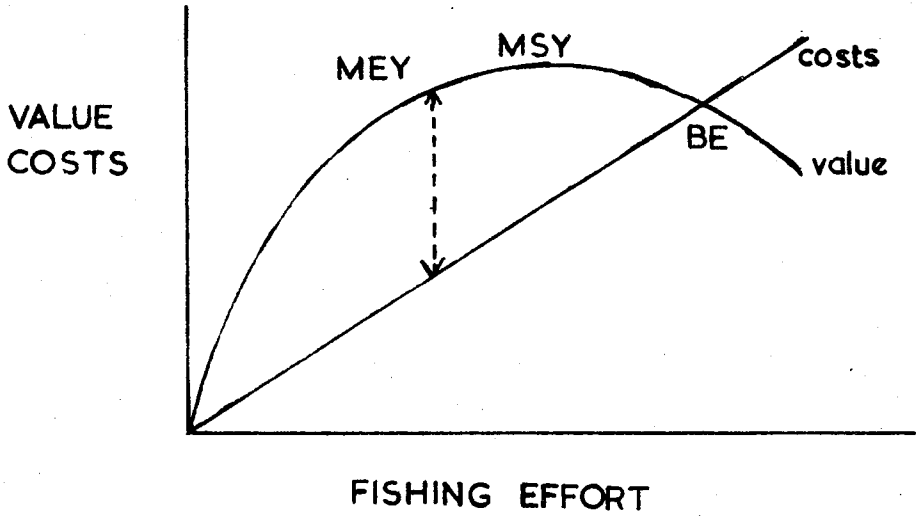
When the confines of a fishery are international because of the transient nature of the species, management must necessarily become international - the International Whaling Commission is the most significant example of Australia's involvement in international fisheries management.

Fishing as an industry differs considerably from other primary industries because it depends on a common property resource that is a resource belonging to all people - the only exception being fish in privately owned waters.

The right to exploit a common property resource therefore belongs to all people.and it must be seen that the resource is shared fairly and equitably in accordance with the needs of interested groups.

Management of a fishery should relate to the cost and yield curves as illustrated in Figure 1.

FIGURE 1



As a fishery is developed, the fishing effort increases until production is maximised or the maximum sustainable yield (MSY) point in the curve is reached. Beyond that point an increase in fishing effort will not increase the catch. If the fishing effort is increased unduly, in some instances, it is possible to adversely affect recruitment. The break-even (BE) point is the point at which profits are no longer made and the cost and value curves intersect.

The maximum profit margin between total costs attributed to units in the fishery and value of the catch is attained at the maximum economic yield (MEY) point in the curve. This may be the point at which management steps in and places limitations on the fishing effort. If, however, reasonable profit margins can be sustained beyond this point then management may endeavour to place limitations on the fishing effort at some point approaching MSY so that there may be a greater distribution of the wealth.

In order to replenish stocks in a depleted fishery the population must be allowed to grow, that is the catch must be less than that which allows the population to maintain itself at a given level.

In order to maximise the number of fishermen in a fishery on a reasonable rate of return on investment, management may limit entry to the fishery or legislate for inefficiency by placing limits on mesh and net size, number of pots and provision of escape gaps, size of boats or by introducing a closed season. Other management measures with biological objectives such as prohibiting the catching of berried lobsters or placing a minimum limit on fish size may be necessary to achieve the same end.

AUSTRALIAN FISHING FLEET

Until comparatively recently the Australian fishing industry has been catered for, in the main, by small vessels, owner operated and fishing limited areas generally close off-shore. Within the last two years this picture has been changing rapidly and numbers of much larger vessels are being introduced, some of these are in excess of 200 gross tons, and are capable of ranging over long ocean distances. In addition, the catching of ocean ranging species of fish is now being undertaken and a rapid expansion in this field is under way. Another growth area is the deep water trawling for demersal species. Apart from the size of the vessels and their sophistication (in terms of electronic equipment, refrigeration, hydraulics and other machinery), the complexity of the fishing operations (purse seining, mid-water trawling and pair trawling) is greater than was the case in older established fisheries which have been the backbone of the Australian fishing industry for so many years.

Table 1, below sets out the composition of the total Australian fishing fleet by size classification. Table 2 indicates the number of ocean going fishing vessels licensed to fish beyond the 3 mile territorial limit.

TABLE 1

SIZE CLASSIFICATION OF BOATS EMPLOYED IN GENERAL FISHERIES STATES, 1973-74

Length of boat (metres)	*NSW	VIC	QLD	SA	WA	TAS	NT	AUST.
Under 6	2215	225	1064	1771	501	127	109	6012
6 and under 9	470	247	461	410	493	82	13	2176
9 and under 12	160	147	272	181	320	129	21	12301
12 and under 15	169	102	305	114	131	151	18	990
15 and under 18	80	43	122	42	89	77	28	481
18 and under 21	21	12	43	21	18	15	22	152
21 and under 26	5	3	28	14	8	9	45	112
26 and under 30	4	1	12	1	..	1	11	30
30 and over	..	1	7	4	2	3	9	26
Total	3124	781	2314	2558	1562	594	276	11209

Source: Australian Bureau of Statistics

* Estimated by Fisheries Division, Australian Department of Agriculture

TABLE 2

AUSTRALIAN GOVERNMENT FISHING BOAT LICENCES ISSUED DURING 1974

STATE	NUMBER
N.S.W.	626
VIC.	223
QLD.	1,326
S.A.	194
W.A.	1,054
TAS.	292
N.T.	14(incomplete)
AUSTRALIA	3,729

Source: Fisheries Division, Australian Department of Agriculture

The tendency is for the larger vessels (over 20 metres in length) to be constructed of steel whereas the smaller vessels are constructed of steel, wood, glass reinforced plastic (g.r.p.) or ferro-cement. Very small vessels are generally built of aluminium or g.r.p.

The operation of a fishing vessel is significatnly different from that of other sea-going carriers as illustrated in the port to port operation in Attachment 1. It will be noted that the cargo (catch) carrying capability has a number of interrelated influences each of which signifies an inflexible dependency.

Attachment 2 shows the principal fishing ports in Australia and the localities of the fishing resources under exploitation.

Tables 3 to 13 summarise fishing vessel operations in Australia with respect to fisheries which employ vessels of between 15 and 60 metres in length.

TABLE 3

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
OTTER TRAWLING Season Whole Year Main Ports NSW - Ulladulla, Eden, Wollongong, Sydney, Newcastle Vic - Lakes Entrance, San Remo Main Species - Tiger Flathead - Hake - Morwong - Nannigai (Redfish) - John Dory - Shark - Latchet	Engine 75kW - 185kW Length 12m - 23m Mostly wooden construction. Wheel-house forward, clear deck aft.	Two-way radio Echo-sounder Some auto pilots and /or radar	Net Mesh - wings 4½ in (114mm) - body/codend 3½in (89mm) Headline - 12fms - 25fms (22m - 46m) Warp - 10mm - 14mm wire - to 750fms (1372m) length Trawl Doors - wood with steel shoes and steel or chain brackets - 2.3m x 1m - also 'vee' form steel doors in use Sweeps - 22mm combination rope - to 150fms(275m) length Other Gear - mechanical or hydraulic winches - warp load 600kgms - 1000kgms	A number of small (<14m) prawn trawlers rig part time for the fishery in NSW The otter trawl can be rigged to fish rougher and more restricted areas than the Danish seine and is more adaptable to strong currents and poor weather conditions. Some boats are equipped with a large drum on to which the net and sweeps may be wound.

TABLE 3 CONTINUED

The trawl fishery had its beginnings in 1909 when a research vessel commenced taking encouraging catches off the east coast of Australia. This was followed by the introduction in 1915 of a number of steam powered otter trawlers. Stimulus was given to the fishery with the introduction of diesel powered stern trawlers during the late 1960 s (this followed a period of difficulty due to rising costs and poor catches).

Annual catch for the east coast trawl fishery varies between 4,000 and 5,000 tonne (total for both otter trawling and Danish seine).

Regulations exist in regard to minimum legal lengths for many of the species and also mesh sizes.

TABLE 4

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
DANISH SEINE Season Whole year Main Ports NSW- Ulladulla, Eden Vic - Lakes Entrance Main Species - Tiger Flathead - Morwong - Nannygai - Shark - Latchet - School Whiting	Diesel engine 110kW - 150kW Length 12m - 22m Boats mainly wooden construction with wheelhouse forward clear deck aft	Two-way radio Echo-sounder Some auto pilots and/or radar	Net Mesh - Wings 4 in.(102mm) - Body/Codend 3¼ in (82mm) Seine rope 7 coils of hard laid manilla or synthetic rope 19-22mm on either side Other Gear Seine winches and rope wells	Some vessels double as tuna pole boats in early summer The 'fly dragging' technique is employed where a free floating instead of an anchored buoy is used to overcome the problems of operating in deep water and strong currents when casting the net.

In 1936 Danish seine vessels were introduced on an experimental basis and soon became a popular method of fishing the inshore grounds of the N.S.W. coast. After World War II there was a rapid increase in the number of Danish seiners and more than 100 were operating by the late 1940's. These numbers have since declined.

Regulations cover minimum mesh size and minimum length for most species in the fishery.

TABLE 5

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
PURSE SEINING Season NSW - (Oct. to Jan.) S.A - (Jan to May) Fishing Ports S.E. Australia Main Species - Bluefin tuna - Striped tuna - Jack Mackerel - Anchovies - Pilchards	Diesel engine 225kW - 1120kW Length 23m - 42m Boats using ring nets are as small as 12m	Aircraft for spotting of fish Radar Sonar Echo-sounder Two-way radio The largest purse seiner has bow and stern thrusters which eliminate the need for a power skiff to keep the vessel out of the net. However other vessels may carry a power skiff	Net Size of net depends on species sought and size of boat. Nets vary from Ring net - 100m long by 15m (stretched) deep (13mm stretched mesh size) weight ½t Large Purse Seine - 1000 m long by 140m (stretched) deep (105mm stretched mesh size) weight - 20t Winch gear is hydraulic as is net handling power block or hauler. Other Gear A brailing device or fish pump is used to remove fish from the net	Need for fair conditions and also boat with good displacement and stability for successful operation of purse seine net. The ring net is used for catching live bait and is a much smaller net than the purse seine net. It is hauled from both ends simultaneously having a central bunt. Hauling is usually by hand. Ring nets can be cast from a small boat

TABLE 5 CONTINUED

The steel purse seiner 'Maria Luisa' is the largest commercial fishing vessel ever built in Australia. Equipped with the most up-to-date electronic fishfinding, navigational and purse seine fishing gear available, the vessel fishes for tuna, jack mackerel, pilchards and other pelagic fish off Australia, mainly in south eastern waters.

TABLE 6

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
TUNA POLING Season NSW - (Oct to Jan) SA - (Jan to May) Fishing Ports NSW - Eden SA - Port Lincoln WA - Albany and Esperance Main Species - Southern Bluefin tuna - Striped tuna	Diesel engine - average 65kW for smaller NSW boats to 260kW for 'full-time' tuna boats (i.e. boats that fish both NSW and SA season) Boats as small as 7m in length used but minimum size suitable for the east coast considered to be about 13m. In South Australia where fish are usually found further offshore vessels are generally more than 16m in length Storage facilities for holding bait fish alive	Two-way radio Echo-sounder Sonar Aircraft for fish spotting	Bamboo pole up to 3m in length tapering from 50mm diameter at butt - approx 25mm at tip. To this is secured a leader, a trace (nylon or wire) and a weighted barbless hook. Feathers are used as a lure The total length of the leader, trace and hook is shorter than pole. A small pursed ring net with a headline length of 50fms - 100fms (91m -183m) operated in conjunction with a powerful lamp is used to catch bait	Ice is used rather than refrigeration in seasonal tuna boats. In contrast 'full-time' tuna boats have adequate brine refrigeration. Fish are chummed to the surface with live bait

TABLE 6 CONTINUED

The introduction of tuna poling in New South Wales and South Australia stemmed from successful demonstrations of this method by Fijians during 1951.

The tuna fishery is mainly confined to the west coast of South Australia and off the New South Wales south coast where large concentrations of southern bluefin tuna are available in season. Juvenile bluefin 2-5 years old and weight to 20kg constitute the bulk of the catch.

The 1974-75 tuna catch is expected to approximate 10,500 tonnes (1973-74 9,000 tonnes, 1972-73, 13,600 tonnes)

Most Australian-caught tuna is consumed domestically in canned form - about 85 per cent in recent years.

TABLE 7

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
SHARK - GILL-NETTING AND LONG LINING Season All year - largest catches made in spring and summer Fishing Region Coastal waters of southern NSW, SA, Vic and Tas Main Species - School Shark - Gummy Shark - Dog Shark - Saw Shark	Diesel engine 75kW - 185kW Length 6m - 25m Practically all vessels have the wheelhouse aft and a wet well amidships. Ice room or refrigeration is usually provided ahead of the well. Living quarters are usually aft of the wheelhouse as this arrangement is more comfortable in the sea conditions generally experienced in Bass Strait	Two-way radio Echo-sounder Some vessels automatic pilots	Gill-net: Net is set from a hydraulically powered drum over the stern and hauled on to the drum over a roller positioned in the bow. The net is of 140mm-180mm mesh mono filament nylon of approx. 22kg breaking strain Long-line: The main line consists of a 6mm-8mm dia. sisal or manilla rope. The snoods (permanently attached or clip-on) are normally made of cotton seine twine but sisal, manilla or nylon rope is sometimes used. A wire trace and hook, or a special long shank hook is attached to the snood. Up to 2,500 hooks may be set from one boat but	Many vessels fish for shark in the rock lobster 'off' season and when long lining use the pot hauler for handling the long line Gill-netting has generally superseded long-lining in recent years

TABLE 7 CONTINUED

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
			average number would be approx. 1,200 per set.	

The shark fishery received a valuable stimulus during World War II when sharks were caught for their vitamin-rich liver oil. In addition the eating qualities of shark flesh were favoured, particularly in Victoria. However in 1972 the Victorian Government prohibited the landing in Victoria of school shark of certain sizes because of unacceptable mercury content in the larger fish. Because of this the fishery is now more orientated towards the catching of the smaller gummy shark.

TABLE 8

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
SOUTHERN ROCK LOBSTER Season Late spring, summer and autumn Fishing Ports Widespread in Vic Tas and SA Main Species - Southern Rock Lobster - Reef Fish (used for bait) - Octopuses	Diesel engine 75kW-185kW Length 10m-30m. Mostly wooden construction Vessel design is similar to shark boats as many vessels operate in both fisheries	Echo-sounders and two-way radio fitted to most boats Small tender boats are carried on some larger vessels permitting traps to be set close inshore	A few of the vessels use pot tippers and all except some of the small boats are fitted with pot haulers. Beehive type pot is used. Materials for construction vary, wire and lock mesh are popular. The pots are woven with ti-tree or cane. Plastic pots are being introduced	The lobster are kept alive in wet wells or circulating sea water tanks during transportation from fishing grounds

The southern rock lobster fishery has existed since the last century but there was no significant expansion until after World War II when exports commenced.

Regulations are extensive - licence limitation, pot limits, size limits, protection of berried (egg laden) females and closed areas are enforced.

TABLE 9

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
SCALLOPS Season Vic all year Tas- April to Nov. Qld - all year Fishing Ports Widespread Main Species - Saucer Scallop - Doughboy Scallop - Commercial Scallop	Diesel engine 75kW-185kW Length 7m-28m	Larger vessels usually fitted with echo-sounders Most have two-way radios	Working platform Gantry Mechanical or hydraulic winch Dredge - Baird Oldham and Liptype dredges are used Most Victorian boats have installed a self-tipping device. Boats operating in the northern scallop (saucer) fishery in Qld, and WA use otter trawl nets modified from ordinary prawn net designs	Tasmanian vessels originally operated two dredges alternately but now most scallop boats use only one dredge as automatic tipping devices enable safe use of larger dredges

Scallop fishing, once confined to Tasmania has now spread to other States.

Regulations cover width of dredge, minimum size of shell diameter, entry to fishery and fishing hours.

Extreme fluctuations in catch rates exist probably due to high natural mortality and variations in spatfalls.

TABLE 10

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
NORTHERN PRAWNS Season Tiger prawns - year round, Banana prawns - March to June (may be caught until Nov.) Fishing Ports Darwin, Groote Eylandt, Karumba Normanton, Weipa Thursday Island Cairns Main Species - Banana Prawn - Brown Tiger Prawn - Green Tiger Prawn - Western King Prawn - Endeavour Prawn	Diesel engine 45kW-410kW Length 16m single rig to 40m double rig Most are double rigged with wheelhouse forward	Echo-sounder Sonar Two-way radio	Otter trawls constructed of synthetic materials with various net designs and rigging methods used. Most vessels are equipped with hydraulic winches. Some have separate winches for double rig gear The nets are made from 2in (51mm) webbing usually with a $1\frac{3}{4}$in (44mm) cod end Material is either nylon or polyethylene	Because of tropical conditions all vessels are equipped with some form of refrigeration Possibility of taking large catches of banana prawns necessitates large storage capacity

TABLE 10 CONTINUED

Development of the northern prawn fishery followed a combined survey undertaken by CSIRO, the Commonwealth and Queensland Governments between 1963 and 1965. Following successful pilot commercial operations 14 vessels operated from Karumba in 1969 where a processing base was first established.

Closed seasons apply in various parts of the Gulf of Carpentaria under Australian and Queensland Government legislation.

Minimum mesh size and maximum headrope length are controlled in Queensland.

TABLE 11

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
EAST COAST PRAWNS Season Depends on species and whether Qld. or NSW fishery Fishing Region NSW - Batemans Bay to Qld. border Qld - NSW border to Princess Charlotte Bay Main Species - Eastern King Prawn - Greentail Prawn - Brown Tiger Prawn - Banana Prawn - School Prawn	Diesel engine (110kW-185kW) Length 8m-28m Mainly wooden construction, but many larger vessels now of steel construction. Wheelhouse is usually forward leaving a clear work area aft.	Most boats equipped with two-way radio and echo sounder. Many boats have automatic pilots and some boats carry radar	Larger vessels use double rig gear. Trawls are built of synthetic materials and numerous net designs and rigging methods are used. Low headline trawls with long wings are used for most species but high fishing trawls are required for banana prawns. The winch is driven mechanically or hydraulically from the main or an auxillary engine and is usually placed immediately behind the wheelhouse with the overhead gallows or goal post rig just above or a little aft of it. Washing tanks and an oil or gas fired cooker are included in the deck equipment	Many boats are fitted with refrigeration. Catch is held in an ice box under the sorting table, in ice in the hold or in tanks in a mixture of ice, and brine.

TABLE 11 CONTINUED

In 1950 large stocks of prawns were found north of Newcastle and near Evans Head in New South Wales. This led to development of deep water trawling techniques.

Before the development of the northern prawn fishery, this region produced more than three quarters of the total Australian prawn catch.

Minimum mesh size is regulated - 1½in (38mm)

TABLE 12

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
SOUTHERN PRAWNS Season Whole year Fishing Region Gulf St. Vincent, Spencer Gulf, West Coast of South Australia near Streaky Bay Main Species - Western King Prawn	Diesel engine 75kW-260kW Length 12m-28m	Echo-sounder Two-way radio Some vessels radar and automatic pilots	Larger vessels use double rig gear Winches vary considerably some of the larger boats using old tractor chasis and engines No specific net design has evolved and various low opening trawl designs in use.	Many of the larger vessels were tuna poling boats which are now fitted for use in both fisheries Trawling is undertaken at night due to nocturnal habit of the western king prawn Tuna/prawn boats are equipped with some form of refrigeration where as over 20 percent of boats fishing exclusively for prawns rely on ice holds or boxes to store catch

In prawn surveys between 1957 and 1964 promising results were recorded. Then in 1968 consistent and large catches which led to many vessels entering the fishery necessitated a zoning and permit system to control fishing activities.

TABLE 13

FISHERY	BOAT DESCRIPTION	AIDS	GEAR	REMARKS
WEST COAST PRAWNS Season Shark Bay, Nickol Bay, March to Sept. Exmouth Gulf, King and tiger prawns (March to Sept) banana prawns (Aug. to Sept) Main Species - Western King Prawn - Brown Tiger Prawn - Banana Prawn	Diesel engine 110kW-185kW Length 15m-25m Mostly steel hulled Wheelhouse is usually forwarded leaving a clear working deck aft.	As for other prawn fisheries		

Commercial quantities in Shark Bay and Exmouth Gulf were discovered in 1952 but it was not until 1962 that commercial operations were established.

Regulations cover limitations on the number of boats fishing in Shark Bay and Exmouth Gulf.

EFFECT OF CHANGE ON A FISHERY

(a) Technology

There are a number of technological developments which, if incorporated in a fishing vessel, may affect its catch efficiency viz:

- modification or replacement of engine;
- installation of fishing and/or navigational aids;
- outfitting with larger gear or a greater number of gear units;
- modification of existing or introduction of new fishing gear and/or equipment
- increasing the size and improving the quality of fish holding facilities.

Initially the effects may be seen as beneficial because the unproductive time at sea is reduced and consequently production and catch rates are increased. This, of course, must be balanced against the increased capital and running costs of the vessel; over-capitalisation on any item of equipment must be guarded against because when the optimum has been determined anything in excess effectively becomes lost income.

Increased production may lead to a reduction in price and possibly over-fishing resulting in reduced catch rates. In the latter case, where the species being exploited has a low fecundity, the fishery may subsequently collapse.

Possibly the most positive effect of technological change is that it encourages the exploration of previously unproductive grounds and turns them into economically viable fisheries. If the technological change reduces operational manning of the vessel this also may be considered as a positive measure.

(b) Training

Increased crew efficiency resulting from training may be seen as a technological change if it increases the productivity of the vessel.

Where no training facilities are available the disparity in productivity between vessels of a similar size and type, operating within the same fishery can be considerable. In order to reduce the productivity gap, proper training facilities are needed and desirably the training should be compulsory. Voluntary training has the draw-back of attracting, in relative terms, those who least need it.

Certificates of competency requirements, although primarily for safety purposes, impose a form of compulsory training but seldom do the criteria for safety extend themselves to proficiency.

The development of the fishing industry requires highly skilled personnel in the fields of electronics, refrigeration, engineering, food technology and fish biology. This points to a very different fishing master, fishing mate or engineer from those required in the past. Illustrative of this problem is the difficulty of obtaining trained personnel for the larger and more sophisticated Australian fishing vessels - even company cadet schemes have proved far from successful.

The only formal education establishment in Australia at which training for the fishing industry is given is at Fremantle Technical College which conducts a pre-sea induction course for deck hands. The course has an annual intake, at present of 26 students and is virtually limited to residents of Western Australia. While training at this level is highly desirable there is an existing need for training to a much higher level and on a more comprehensive scale.

There is no national system of certification of fishermen. Following varying terms of sea service and experience in the fishing industry, fishermen are able to apply to some State authorities for certification as to their competency as master or engineer of a fishing vessel.

The standards presently are not uniform between the various authorities and the certificates granted have limited validity. They certainly do not qualify fishermen to command large ocean ranging vessels such as are being introduced into the fishing industry at the present time.

The Australian Government's recent decision to establish an Australian Maritime College is a big step in the right direction.

Australian and State Government fisheries authorities provide a useful service by way of information and the organisation of workshops, short courses and symposia on problem areas applicable to the industry. In all probability, what ever education and training facilities become available in the future, there will continue to be a need for such services.

At this point, I should like to put in a plug for the first Australian Fisheries Exposition which will be held in Melbourne from the 21 to 23 September, 1976.

(c) Safety Standards

Government has the responsibility of ensuring that minimum safety standards on board fishing vessels are adhered to. The safety demarcation line is often difficult to define and it is generally more practicable to over-regulate than to risk the vessel being unseaworthy. The danger of introducing safety standards which are too high is that there is a likelihood of imposing an unreasonable burden, either practicably or financially, on the industry.

In the case of crew accommodation requirements, for example, it is reasonable to legislate for:

- adequate protection against the weather and health hazards;
- adequate means of access;
- provisions for the relief of fatigue.

It is questionable, however, particularly in the case of the small owner-operated vessel, whether the degree of comfort to be incorporated in a vessel should be stipulated.

A similar quandary exists in the determination of the manning and qualifications requirements for a vessel. Fishermen are essentially skilled operators and the theoretical knowledge required to obtain a certificate of competency should be limited to that which is necessary to ensure the safe operation of the vessel with respect to the function of the person holding the certificate.

(d) Marketing

(i) General

The catching and marketing sides of the fishing industry are inseparable as one is directly dependant on the other.

With the exception of Tasmania, where there is no fish market, most of the fish caught for the domestic market are sold through the auction system, under the control of the various State authorities. Unfortunately the auction system on its own and without the back-up of preservation facilities and/or long term contracts as price regulators, leaves a lot to be desired.

There are a number of factors which contribute towards a depressed market viz:

- over-supply of a species;
- consumer resistance;
- competition with other protein sources;
- competition with imports.

It is a sad reflection on the Australian fishing industry that the annual consumption of seafood in Australia is about 5.5kg per person (half of which is imported) as against 100 kg per person for meat produce.

The grounds for buyer resistance to many species are often without justification and the strategy may well be to change consumer attitude by effective promotion.

(ii) Exports

The export market is almost entirely dependent on the economic climate overseas, particularly that of the United States and Japan who are the principal buyers of our marine produce.

Generally speaking, it may be said that the export fisheries such as rock lobster, prawns, scallops and abalone have a history of satisfactory returns and the more efficient fishermen have developed very satisfactory enterprises.

Currency devaluation is probably the only positive remedy that Government can enact to boost export sales. However, because of the broad implications of such a measure it is hypothetical to consider it being implemented solely for the protection of export fisheries.

(iii) Imports

Customs Duty and Primage Duty (a non-protective revenue device) are applied to the import of most marine produce. When suitably equivalent produce is not reasonably available from Australian production access may be granted for imports on a duty free basis under Customs By-Laws.

The Industries Assistance Commission has the responsibility of advising the Australian Government on tariff policies and the level of protection that should apply to any industry.

With respect to fish imports, unless protection was severe, it is unlikely that increased tariffs would have any significant effect on the state of the domestic market.

CONCLUSION

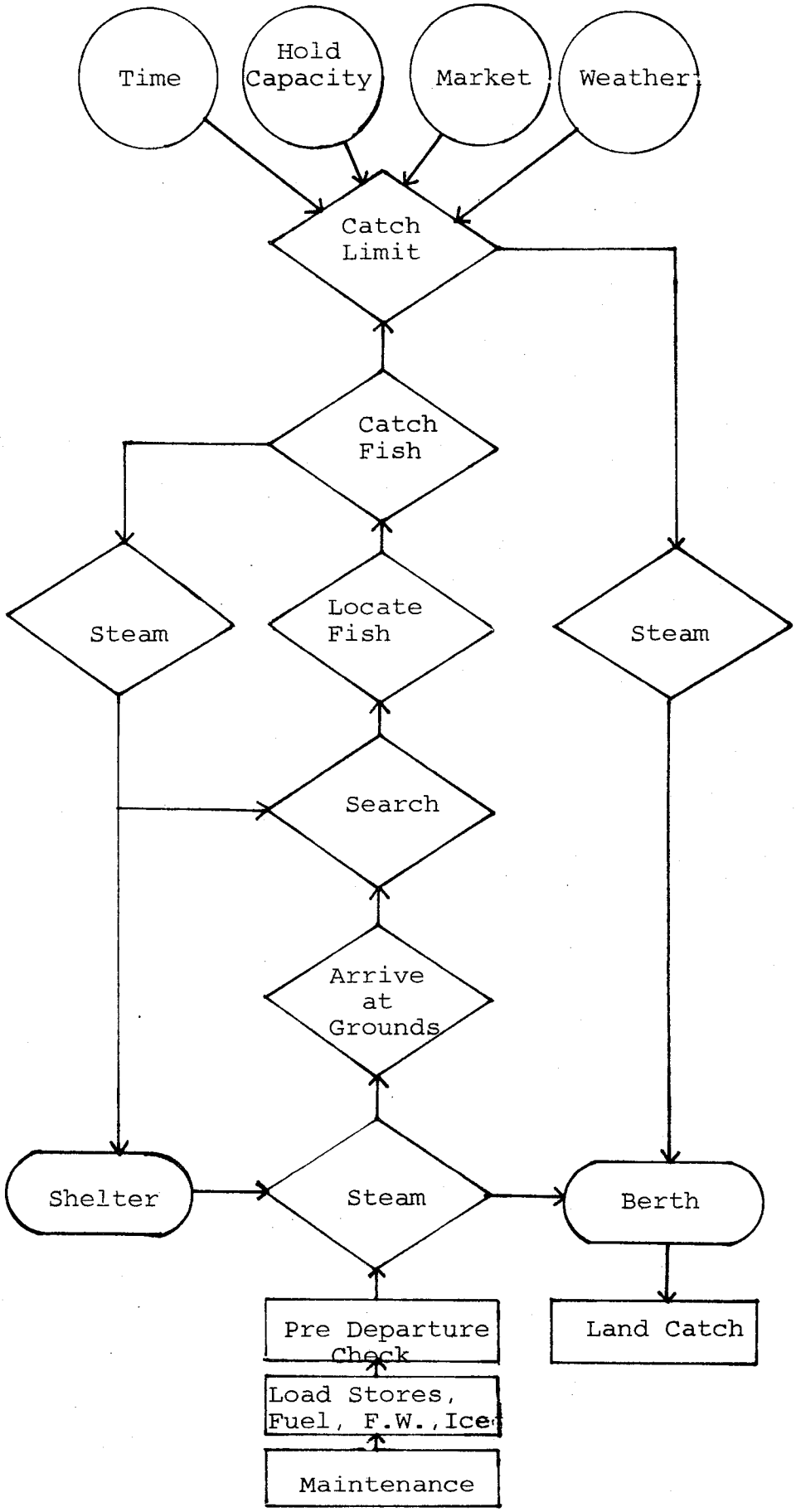
The primary sector of the Australian fishing industry is endowed with physical and economic risk which reflects in the nature of the men employed in it.

Fishermen may be likened to hunters who have developed their skills by experience and/or by the direction and advice of their contemporaries; outside direction or advice is often treated with contempt. The environment and conditions are foreign and abhorent to the man ashore and, in part, to other mariners.

Most Australian fishermen appear to use their tools well. Their main tool, the boat is chosen carefully, often without the benefit of standard specifications but through his inherent intuition which, surprisingly enough, usually approximates the ultimate in efficiency.

To change the fishing vessel you must change the nature of its master; such a process requires education and training both of which may inadvertently have undesirable side effects.

ATTACHMENT 1



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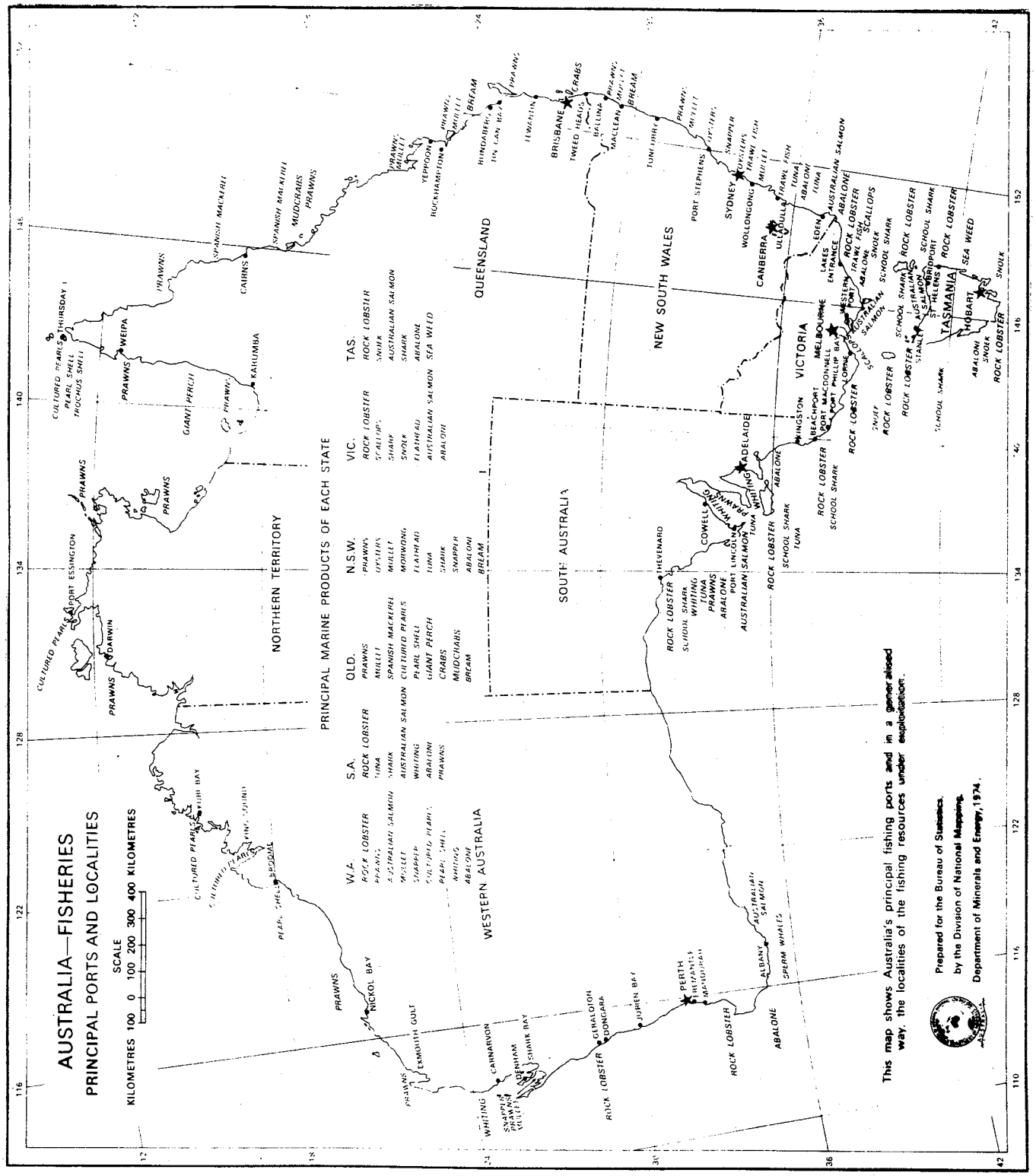

CAN THE MURRAY-DARLING RIVER TRADE OCCUR AGAIN?

by

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I. SUMMARY

Seventy years ago, there was considerable shipping on the Murray, Darling and Murrumbidgee Rivers. Twenty years before, these Rivers had been the 'Highways of the Inland", transporting huge quantities of goods. So big, that for many years, two-thirds of the N.S.W. wool-clip is said to have been shipped on the Rivers. The craft were heavily loaded paddle steamers, towing barges piled high with 2000 bales of wool, or sacks of wheat.

These vessels opened up the Inland of Eastern Australia, but inter-Colonial, then inter-State rivalry had killed all but a remnant by 1914.

A scheme to lock the Murray, Murrumbidgee and Darling is proposed, taken from an undergraduate thesis being completed this year. Twelve further locks are required on the River Murray to completely lock the River to Echuca, 30 locks on the Darling to enable navigation to Walgett, and 9 locks for the Murrumbidgee, for navigation to Hay, costing about $28 million and enabling at least 350000 tonnes of primary produce to be shipped annually.

II. HISTORICAL BACKGROUND

At Gameracha in early 1853, William Randell and his brothers cut and fashioned the timbers for a river boat, carted them across the hills by bullock drays to the Murray bank near Mannum. As they had never seen a steamer, it was inevitable that many details were rough. The crudest of all was the rectangular boiler of thin iron plating wrapped in bullock chains.

By April, William Randell had completed a successful voyage in his MARY ANN from Goolwa to Lake Bonney with a cargo of groceries. A second steamer, Francis Cadell's LADY AUGUSTA, with the EUREKA barge, entered the River in August, and forced their way up river to Euston in 22 days. The MARY ANN, following, reached Moama in late September. The river trade had started.

In 1856 Cadell's The River Murray Navigation Company owned 3 steamers and 7 barges. The South Australian Almanac of 1857 lists 8 steamers and 7 barges engaged on the Rivers. The increasing number of river boats brought jubilation to the river pastoralists, many of whom had been deprived of bullock transport when the bullockies flocked to the goldfields. By 1858 there were 28 vessels steaming up from South Australia with over £ 80000 of cargo. Most carried wool down river on the return trip.

The Rivers Murray and Darling were, for the life of river navigation in Australia, to result in 218 paddle-steamers being built for the trade, almost one quarter of all that operated in Australia. Steamers and barges were built mainly at Goolwa, Echuca, Moama and Mannum. Peak building occurred from 1874-1878, when 53 paddle-steamers and 51 barges were completed. After 1913 building essentially ceased. Goolwa was the only building town which boasted a complete shipyard and engine works.

THE MURRAY-DARLING RIVERS

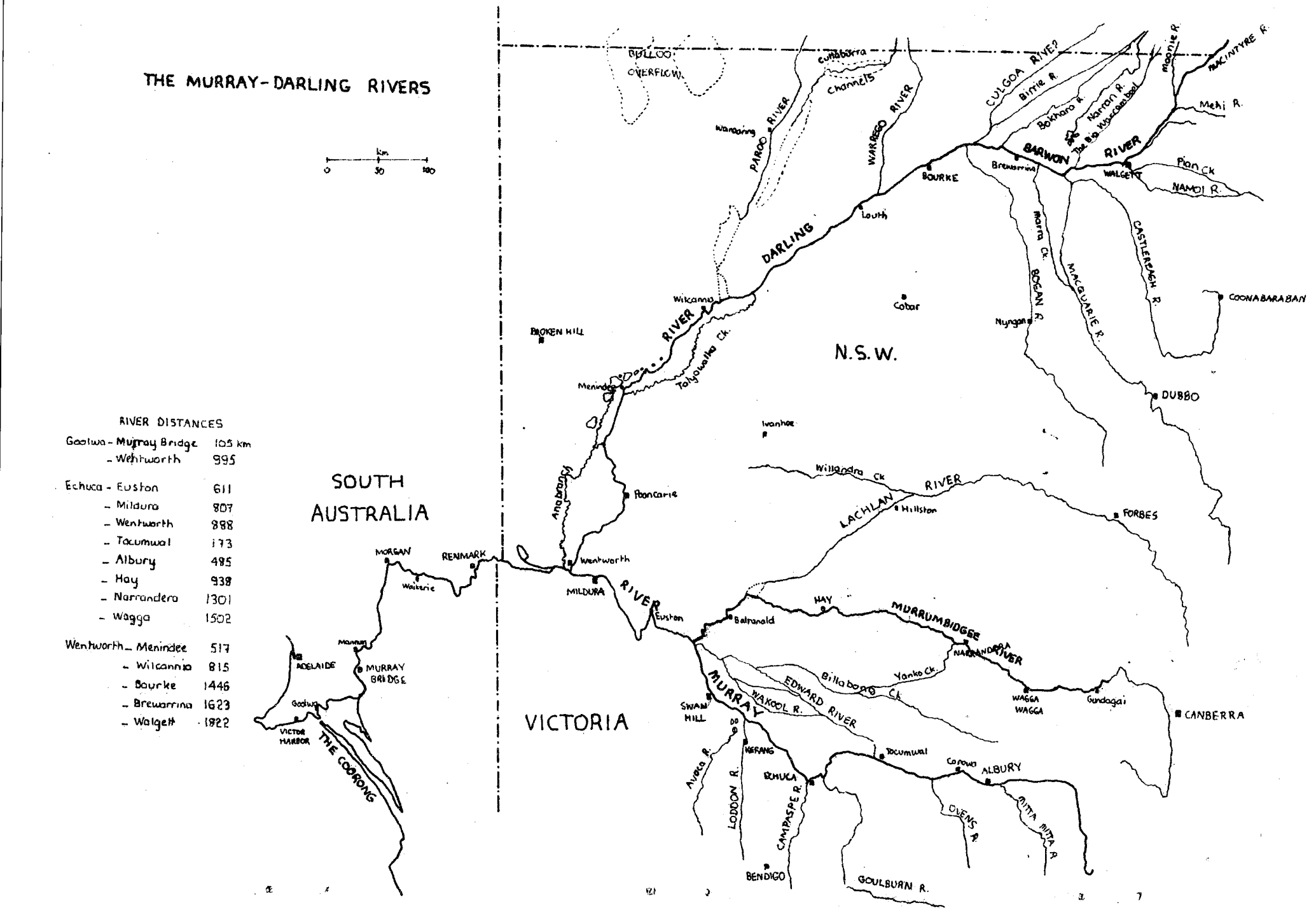

TABLE 1

River Trade Growth

Period	Steamers Built	Barges Built
1852-1859	17	13
1860-1869	52	21
1870-1879	68	69
1880-1889	30	23
1890-1899	23	7
1900-1909	14	6
1910-1919	11	6
1919-present	3	2
	218	147

(Phillips p.7)

Adventurous masters soon pushed trade up the tributaries of the Murray-Darling, braving shoals, reefs and overhanging trees.

Steamers began appearing at delighted towns on the Murray, Darling and Murrumbidgee Rivers, changing the history of the interior, and the life-style of its people. The Western Rivers had become the highways of the inland. Settlers could increase their flocks, for wool could be transported cheaply and quickly to the coast. Labour became more readily available. Shearers could move through the stations as required. Life was more comfortable for the settler's family, their housing more substantial, where previously only the barest essentials had been available. Trading steamers brought luxury goods up river. Piano sales boomed.

Adventure with profit, particularly profit, infected the Rivers. "In one trip sales have been effected to amount of £24,000; in another case £10,000 worth of hay has been sold....sometimes when a trip has been a short one.....sales have amounted to something above £2,000 or £3,000, but at other times....as high as £15,000 and £16,000. One Adelaide Firm is said to have earned in not many years, and with a few boats, sold goods worth £229,687." (Bean The Dreadnought of the Darling p.195).

Plans, and some vessels were ordered from British shipyards to meet the demand. The early Goolwa boats were of British design - built of iron with long, narrow lines. As river boat experience and knowledge increased, local designs replaced the British designs. Locals favoured broad-beamed, shallow draft steamers, built of Echuca red or blue gum, which alone was able to withstand the shock of striking a snag at full speed. Iron, later steel, Swan River mahogany were tried, but Echuca redgum was used for all but a few specialised steamers.

Stern-wheel paddle-steamers were initially popular, but they lacked the stability of side-wheelers. Barge handling was more difficult for stern-wheelers, and the stern wheel could be more easily damaged. To prevent this, vessels such as the COROWA, WARADGERY and PRIDE OF THE MURRAY lashed their barges alongside.

Sandbars were a constant problem. A small bar could be rushed, and the steamer scrape over. Wider bars were crossed by connecting a cable to a stout tree, then winching the steamer across. If a winch were not available, the cable was wound-around the paddleshaft.

Adventurous journeys were the rule rather than the exception. Skippers were convinced that their steamers could go anywhere there was water, or where the river-bed was even damp.

When the Rivers were in flood, narrow channels became navigable, and there were more short cuts - but at the same time it was easy to get lost. During the 1870 flood, a steamer sailed from the Darling up the Paroo Channel into Queensland, 320 km from the Darling. The JANE ELIZA called at isolated, far from the River homesteads. The ARIEL steamed 95 km off the Darling to somewhere west of Menindee. The ENTERPRISE delivered workmen from the boiling-down works to within 200 m of their homes in Echuca, and the JULIA steamed up Echuca's High Street, tying up at Redmond's "Commercial and Family Hotel" during lunch.

Wool was the mainstay of the river trade. New and more powerful steamers were added to the trade, to tow the large, wide barges. Ports were renovated to handle the increasing quantity of goods. At Echuca, the old Queen's Wharf was replaced by an enormous 3 tiered structure, with storage sheds, a row of powerful cranes and railway shunting yards. Even after 1906, 16 steamers and their barges would be loading and unloading at the wharf, from where steamers traded up to Corowa on the Murray, to Wagga Wagga on the Murrumbidgee, up the Goulburn, and to Walgett on the Barwon.

From 1860 to 1881, one third of the New South Wales wool-clip is believed to have gone down to Victorian and South Australian ports. Wool did not deteriorate on the journey to the markets, and no longer required storage on the sheep station. The cost of transporting wool over the enormous distances did not prevent squatters and land-owners from selling wool at a good profit.

In ordinary seasons the Darling was only navigable for 7 months - June to December, but steamers were, at times, marooned in baked mud for more than a year awaiting the rise. During the dry, rows of steamers and barges lay by the wharfs, ready to leave on the first rise. The tragedy of the river ports was that they were in wool districts, which were dry and sparsely settled.

Some craft were used in the difficult and dangerous job of removing snags from the Rivers. They were usually small vessels, fitted with powerful engines, winches and strong tackle, to drag or lift snags out of the Rivers. River men readily defended the reputation of these brave men, who manned overworked boats, and whose presence ensured navigation, and salvage in the event of a sinking.

Four basic types of river vessels were built. Small draft steamers of about 16 m or less were common, collectively known as the "Mosquito Fleet", and were used for fishing and general trading; the fish-boats bringing down their catches live in semi-submerged boats lashed alongside. The tow-steamers of 20 to 25 m appeared in large numbers. These were used when the river was low, employing small crews, they were more versatile than the larger wool steamers, which were built for the wool trade. These great steamers could carry hundreds of bales, and tow the heavily loaded barges. But the finest boats were run by The Gem Navigation Company - GEM, MARION, RUBY, ELLEN and COROWA, of which the first 3 have been preserved. They operated fast, regular services on the lower Murray, travelling day and night at full-speed. Passengers occupied comfortable single or double berths with hot baths and showers, relaxed in the smoking or lounge rooms, and were served 5 elaborate meals a day.

Initially the railways advanced river transport. The 1864 line to Echuca enabled Echuca to become Victoria's second most important port. Railways to the Riverina provide Australia's worst example of rabbit-railway warfare. River trade had slumped badly by 1900, but probably before its time. The railway boom was determined by criteria, which, at times, were more political than economic, sealed the fate of a trade which could have remained economically viable for some years (Griffin p.175).

Producers were interested only in direct, cheap and reliable transport for their goods. If a choice between rail and the river occurred, the railways usually took precedence, for they were reliable, the rivers were not.

The River Trade After 1910.

The only areas left to the river trade, free from rail ingression were the Murrumbidgee below Hay, The Edward-Wakool and the timber trade from the Barmah forests. Boats traded out from Echuca, returning with cargoes of wheat and wool.

Locking the Lower Murray between 1910 and 1923 employed many steamers and barges, but the locking was carried only to Wentworth, stopping short of the big production areas along the Murray. Locking came too late, river men were getting out, their vessels being left to rot.

During the 1930's only a few steamers were kept running. PEVENSEY, INVINCIBLE and ULONGA continued to trade the lower Murrumbidgee and Edward Rivers, when the Murray was high enough for navigation. The last wool to go across Echuca Wharf was in 1936 when the ULONGA unloaded her barge using the steamer's winch - the railways had made the wharf cranes inoperable.

Melbourne faced a fire-wood shortage during World War II. The Forestry Commission bought the MELBOURNE, EDWARDS, ADELAIDE, HERO, MURRUMBIDGEE and several barges to bring down fire-wood to Echuca from the Barmah forests for railing to Melbourne. MURRUMBIDGEE went up to Hay in 1943, much delayed by State authorities at Redbank and Maude weirs, but had to wait until a good rise in 1947 before she could return to Echuca, where she underwent conversion to a two decked tourist steamer, thriving in this role until burned in 1948.

ULONGA left the river in 1949, being converted to a twin screw auxilary ketch, and still trades the South Australian coast.

The ADELAIDE, MELBOURNE and EDWARDS ran the timber trade until the late 1950's, towing the big timber barges to the Barmah Lakes where they rolled logs onto the barges, then letting the barges drift down to the Echuca sawmills.

As the conventional trades ceased, a thriving tourist trade grew. The big COONAWARRA began regular tours in 1951. The AVOCA, WANERA and MAGGIE followed. The steel MURRAY RIVER QUEEN entered service on the Lower Murray in late 1974. Nine smaller boats offer day cruises out of Echuca, Swan Hill, Mildura or out of the Lower Murray ports.

The 1909 built, and privately operated, OSCAR W., still trades the Lower Murray. PEVENSEY, at time of writing, is on the slip at Echuca, and may enter the tourist trade.

It was during the great floods of 1955-56 that the river boats were fully employed, acting for months as rescue vessels to flood-bound towns and

stations. The SUCCESS came down from Bourke with the VEGA barge, loaded with £75,000 of wool from Para Station. When the Rivers went down, the boats returned to their moorings to rot, or to enter the tourist trade.

Details of 15 paddle steamers can be found on pages II-71 and II-72.

New River Craft.

Experience on the Rivers showed that Echuca red or blue gum was the only building material capable of withstanding the shock of striking a snag at full speed. Steel craft such as the OSCAR W. entered the trade early this century, but these vessels were sheathed in redgum, usually about 7.5cm thick. Snags are a problem which always have existed on the Rivers, in spite of snagging operations, so river craft will need some protection. For this reason paddle wheels are favoured - repairs to a paddle can be effected quickly without slipping, paddles are less likely to be snagged, they improve stability, which is important when towing a barge around a tight river bend. Blunter stern lines are allowable with paddles, and almost all of the vessel's hull can be used for cargo stowage. The paddle shaft can also (and was) used as a winch for cargo handling.

New river vessels would be up to 35m long and about 8m across the hull, 12m over the paddle boxes, with a draft of no more than 1.8m. Nett tonnage would be about 100 to 150 tonnes. Height of the vessel should be under 6m to enable clearance beneath the many lift span bridges. The craft must be very manoeuverable. Vessels longer than 35 to 40m were found to be too unwieldy on the Darling, Murrumbidgee and Upper Murray, though bigger craft could be used on the Lower Murray.

Two types of paddle-boats are envisaged - tow boats of 25 to 30m which act as general traders and barge towing boats, and 35m great steamers*to tow and bring down big loads of wool and wheat. Provision must be made for a winch, and perhaps a crane on the steamers for cargo handling - a big barge may carry 1500 wool bales - there are 4 to 5 bales to a tonne.

Several options are open as to barge types - the 370 tonne LASH and SEABEE type barges are too deep for all but the bottom of the Murray, but the 170t BACAT barges are far more promising. There is also the traditional barge. Barge types will depend largely on exporting facilities at Murray Mouth and cargo handling at river ports.

Barges can be expected to receive rough treatment, and should be wood; or wood sheathed, or ferro-cement.

III. THE WESTERN RIVERS

Because Australia is a flat country, many river systems have very small declivities along their courses. Once the Murray-Darling Rivers leave the Dividing Range, their waters flow along valley floors of almost zero declivity at a phenomenally low rate.

The Murray-Darling catchment covers 1.1×10^6 km^2; about one seventh of the area of Australia. This river system is one of the big river systems of the world, but it carries little water. Of the huge catchment, only one twentieth has an average rainfall above 75cm. The Upper Murray Catchment above Albury is 1.7×10^4 km^2 - less than one fiftieth of the total catchment,

* steamer, in the inland sense is an engined vessel.

yet provides one quarter of the water (Gill p.12).

Flow for the River Darling practically ceases for much of the year. The River has high banks and a small fall - an average of 4.7cm.km^{-1}. During the dry season, most of its length is a series of water holes at varying levels. In a "fresh", the River rises to a great height. The Darling is essentially a gutter flowing through arid, or at best, semi-arid country. Rivers which should, and once did, feed the main channel, never, or rarely ever reach the Darling, but instead disappear in the dry country surrounding the Darling.

The Murray was normally suitable for 6 to 7 months navigation to Albury, and for 12 months in much of South Australia. The great drought of 1901 prevented navigation above Morgan, and the 1914-1915 drought reduced the Murray between Tooleybuc and the Wakool Junction to a series of water-holes.

Apart from the Murrumbidgee, the main tributaries rise in Victoria - the Mitta Mitta, Owens, Goulburn, Campaspe and Loddon Rivers

It was not until 1910 that authorisation was given to the Murray Works Act, under which the William R. Randell Lock (Lock 1) was already being constructed. The Act authorised the construction of the Lake Victoria Storage, two weirs with locks on the Murray in N.S.W., and locking from Blanchetown to the South Australian Border. South Australia engaged the services of Major E.N. Johnston, Corps of Engineers, United States Army, to carry out the scheme. It was upon Major Johnston's plans, reports and estimates that this work was commenced.

The River Murray Waters Agreement

The 1910 Agreement flopped in N.S.W. and Victoria, and in 1913 the last Agreement, the River Murray Waters Agreement, was reached, involving the 3 River States and the Commonwealth.

The Agreement established the River Murray Commission, to build and control works on the River for maintenance of water for irrigation and navigation. The Agreement provides for a minimum quantity of water to be available to South Australia.

The River Murray Waters Agreement was amended in 1934, eliminating all but two of the Locks and Weirs remaining to be built; Lock 15 at Euston and Lock 26 at Torrumbarry, for weirs for irrigation were required at those sites. A weir without a lock was built at Yarrawonga, and two weirs without locks on the Murrumbidgee.

IV. NAVIGATION REQUIREMENTS

In the locking programs proposed during the 1880's and 1890's, and even as late as 1914, all considered the dimensions of the vessels then using the Rivers.

The 1899 proposal considered that 1.8m of water on the lower lock still was quite sufficient, for the deepest boat on the Darling, when loaded, was 1.7m. In the wet of 1890-1891 the River was freely navigated for 6 months with 2.7m of water over the proposed locks. This scheme recommended locks 61.0m long between gates, and 11.2m wide, with lifts varying from 1.85m to 3.05m. This length would admit the passage of a steamer and its barge. Weirs were to be constructed at the lower end of the locks, as far

from the entrance as possible, to obviate the risk in time of flood of a steamer being taken by the flood-current over or against the weir. As an additional precaution, a line of piles were to be placed above each lock, to which a vessel may tie-up. Weir heights were to be 4.0 to 4.9m, according to the lifts provided for at the various sites, and the drop behind the weirs to supply the locks with 1.8 to 3.0m of water.

No apprehension of the lack of water in the River Darling to meet the navigation and agricultural requirements was held by the Engineer-in-Chief for Public Works. There would be water to allow for losses by lockage, evaporation, soakage, or any other cause. The average depth of the River was to be 2.6m. Weirs were to be well below the bank, and a flood of 2.6m over the weir would still be below the bank top. To prevent flood damage to the weirs and locks, it was envisaged that the weirs would be built into the banks until firm ground was reached, then throwing-out long concrete wings or butments from 2.7 to 3.3m above the tops of the weir, and facing the banks with stone.

The Royal Commission of three inter-State experts in 1902 reported that a scheme for locking the Murrumbidgee to Hay, the Murray to Echuca and the Darling to Walgett, would cost £2,571,750, and require 59 locks (26 on the Murray, 24 on the Darling, 9 on the Murrumbidgee). These works would make 4000km of the Rivers permanently navigable (P.S.C. 1899 p.3-6).

At their 1911 Conference, the Premiers of New South Wales and Victoria refused to recognise the claims of navigation in any way, or that South Australia had any claim to receive sufficient water to maintain navigation, but South Australia was allowed to undertake locking works on the Lower Murray at her own expense. For many years the sole lock above South Australia was the experimental lock at Bourke. Victoria later built two locks - Lock 26 at Torrumbarry and Lock 11 at Mildura, but it was at Mildura that navigation ended.

The 10 locks between Blanchetown and Wentworth are 83.8m between gates and 17.0m wide. Lock 11, Lock 15 at Euston and Lock 26 at Torrumbarry are only 51.8m long and 17.0m wide.

Weirs below Mildura have a navigable pass consisting of collapsible trestles supporting Boulé shutters and sluice openings, closed by stop-logs. During periods of high river, the shutters are removed and the trestles dropped onto the bed of the River, affording a large, clear opening for navigation.

The Mildura and Torrumbarry weirs are of the Dethridge type, and can be winched from the River during flood periods or for maintenance.

Losses in storages were roughly estimated as 1.2m in depth per annum in the Upper Murray, 1.8m at Lake Victoria, and 2.7m below Lake Victoria, disregarding the expansion of the River Murray into Lake Alexandrina and Lake Albert (Dare p.95).

V. EXISTING LOCKS

There are 13 locks on the River Murray, one on the River Darling just below Bourke. Two weirs on the Murrumbidgee River, Redbank Weir above Balranald, and Maude Weir at Maude have provision for locks.

TABLE 2

Lock Traffic on River Murray 1972-1973

Lock	Location	Number Lockages	Number Vessels	Number Barges	Total Craft	Total Passengers
	Goolwa Barrage	3124	3846	-	3846	22,273
1	Blanchetown	423	513	-	513	5,626
2	Waikerie	278	502	-	502	1,692
3	Overland Corner	161	205	-	205	842
4	Loxton	497	675	-	675	3,426
5	Renmark	1050	1255	-	1255	7,250
6	Murtho	709	758	-	758	3,757
7	Rufus River	38	48	-	48	212
8	Wangamma	4	4	-	4	18
9	Kulnine	15	15	-	15	61
10	Wentworth					
11	Mildura		526	-	526	19,978
15	Euston					
26	Torrumbarry	5	5	-	5	
		6504	8352		8352	65,135

Lock 7 closed until September, Lock 8 after November, for gate replacement
No figures available for N.S.W. Lock 10, Lock 15.
Snagging above Lock 4 (R.M.C. 1972-73).
Most of the vessels are private pleasure craft.

12 further locks are required to enable Murray navigation to Echuca, 30 locks on the Darling-Barwon for navigation to Walgett, and 9 locks on the Murrumbidgee to open up the Murrumbidgee to Hay and parts of the Edward-Wakool system.

VI. REQUIRED LOCKS

Required Murray Locks

Lock	Site	Pondage Length	Pondage Altitude	River Distrance from Goolwa
12	Nangiloc	75.0 km	41.60 km	1132 km
13	Ki Bend	81.2	45.80	1207
(15	Euston	96.5	49.40	1288) *
16	19 km below Murrumbidgee	63.2	54.00	1385
17	2km below Wakool R.	25.5	57.60	1448
18	12km below Talleybuc P.O.	63.3	62.30	1474
19	below Puah Ck.	38.2	65.80	1537
20	Swan Hill	52.9	69.40	1575
21	7km below Loddon R.	43.0	72.20	1628
22	5km above Murrabit P.O.	27.5	74.80	1671
23	Koondrook	21.9	77.70	1698
24	21km above Koondrook	37.7	80.50	1720
25	17km above 390 mile Lagoon	48.0	83.60	1758
(26	Torrumbarry Weir	-	87.10	1806)

* Brackets indicate existing locks.

Required Darling-Barwon Locks

Lock	Site	Pondage Length	Pondage Altitude	River Distance from Wentworth
(10	Wentworth	47.5 km	33.30	0
TAPIO	1km below Tapio H.S.	63.5	35.80	47
PARA	1km below Para H.S.	37.0	38.60	111
BURTUNDY	3km below Jamesville H.S.	66.0	41.50	148
CARSTAIRS	6km above Carstairs H.S.	59.0	45.30	214
MULLINGAR	5km above Mullingar H.S.	59.0	48.40	273
COONA	4km above Yalta Ck	101.0	51.10	333
BINDARA	4km above Bindara H.S.	18.5	53.80	434
BIRCH	7km below Keiara H.S.	86.5	55.60	452
MENINDEE	Menindee Weir	40.5	-	538
WINDALLE	9km above Windalle H.S.	73.0	59.20	579
BARRAROO	3km above Barraroo H.S.	62.0	61.80	652
BAKARA	at Bakara H.S.	33.0	64.00	714
CULPAULIN	17k above Billilla H.S.	41.0	66.70	747
WOYTCHUGGA	27km below Wilcannia	58.0	69.50	788
BARRADALE	Murtee H.S.	60.0	72.80	850
TALLANDRA	17km above Kennedy Reef	109.1	76.30	910
NELYAMBO	46km above Cultona H.S.	47.5	78.90	1020
MYALL	3km below Myall H.S.	47.2	81.10	1068
TILPA	Weir 24	69.2	84.80	1115
IDALIA	Weir 21 - Idalia H.S.	55.1	87.50	1184
LOUTH	at Louth	45.5	90.20	1239
OURAWEIA	6km below Warrego R.	73.2	93.70	1295
YANDA	12km below Yanda H.S.	27.5	95.90	1368
JANDRA	Weir 19A	45.4	97.50	1395
(BOURKE	Bourke Lock and Weir	40.7	100.60	1441)
STONY POINT	on Stony Point	109.5	105.30	1480
BOKHARA	below Bokhara R.	32.5	108.40	1589
BREWARRINA	Weir 15 - Brewarrina	54.1	112.60	1622
MARRA DOWNS	above Marra Ck.	28.3	116.00	1686
BOOROOMA	8km above Riverview H.S.	35.4	118.70	1714
BORUMBIL	3km below Moorabie H.S.	-	121.80	1750

River Murray locks are located to provide 2.0m water depth, River Darling locks to provide 3.0m

At present, weirs exist at Appin H.S. (Weir 32) below Menindee, at Menindee, above Wilcannia (Wilcannia Weir), Tilpa (Weir 24), below Louth (Weir 21), below Bourke (Weir 19A), Bourke Lock and Weir, at Brewarrina (Weir 15) and below Walgett (Weir 11A). A further 5 or 6 weirs are projected by the Water Conservation and Irrigation Commission, to be located between Bourke and Menindee.

VII. COST OF RIVER LOCKING

The cost of additional locks on the Murray and Murrumbidgee would be borne by South Australia, Victoria, New South Wales, and the Commonwealth, in accordance with the River Murray Waters Agreement. Further weirs are proposed for the Darling by the New South Wales Government, but ideally the Commonwealth would fund the Darling-Barwon locking scheme.

River Darling Locking

Initial costs

30 locks at $300,000 each	9,000,000
25 weirs at $120,000 each	3,000,000
Addition to 5 weirs	500,000
Wharf and cranes at Pooncarie, Menindee, Wilcannia, Tilpa, Louth, Bourke, Brewarrina, Walgett	800,000
30 lock-keepers cottages	240,000
Surveys	350,000
Weirs on and branches	200,000
Snagging, contingencies	500,000
	$14,590,000

Annual costs

Maintenance	30 locks and weirs	360,000
	30 lock keepers	240,000
	40 wharfmen	320,000
	snagging, miscellaneous	120,000
		$1,040,000

River Murray Locking

Initial costs

12 locks at $300,000 each	3,600,000
12 Dethbridge weirs at $210,000 each	2,520,000
12 lock-keepers cottages	1,200,000
Cranes and wharfs at 15 sites	1,500,000
Surveys and snagging, contingencies, levees	300,000
	$9,120,000

Annual costs

12 lock-keepers	96,000
80 wharfmen	640,000
Maintenance, 12 locks, weirs	144,000
Snagging, miscellaneous	60,000
	$940,000

Murrumbidgee River Locking

Initial costs

6 weirs at $190,000 each	1,140,000
6 locks at $300,000 each	1,800,000
3 locks to existing weirs	600,000
Snagging, surveys, contingencies	400,000
Cranes at 4 sites	400,000
	$4,340,000

Annual costs

9 lock-keepers	72,000
20 wharfmen	160,000
Snagging, miscellaneous	100,000
Maintenance to 6 locks, 6 weirs	72,000
	$404,000

So total initial cost is about $28 million, with annual costs of $2.4 million - neglecting cost of river craft and interest.

Almost $5 million could be deducted from the initial cost if locking of the Murray is not extended from Lock 19, below Swan Hill, to the Torrumbarry Lock as this region has a well developed rail system, and is only 200 to 300 km from Melbourne. About $0.5 million could be taken from annual cost by cancelling Locks 20 to 25.

For the River Darling, weir costs are based on the cost of Weir 21 below Louth and Weir 24 above Tilpa, which cost about $110,000 and $130,000 respectively. These weirs were much delayed by floods, and took about 3 years to complete. Weirs for this scheme would hopefully be completed in a few months.

The proposed weirs are of the sheet-piling type; several rows of piles are driven, and steel sheeting resting on the up-river side of the piles. The gap between rows is rock filled. This form of weir is cheap, almost maintenance free, rugged and quick in construction.

Lock walls would be essentially sheet-piling walls with concrete supports for steel lock gates at each end. Lock bottoms would be "soft" - an earth bottom with ballast to prevent scouring. All-concrete locks cost would almost be prohibitive because of the distances involved in transporting cement and the gravel aggregate.

Miscellaneous, snagging and survey costs have little or no basis.

Maintenance is based on the average cost for maintaining the 13 Murray Locks and weirs for 1972-73 (average $12,000). The Murray weirs are of the Dethbridge type - far more complex and costly than the projected Darling Weirs, and so, Darling weirs' maintenance is probably far too high.

VIII. POTENTIAL RIVER TRADE

The best indications of the amount of trade in river areas is the railway inwards and outwards tonnage for the rail-heads, but this information is unavailable to the public.

To gauge, to some extent, the quantity of agricultural produce that could be captured by river craft, the production by statistical areas has been added. On the Darling and Murrumbidgee, production between the River and a line equidistant from the River and the nearest railhead is considered to be available to river craft. On the Murray, production within 25km of the River is for river craft. This criteria is to provide an estimate only. If river freight rates are lower than corresponding rail concession rates, more trade would almost certainly be captured, providing good facilities are available for exporting the produce, or for conveyance to the domestic market.

Wheat, wool, beef, barley and oats are the primary products considered. Details of soft and stone fruit, dried fruit, wine, grains and oilseed are unavailable, nor at present, is any indication of a potential back trade of manufactured and imported goods. In the great days of the river trade, wool was the major trade, but transporting manufactured and imported goods was the real money earner.

TABLE 3

POTENTIAL RIVER TRADE

River Section	Wool	Wheat	Beef	Barley	Oats
Bourke to Walgett	9,650		6,300		
Menindee to Bourke	12,050		3,000		
Wentworth to Menindee	3,350		-		
Total Darling-Barwon	25,050		9,300		
Echuca to Swan Hill	1,740	21,200	3,600	2,040	9,500
Swan Hill to Mildura	2,140	21,100	1,200	3.060	7,160
Mildura to Morgan	2,140	111,000	-	18,400	21,500
Below Morgan	1,340	31,600	1,200	17,400	11,940
Murrumbidgee-Edward	4,150	10,500	900	1,020	-
Total Murray-Murrumbidgee	11,510	195,300	6,900	41,920	50,150

Total tonnage 248,060 tonnes wool, wheat, beef, plus 92,070 tonnes barley, oats.

Wool, wheat and beef are mainly export produce, barley and oats are domestic products.

Wool tonnage is assessed as 4.45kg wool per sheep, wheat at 1.32 tonnes/hectare, barley 1.28 t/ha, oats 2.39 t/ha, and beef at 125kg/animal. These figures are obtained from the Commonwealth Year Book, 1972 by considering the means per animal or per hectare for 1966-67 to 1970-71, which includes the very bad year of 1967-68.

IX. CONCLUDING REMARKS

Trade by paddle steamers can occur again on the Rivers Darling and Murray. The water is available, the expense is not prohibitive, but needs a change in Governmental policy back to river transport , which it neglected, indeed discouraged.

Cargo movement on the Rivers will not destroy existing transport facilities, but change their direction from the Rivers, to the Rivers. It promises employment and town revival to the unique River districts of Eastern Australia.

But best of all, it should make possible cheaper freight rates to primary producers, hard-hit by high, and rising, freight costs.

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DETAILS OF SOME RIVER STEAMERS

Vessel Reg.No.	Year Type	Construction	Builder	Nett tonne	Gross tonne	Length m	Beam m	Depth m	Power kw	Engine	Fate
Albury ON31 576	1855 Side	Iron	R.Napier Glasgow	98	139	36.60	4.88	1.83	37.3		1887 converted to tug and lighter, scrapped Adelaide 1900.
Brewarrina ON74 945	1877 Side	Iron	S.Thomas Echuca	22	28	17.42	3.86	1.51	7.4		1926 wrecked on Murrumbidgee.
Corowa ON38 870	1868 Stern	Iron	J.Anderson Moama		96	28.92	6.07	1.83	37.3	Originally steam by Anderson, McCaul Black of Melbourne; later common non-condensing direct acting by A.Graham,1868	Sank 3 times on maiden voyage; built on remains of Lady Darling, stripped 1930. Last seen Morgan 1944.
			Rebuilt W. Smith,Corowa	130(1871) 71(1921)	181 134						
Ellen ON71 780	1876 Side	Iron	S.Sherliffe, Goolwa	96 85(1884)	134 134	36.60	5.76	2.29	59.7	1877 engined, compound non-condensing double acting 2 cyl. 107.2cm stroke	Vandalised and fired Morgan, 1930.
Gem ON74 652	1876 Side	Composite	Air & Westgaard	101	143	28.50	6.23	2.05	29.8	Horiz. H.P. Steam by Davey Bros. Ballarat	Folk museum Swan Hill Post 1962. Known as Isabella until lengthened in 1883.
			Moama	183(1883)	228	40.75	6.23	2.02			
Industry Not regd.	1911 Side	Wood	A.J. Inches, Goolwa			32.41	5.67	2.62	22.4	2 cyl.non-condensing by Roberts & Sons of Bendigo Loco boiler	Based Renmark; in service until 1971.Used as snag-boat.
Lady Augusta ON40 522	1852 Side	Wood	T.Chowe, Pyrmont Syd,	29	90	29.88	3.46	1.68	29.8	Engine by Napier & Co. Sydney	Abandoned Echuca 1872. Converted to barge, carried name Lady Agusta for whole life.

Vessel Reg.No.	Year Type	Cons-ruction	Builder	Nett tonne	Gross tonne	Length m	Beam m	Depth m	Power kw	Engine	Fate
Marion ON112 509	1897 Side	Compo-site	A.Land-seer, Milang	99	157	32.94	6.90	1.58	14.9	Rope geared	Nation trust 1963 Mannum. Served early life as hawker.
Mary Ann Not regd.	1852 Side	Wood	J.& W. Randell, Mannum	20		16.8	2.7		5.2	Engine by Ghelkin, Adelaide	1955 hull for Gemini, rotting near Mannum.
Melbourne Not regd.	1864 Stern	Iron	Anderson & Stuart, Echuca			24.45	4.3	1.2			Remains at Cooper's Slip, Goolwa.
Melbourne Not regd.	1912 Side	Wood				29.86	6.41		18.6		Tourist boat out of Mildura with original engines.
Pevensey ON120 770	1910	Compo-site	Permewan Wright, Moama	86	130	34.06	7.02	2.08	44.8		Damaged by fire 1932 at Morgan; rebuilt, operates from Mildura.
Success ON74 926	1877 Side	Iron	G.B. Air, Moama	97 54 (1908)	129 34	25.22	5.03	1.83	18.6	By McCall, Anderson & Co. Melbourne	Wreck destroyed by fire, Merebin 1971.
Trafalgar ON74 916	1877 Side	Compo-site	J. Mc-Donald Echuca	158 87 (1932)	228 127 116	32.31	5.76	2.43	44.8		Barge 1937. Wreck at Pt.Adelaide. Deckhouse at Moama.
Ulonga ON120 769	1910 Side	Compo-site	Permewan Wright, Moama	87 98 (1949)	127 119	34.06	6.70	2.11	14.9	2 cyl. non-condensing	1949 converted to twin-screw aux. Ketch- still operates on S.A. coast.

SOME ASPECTS OF FINANCIAL PLANNING IN THE SMALL SHIP INDUSTRY

by

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In our society at present the time value of money is decreasing, even in the well managed and sophisticated industrial countries, at an unprecedented rate. The need to control inflation is uppermost in our minds as industrial managers but the problems are complex and the control techniques are of a socio-political nature such that the rate of change is likely to be, in all prudence, gradual rather than dramatic in its nature.

In 1964 the net profit of listed manufacturers in Australia averaged 10% of shareholders' funds. In 1973 it had fallen to about 9.5%. Although the fall was slight, other listed companies had shown an average increase. This comparison has shortcomings but in real terms over the period it would seem that industry investment has stagnated while labour cost has increased about 170%, and since 1970 by about 100%. Combined wages and materials cost has increased about 130%, and 80% respectively.

The planner in industry is faced with the need to increase the funds available for capital investment and operating expenditure relative to constant work volume in an environment where it is inevitable that the cost of funds in the market place is high and the availability limited.

He needs to provide for a rate of growth compatible with market potential and at the same time deal with the effect on costs of the equally inevitable escalation in the unit cost of labour.

In this environment, capital gearing which is simply the direct relationship between borrowed or debt funds and equity must be subject to review.

A company financial structure is said to be highly geared when debt capital predominates and low geared when equity capital predominates. A high stable profit history may justify a high gearing but if profits are likely to fluctuate such as in the heavy engineering, construction or metal manufacturing industries a high gearing is undesirable. It may well create instability within the company and in periods of low profitability acts to reduce the earnings rate per share, the very factor that high gearing is often aimed to protect. The point is illustrated by the following simplified example -

	Year 1		Year 2	
	A Company	B Company	A Company	B Company
Term borrowing @ 15% pa	-	10,000	-	10,000
Equity funds	20,000	10,000	20,000	10,000
Profit before interest	10,000	10,000	2,000	2,000
Interest on term borrowing	-	1,500	-	1,500
Profit before tax	10,000	8,500	2,000	500
Tax (say 50%)	5,000	4,250	1,000	250
Earnings Rate (% equity funds)	25%	42.5%	5%	2.5%

In this case the earnings rate per share in Year 1 is improved by the introduction of a term loan but after the profit drop in Year 2 the return per share is reduced as a result of the introduction of borrowed funds.

Some companies have established ideas about gearing of their structures and there is an optimal arithmetical combination of equity and debt best suited to any point of time in each undertaking. It is sometimes said that this can best be calculated by assuming it to be the point at which the weighted cost of capital is lowest but it is submitted this is a considerable oversimplification.

Gearing controls not only the potential earnings per share but the rate of growth and development of the company by the application of financial leverage for uses such as the provision of profit earning plant and equipment. No hard and fast ratios can be laid down but two extreme examples might serve to demonstrate the range of gearing expected. In companies having a high investment in fixed assets such as engineering manufacturers, equity often stabilises at about 60% of funds employed. On the other end of the scale companies in the finance industry, having as their main source of business current hire purchase agreements or the like, may have total equity funds representing only 15%/20% of funds employed.

Clearly, the difference rests in the use of funds. In the case of the manufacturer, his funds would normally be invested in plant and equipment which must be usefully and economically employed in order to maintain growth and financial stability. In the case of the finance house with a high percentage of the debt funds normally invested in current hire purchase or lease agreements, the company has a predictable and normally secure rate of return.

Borrowings are provided by a range of organisations within the finance industry for a variety of purposes but, essentially, either as leverage to increase the rate of development or effectiveness of the company or as working funds to enable the company to finance its day to day operations. The policy of these organisations to this extent therefore qualifies the rate of growth, efficiency and trading capability of a company and may become a factor in the term planning of the company.

The high cost of money has not unnaturally reduced significantly the availability of low interest rate loans for special purposes. In industry today, funds are normally available at commercial rates, that is the cost of money to the financial institution plus operating margin. The Commonwealth Development Bank of Australia and the Australian Industry Development Corporation are the nationally constituted bodies providing term loans in the medium to long term for industrial development purposes.

A term loan, as its name implies, is provided for a specific period. Repayment is normally scheduled on equal annual or bi-annual instalments calculated to include interest and capital reduction at a level designed to suit the company capability and according to a contract agreed between the lender and the borrower.

The trading banks will also provide term loans when funds are available. Usually these are of relatively short term for special purposes in support of the fundamentally vital role of the trading bank to provide working capital assistance to the company. This latter class of funds is usually provided on a fluctuating basis within agreed overdraft limits.

Finance houses provide funds at commercial rates by the excellent medium of hire purchase and leasing arrangements. These funding systems are likely to be of increased importance to skilfully and prudently managed industries in the future. They can be quickly and conveniently applied for provision of new plant and equipment to assist as far as possible to counter a rapid increase in labour cost or to improve the unit rate of output of the industry.

At the National Fisheries Seminar in Adelaide, August 1974, two papers were presented both titled "The Fisherman as a Borrower".

K F Lane explained the Commonwealth Development Bank of Australia is essentially a prospects lender and that the bank investigates in some depth technical and operational aspects of a proposal as well as evaluating the conventional financial parameters.

Lane mentioned that the policy of the Development Bank was recently broadened to include secondhand fishing vessels. It may be of interest to those concerned that the section of the bank's current lending policy statement referring to that industry is now stated as follows -

In relation to the fishing industry, the bank considers applications for finance for -

- The purchase or construction of new fishing vessels and the acquisition of gear and ancillary equipment.
- Improvements to fishing vessels.
- The change of ownership of fishing vessels in appropriate circumstances.
- Repayment of debt on fishing vessels arranged on unsuitable terms and conditions.

Additionally, of interest to the small ship industry, the Development Bank can provide finance for the establishment or development of industrial undertakings, particularly small undertakings. In determining whether or not finance shall be provided the bank shall have regard primarily to the prospects of the operation becoming or continuing to be successful and shall not necessarily have regard to the value of the security available in respect of that finance.

The bank pays particular regard to the industrial significance of the activities concerned. Except in special circumstances, the bank does not approve loans which merely involve change of ownership of assets or the taking over of debt from another lender. It is necessary to establish that the finance sought is not otherwise available on reasonable terms and conditions. No maximum amount has been set but because of the bank's special function, loans are rarely approved for sums in excess of $200,000. Applicants are normally expected to have reasonable equity in their undertakings.

Finance is usually made available by intermediate or long term loan, repayable over a period suited to the circumstances of the borrower. In suitable cases finance may be provided under hire purchase agreement for the acquisition of income earning plant and equipment when the maximum available term will depend on the type of goods financed.

The other paper, titled "The Fisherman as a Borrower", T.F. Meany, describes a study carried out by the Fisheries Division of the Department of Primary Industry, among fishermen holding Commonwealth licenses. It schedules the sources of finance available to Australian fishermen. The paper also outlines the type of information the fishermen should provide to a potential lender and the form in which this should be presented.

Both papers are also recommended to those interested in the sources of loan funds for the construction of small ships in Australia, as excellent sources of background information and procedures.

While fishermen may also have access to some funds, mainly working advances, from fish processors and co-operatives the small shipbuilder is, in the normal course constrained to the sources of funds usually available to companies or persons participating in industrial undertakings.

This includes access for financial assistance to the previously mentioned A.I.D.C. A more recently established national Corporation, it is able to make medium and long term loans to commercially viable enterprises in the industry. Such loans are made at commercial rates of interest. The Corporation places particular emphasis on assessment of viability and the tailoring of its loan funds to the requirements of the enterprise under consideration. There is a preferred downside limit of $500,000.

While term lending by the Development Bank and by A.I.D.C. may be available for longer terms than usually preferred by the trading banks and other commercial houses due to the special responsibility these two organisations have to the industrial community, emphasis in term lending by both A.I.D.C. and the Development Bank is placed on the commercial viability of the package under consideration. Essentially, the loan should maintain the financial stability of the enterprise while providing leverage for development, the benefits of which can be assessed on physically demonstrable factors.

Incidentally, while it is not the intention of this paper to explore security arrangements, it is necessary in respect of ships to be able to prove ownership and title to a vessel in order to be able to give a satisfactory mortgage charge over the vessel. The accepted instrument of title is registration of the vessel as a British ship. The procedure can be a significant delaying factor in loan funding if some impediment in registering the vessel's name or obtaining a builder's certificate should arise. The system has stood the test of time but there must now be some merit in Australia establishing its own register of ships.

It is often accepted, as a starting point for planning purposes in small metal manufacturing companies that the ratio of proprietorship or, equity funds to total outside borrowings should be in the order of 50/50% while in more conservative quarters, it is not unusual to see the preferred ratio shifted to 60% equity, 40% borrowings for the purpose of regulating small company leverage.

The skill in our modern society is to obtain a ratio commensurate with a reasonable rate of growth and development without generating financial instability in periods of industrial difficulty, or recession which may occur during the predicted repayment period. The high cost of funds will have an adverse affect on earnings rate if the gearing becomes too high and the competitive marketing position of the company can deteriorate notwithstanding the cost of construction of the vessels or components manufactured is increased in accordance with standard direct cost allowances for escalation.

So in the well planned developing company the gearing ratio may be expected to vary periodically within controlled limits to provide the leverage required. The gearing, if extended to finance the purchase of equipment is then expected to reduce progressively not only according to the repayment programme but also due to the improvement in productivity resulting from the installation of the new equipment.

The working capital requirement which affects the gearing ratio, may also be expected to vary when funds are provided for new capital works. So, in Australia, more than one financing house is likely to be involved in the company plan.

Correlated technical and financial planning is required and it is in this area that production oriented management can materially assist in the better communication between the owners of the proprietorship and borrowed funds in the company.

It has been pointed out that medium and long term lending is based essentially on assessment of the viability of the package under consideration. If an approach to the lender can be supported by detailed feasibility study including market appreciation, operating and administrative cost estimates then the ability of the lender to more effectively assess the worth of the proposal is enhanced.

Most term lenders, particularly those involved in the longer terms, have access to engineering expertise and experience by one means or another and are therefore able to participate in depth in the company's term planning when it is necessary. It is by such closer technical and financial co-operation in forward planning and appraisal that the major term lenders seek to more effectively vary the gearing ratio to benefit the rate of growth and development of the company without detracting from its basic stability or operating cost effectiveness.

Students of discounted cash flow techniques will be familiar with Comparative Rate of Return calculations. In this type of study the company is required to adopt a minimum acceptable percentage annual rate of return of funds to be invested in new plant. If then, the purchase price and operating costs are known and the life and residual value can be estimated, an economic comparison can be made to compare new processes or equipment with those existing or to evaluate alternative new processes. Such studies have the value of not only conveniently enabling the manager to make an understandable and concise appreciation of a new method but also enable him in turn to explain, in finite financial terms to his directors, the benefits expected to accrue from expenditure on productivity improvement equipment.

The use of such techniques, being time consuming are probably restricted for practical purposes to major items of plant or procedural methods. However the selection of a preferred percentage R.O.R. gives cause for careful consideration by management of the overall cost benefit required of new plant relative to the increase in gearing needed to pay for its installation.

Rate of development must depend fundamentally on business opportunity. In Australia we could do well to take note of the efforts being made by the small but technically advanced countries such as Sweden to expand their traditional areas of market penetration. Whilst it is true at present currency exchange rates that some of Australia's secondary manufacturing industries are not internationally competitive, those industries having a high technological content seem to have the better opportunity.

Depth of experience in specialised manufacture can open the door to international markets.

Design and product quality in Australia is particularly high in the shipbuilding industry so it might be expected that this aspect should place our industry in a good position to selectively market overseas if relative cost efficiency can be maintained in the yard. This can possibly be helped by designing to suit multiple construction of vessels for which a broad band demand pattern exists or by manufacture of specialised components for vessels.

Component manufacture with its resultant higher volume of a more specialised range of product can improve productivity by permitting the early introduction of specialised plant and equipment and by better utilisation of capital invested in plant and equipment.

For instance, to move to a related industry for an example, the pleasure boat industry in Australia, has been particularly successful in the field of component supply both to the Australian and the overseas market. Significant and successful growth rates in the field of stainless steel fittings and in the manufacture of geared yacht winches have been obtained. In these cases Australian companies have shown superior design capability and some have obtained funds on relatively high gearing ratios to service the expanded international market. These companies are not expected to be significantly adversely effected as a group by economic downturn in the industry due partly to their market spread but also by the degree of manufacturing efficiency and, therefore, cost effectiveness developed.

So, in a country such as Australia with its small local market volume there is good sense in looking at specialised fields of manufacture as a means of increasing volume of output. There is of course advantage to the commercial shipbuilding industry as a whole to be obtained from a healthy components manufacturing support system. Development is in hand in some fields and having regard to the relatively high degree of innovative capability already being demonstrated by the industry, we should be alert to recognise if a contained business opportunity is present for the future.

The industry will benefit from related industrial growth and development. For instance, the acceleration of programmes to upgrade the installation of fish processing plant in Australia could increase the percentage of fish consumed in Australia which is provided by local fishermen. So more research in fishing processing could, indirectly, assist the small shipbuilder.

In the field of offshore mining there is to be a complete new generation of equipment, initially for use on the continental slopes and perhaps later for deep floor mining of mineralised nodules and sludge.

The principal financing authorities, naturally, are interested in such possibilities for future development and may sometimes be able to assist in inter-industry communication at the technical and management levels where this is appropriate.

Clearly, and particularly if export sales are to play some part in the future of the industry, any statutory benefits which assist the cash flow in the early critical years after installation of new and sometimes specialised plant must improve the competitive position. Accelerated depreciation allowances for new plant, for example, introduced in a manner designed to ease the tax load can assist, particularly in the very significant problem of cash flow in year 1 after installation. The value of insurance against the consequences of currency re-alignment or deficiency for a variety of causes in payment of overseas accounts is obvious and in the latter respect, the Export Finance and Insurance Corporation now has special policies which may assist some exporters.

We should not however retard planning in the private sector while such statutory matters are under consideration or in the hope that manufacturing on marketing conditions will be improved.

In an inflationary situation the small to medium company can be caught in a treadmill type of situation in which the high borrowing cost of a continually increasing working funds requirement can erode earnings to such an extent that a contraction of the level of work done is the final alternative. Lower asset backing to support investment expenditure may result, so plant and equipment productivity will, if the situation is allowed to continue, eventually contract. Indexation of debt is sometimes suggested as a means of overcoming the mismatch in financial relationships due to inflation but it does not seem to be a practical solution. In the longer term cost pressure inflation has to be controlled by the actions of society itself but industry meanwhile can help itself by carefully planning to protect its liquidity position.

There is the need, more than ever, for technical integration in financial planning. The structure of the company should be related in an effective manner to a sound and practical overall corporate plan in which progressive improvement in productivity and efficiency and an alert perceptive market programme will be the keynote to success. That is, we have reached the stage where financial structuring of the company is dependent to a greater degree than ever before on the technical expertise within the company and the ability of the company to develop and introduce new and more efficient operating and marketing methods.

The purpose of this paper has been to discuss some of the aspects of financial planning which seem at this time to impinge on the relationship between borrowed and equity funding of the company and the benefits which technical management can bring to this area. The subject of accumulation, growth and protection of equity funds has been avoided as its importance and complexity warrants separate consideration. However it is perhaps worth considering that the nature of the equity contribution, particularly in the private and small public company can bear markedly on its source of senior management skills.

The modern company should encourage as far as possible a balance of skills and experience within its shareholding structure which are representative of the wide range of experience necessary to lead and develop the company in an increasingly complex and sophisticated business society. It may well be that in Australia, more inter-relationship between companies having specialist skills is desirable to maintain the degree of operating and marketing efficiency necessary to compete effectively with the technically advanced countries of the world.

A SOLUTION TO THE ADDED COSTS IMPOSED ON THE SMALL SHIP INDUSTRY BY GOVERNMENT ASSISTANCE

by

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SUMMARY:

In its aim to assist the shipbuilding industry by way of subsidies, successive Governments have imposed upon the industry a system run by Public Servants at great cost and to the detriment of the initial intention of those Government's policies. The small Shipowner and Shipbuilder have suffered more in this regard than their large counterparts by this administrative intervention.

The Government's currently proposed Bounty Act does nothing to alleviate the previous injustices to the small establishments or to improve the assistance to the industry in general but it appears to increase the administrative intervention and associate costs.

This paper submits a solution to eliminate the present and proposed costly administrative confusion and the discretionary powers of the Minister and his delegates by replacing the current Bill with a simple scheme able to be easily understood at a low administrative cost making the Bounty obligatory to Shipowners who will be able to safely predict the costs of proposed vessels during early negotiations with Shipbuilders.

I. INTRODUCTION

The subject matter of this paper concerns the small commercial vessel but not those of the pleasure craft industry. Without doubt, for this industry to exist as a viable and economic proposition there must be two ingredients:-

(a) Shipowners and potential Shipowners with a need for small vessels either for existing trades, new trades coming into existence or for old trades changing their previous patterns.

(b) Shipbuilders with capacity to build these vessels at a selling price and within a delivery period which is also economically viable to the trades proposed to allow both the Builder and the Shipowner a profit margin adequate for both to keep operating in their respective trades. The industry cannot exist if either of these parties fail to operate profitably.

In the Australian industrial scene at present the small ship building industry could not survive except in a small way as an industry, if Shipowners had complete freedom of choice to buy or build anywhere they wished to throughout the world. Successive Governments have realised this and have imposed their sanctions, and with good intent, their financial assistance in one way or another over a great number of years.

The initial and principal sanction has been applied through the Customs Act whereby ships are mainly classified as prohibited imports. Briefly this worked as follows:-

After World War II the Government of the day thought fit to create a National Shipping Line and to maintain the then developed shipbuilding industry by introducing the "Australian Coastal Shipping Commission Act" and creating through the "Supply & Development Act" the Australian Shipbuilding Board. The Tariff Board held inquiries into the Australian shipbuilding industry several times to arrive at a level of Government financial assistance necessary to maintain an efficient and viable shipbuilding industry.

At that period the United Kingdom was the leading shipbuilding nation of the world and it was decided that an Australian Shipowner should be able to purchase a ship built in an Australian shipyard at a price equal to that which he could purchase the same ship at a U.K. shipyard.

The Australian Shipbuilding Board was the Body which was to determine the U.K. selling price upon which to base the Australian selling price. The "unofficial" title of this assistance was Shipbuilding Subsidy, as the assistance being given by the Government was an effort to subsidise the shipbuilding industry. However, officially there was no such thing as Shipbuilding Subsidy.

The Minister for Shipping and Transport was given the authority under the Act to buy ships and sell ships. No mention was made as to whether or not he made a profit or a loss. Thus the Minister by contract constructed a ship at a shipyard and sold it to an Owner upon completion at a price which was estimated by the A.S.B to be the current U.K. price, provided the loss involved (or subsidy) did not exceed the percentage set by the Government.

This ceiling has fluctuated from 25% originally to a current level of 40% but for most of the period the percentage was 33-1/3%. The shaky element in this whole exercise was the U.K price estimated by the A.S.B. No recipient believed he ever got the full 33-1/3%, and in fact he did not, because no subsidy was given to:-

(a) Escalation in costs during construction.

(b) Modifications during construction.

(c) Prime Cost excesses.

(d) Delivery costs (these were always conserative estimates).

II. APPLICATION OF THE SCHEME

Small ships, i.e. those under 1000 TDW, in my opinion, were the worst treated under past subsidy schemes, under the existing scheme and in the current "Bounty" proposals, thus the Builders of small ships were and are the ones which suffer most under the subsidy schemes.

Vessels in this small ship range were eligible for subsidy but, in my opinion, under the previous scheme were practically never subsidised up to the level to which they should have been, i.e. the equivalent U.K. price, and under the present scheme the Australian subsidised price can be well beaten by Shipbuilders overseas with subsidy currently at the 25% level.

Under the earlier subsidy scheme this attitude linked with the inquitable taxation depreciation arrangements usually forced Owners to hold

on to redundant vessels and delay for years replacement vessels and vessels for new ventures.

Under the present subsidy scheme Owners are encouraged to seek tenders overseas better than local tenders and if they are lower than the local subsidised price it is not particularly hard to purchase the ship overseas to the detriment of Australian shipyards. The Australian Government's own shipping line leads the way here.

An Owner proposing to build a ship in Australia under the subsidy scheme (now by Bounty scheme) must submit himself to the administration processes associated with this Government scheme and place his project under the control of Public Servants which becomes a most frustrating, time consuming, and costly adventure. A process, which in every Shipowners' opinion, and I venture to say in practically every Shipbuilders' opinion, reduces that quantum of subsidy finally given to a project to a figure much less than the Legislators in Government ever intended, and further reduces that level of subsidy by the added cost to Owners and Builders in delays and extra administrative costs. Here lies an anomalous situation.

Cabinet conceives a means of relieving costs to Owners and/or Builders but by the administrative process through the various levels of Public Service the intended level of assistance is reduced and the taxpayer meets an administration cost in excess of one million dollars per year for Public Service non productive costs. The past system of subsidy and present system of Bounty proposed all call for a very high level of Public Service intrusion at a tremendous cost.

III. ALTERNATIVE SCHEME

I suggest, indeed I categorically state that the shipbuilding Bounty scheme I propose could be run by one 5 Public Servants, more efficiently and effectively than any past or current or previously proposed scheme of subsidy or bounty. My proposal would eliminate the present frustrations, delays and costs associated with subsidy completely, as there would be practically no need for Public Service intrusion. I set out my Bounty proposal on Schedule "A" to this paper and ask you to read this before proceeding further.

The problem facing the prospective Owner of a small ship and the Shipbuilder of a small ship is that there is no differentiation between the small and the large Shipowners and Shipbuilders in the administrative procedures that must be followed to obtain a Government subsidy. The large establishment carries a staff quota which can handle the compulsory administrative procedures at a smaller overall cost percentage of his staff establishment. The size of the project in both physical and cost terms also makes the subsidy administrative costs a smaller percentage item of the total costs for large establishments. However, the small Owner and Builder must carry out the same level of subsidy administrative work as the large establishment both in time and performance. However the time and cost involved for the small establishment becomes a larger percentage in staff work and time involvement against overall costs of the project and the administrative costs bear heavier on the small establishments profits. They have no staff specialised in handling such strange paper work nor used to dealing with the various level of Public Service. This may be the Owners first vessel and his last for quite some time. The cost to the small establishment in obtaining

subsidy cuts into the quantum of subsidy given here by a much larger percentage than the large establishment enjoys.

It is plain to see that this system discriminates against the small establishment. I have known a number of small shipyards where key productive executives were forced to handle subsidy paper work and processes so often that time away from former productive activities cost those shipyards dearly.

I have known small Shipowners to withdraw from proposed projects or defer a project because of the frustrations involved and the time and costs they would face in obtaining subsidy. Of course they could go along without subsidy aid but this overlooks the physocological aspects involved. a Company (and a citizen pays his) tax, his Government decrees that certain help shall be given to his industry by way of subsidy (bounty). He feels he is entitled to that aid and becomes angry and hurt when he finds it so difficult and so costly to obtain that help, and the end result is less than he considers he was entitled to obtain.

I am sure that in Australia there are many many frustrated potential small Shipowners who would give more serious thought to new ship construction if there was a more straight forward and simple way of obtaining subsidy (bounty).

It is interesting to note the considerable number of vessels of a size eligible for subsidy that were not built with subsidy simply because the Owners and Builders concerned could not put up with the red tape and costly delays involved in obtaining that subsidy. These range from tugs, offshore work boats, dredgers, barges, fishing vessels and other small commercial vessels.

IV. DEFECTS IN PRESENT ACT

In the subsidy administrative procedure there are hard and fast rules that must not be broken, e.g. Builders and Owners cannot negotiate as is the practice overseas. It is very difficult for an Owner to beat the gun and proceed to buy in machinery and components to speed things up a little as he will find that it takes twice as long to get his subsidy on these items due to the processes of investigation undertaken by another Public Service Body outside the Shipbuilding Division altogether.

If the Builder buys the very same equipment at a later date which will add months on to the construction time the procurement is not investigated. There are innumerable instances where the Public Service intrusion into the shipbuilding programme causes delays and costs. Delays in decision making and in starting various work and excess costs caused by these delays and the added costs to the Owner in his cash flow problems.

The lower down the administrative scale in the service one finds a more ardent drive to save the public purse at a cost to the industry in excess of the dollars he may or may not save. It is my belief that senior Public Servants are excellent in the policy making areas but are bad in practical production areas and in the lower levels they are inevitably bad in business areas. They should stick to high level policy areas of Government and keep out of productive areas, especially shipbuilding.

My subsidy (bounty) proposal calls for the Government to set out a Bounty scheme and make the Bounty obligatory by law to Shipbuilders and/or Shipowners.

The failure of the present system is that Shipowners never know till after they are contractually committed what level of subsidy they will receive. Even then this subsidy can be withdrawn from them if the Minister so decrees, of course on the advice of a Public Servant administrator, if one of the rules are broken.

The Act I propose makes it quite simple and clear what are the rules for Bounty. No Public Servant should be permitted in any way to interfere with the subsidy rules set out in the Act nor to have one word in its interpretation or be permitted to exercise any delegation. The rules of subsidy must be emphatic and be by measurement without any areas of doubt.

A Builder and Owner must be able to quickly know what level of Bounty is available on a specific vessel under negotiation if they follow the Act. This permits them to follow a normal pattern of business and negotiate with anyone they wish, with a clear knowledge of what Bounty they will receive. There can be no suspicion of malpractice to gain some advantage somehow, if the rules are few and very clear. Make a system involving hundreds of rules and you make a system where it is natural to seek ways to stretch or break these rules.

If my Bounty system was introduced the Shipowner and Shipbuilder would not need to waste time and money (as he must do now) handling the drawn out administrative subsidy processes involved with the Bounty scheme now before Parliament.

V. AREAS OF SUGGESTED IMPROVEMENT

Registration of Shipbuilders

In my view registration is unnecessary and will gain nothing for the industry. It will certainly increase the number of Public Servants needed to handle the flow of paper work involved. I know of no company wanting to rush into the shipbuilding industry to build large ships so registration is unnecessary here.

In the small shipbuilding area I see no gain to the industry as a whole (and that includes Shipowners) in restricting freedom of entry and exit. The economics of the industry will dictate the entry and exit of both Owners and Builders.

I can see no reason why an efficient plant making railway rolling stock, for example, cannot become as efficient in making barges, dredgers, offshore floating plant or even tugs and work boats. We have seen what lack of free entry has done to the small shipbuilding industry under the previous subsidy system. Five shipyards to my knowledge closed down. The industry needs a free enterprise approach if competitive shipbuilding is to survive. Restrict the entry into a Builders' club and it will again fail and create high ship prices which will allow in foreign built ships.

Usually Shipowners of small vessels such as in the fishing industry, tug industry and dredging industry are faced with a very high degree of competition, a low level of liquidity and capital resources and find the level of profits not so very high. Many are in marginal industries and they are very cost conscious. If they are to stay in their business they must cut costs, more so than the larger establishments.

It is much easier for these people to keep vessels in operation longer than would be logical, in an economic sense, on the basis of non viability due to direct physical costs. Small Shipbuilders likewise have problems in the area of liquidity and capital resources and find it harder to expand their plant and machinery in labour saving areas due to lower capital resources and borrowing inadequacies. Thus marginal increases in productivity are labour intensive and costly. These Shipbuilders find it difficult to extend credit facilities to Owners and produce costly bonds if required.

Delays caused by Government and/or Owners during construction is felt much harder by small Builders. Thus the help required to maintain a profitable small shipbuilding industry is in the areas of cost saving and added cost avoidance. Some suggestions here are:-

(i) Deletion of delays in a construction programme by minimising the unnecessary intrustion by Public Servants and Owners during construction programme. Firstly, by limiting the obligatory intrusion of Public Servants by framing a Bounty Act which minimises this intrusion. Secondly, by contracting a cut off date for intrusion not of a compulsory or safety nature.

(ii) Minimise the amount of paper work hurled at small shipbuilders by Government officers in order to achieve for an Owner the Bounty due to him. This must be carried out through a sensible Bounty Act not requiring so much intensive paper work by Public Servants, i.e. a simple scheme readily understood by everyone. Shipbuilders if they have to carry out excessive paper work, tying up a Senior Executive, should be permitted to receive a Government grant to cover same, as the various Departments are being paid by Government funds to do similar paper work. There is no doubt it would be best to eliminate most of the present paper work involvement as required with the present subsidy scheme.

(iii) Tendering along the lines presently followed by the Australian Shipbuilding Board is time consuming and costly to small Shipowners and Shipbuilders and I feel it does not help them in any way. Because the Commonwealth calls tenders, shipyards and Shipowners cannot (openly) negotiate, the small shipyards feel obliged to tender along the lines laid down by the A.S.B Quite often an Owner and a shipyard have reached an agreement between themselves privately but yet the tendering process still goes on at cost to everyone.

(a) To all other shipyards in tendering cost.

(b) To the Shipowner in delays caused by tendering and ascertaining after some months the subsidy level available to him whilst building costs are rising.

(c) To the taxpayer by the cost of operating a tender process involving high salaries, overhead costs, etc to an end result which in many cases has already been decided. Quite often a shipyard having developed a particular skill in a certain area could offer great cost saving benefits if certain changes were made. But this is NOT permitted under the Commonwealth tendering scheme.

An Owner could benefit by these direct project negotiations with the Shipbuilder and get a better ship at a lower price. Each shipyard would be encouraged to initiate design and cost saving benefits to Shipowners for direct negotiation on various projects. I know of a particular case where a tanker Shipowner could have reduced the cost of his tanker by $500,000, saving his own funds and taxpayers' subsidy funds involved in that project.

The A.S.B refused the shipyard permission to quote on a better and lower cost ship design. In the subsidy tendering scheme one sees Government red tape at its worst, under the guise of saving taxpayers' money where in fact it achieves the exact opposite result. Tendering as such should be cut out.

VI. FURTHER AREAS OF GOVERNMENT AID

(a) Taxation benefits that could be introduced to assist both Shipowners and Shipbuilders are many, and if it were possible to computer analyse the benefit achievements from beginning to end, on a wide national basis it would, I am sure, prove that the greatest economic benefits to the industry at the lowest level of cost to the taxpayer would come from use of direct tax assistance to both Shipowner and Shipbuilder. This would introduce a deep economic discussion if I expounded my economic theories in this field.

However, I point out the areas of taxation benefits which, I believe, if applied would give the greatest results to this industry in initiating new construction and lower cost shipbuilding.

(i) Small Shipowners to have a choice of a depreciation period from 3 to 5 years.

(ii) A Shipbuilder to have a choice of depreciation period on plant and machinery from 1 to 3 years.

(iii) No Sales Tax payable on any item incorporated into a ship and no Sales Tax payable on any item of plant or equipment used in the construction of a ship.

(iv) All interest charges incurred by a Shipowner associated with the construction of a ship be written off as a lump sum and not capitalised into the cost of the ship.

(v) Investment allowances to be introduced to encourage Shipbuilders to modernise and introduce labour saving elements.

(b) Monetary assistance could be extended to both Shipowners and Shipbuilders by a Commonwealth Banking Authority. It should be possible for a Shipowner to contract with a shipyard to build a ship on a 15% deposit and balance payable on delivery. Delays in ship construction in Australia are very costly to Shipowners, particularly the smaller company or the individual. He faces high interest rates and loss of liquidity over long periods. The Commonwealth Banking Authority could take a lien on the new ship and grant drawing rights of loans up to 75% of the contract to the Shipbuilder at 5% interest.

Upon completion of the ship the Shipowner should be able to obtain a loan at 5% up to 75% of the subsidised value of the ship from the same Banking Authority for a period of years equal to that chosen by him as his taxation depreciation period. Thereafter he transacts a commercial arrangement if he so desires.

VII. MODIFICATIONS

The Bounty Act now before Parliament for consideration is most unfair to small Shipowners and Shipbuilders in regard to modifications. It appears that no vessel other than those large enough to qualify in the 40% Bounty range will qualify for Bounty on modifications as Bounty is not payable on modifications which cost less than $500,000. This is hard when sometimes an Owner must incur a modification of a compulsory nature to meet Government or safety or union requirements.

The proposed Act appears to be attempting to cut out subsidisation of Modifications as the aim appears to be directed to conversions and reconstruction of older vessels.

In my attach summary of my proposed Bounty Scheme I give more detail in this area.

SCHEDULE "A"

RECOMMENDED SHIP CONSTRUCTION BOUNTY BILL

I offer the following Bounty Scheme to replace that Bill submitted by the Minister representing the Minister for Manufacturing Industry on 21st May 1975 for a first reading.

A. REASON FOR REJECTION OF EXISTING BILL

The administrative procedures involved with the Bill as submitted will be time wasting, confusing and frustrating to the industry it aims to help and its administrative costs in the Government area alone will exceed, in my opinion, $1 million.

Allocation of any level of Bounty is at the discretion of the Minister (or by Public Servants making the Bounty submission to the Minister). The Shipowner has no rights in any way to receive a Bounty payment. Too much discretion in this matter is permitted under the proposed Act and a Shipbuilder or Shipowner will never really know what level of Bounty he will receive, if any, until the whole affair is over. It is most difficult for a Shipowner to make sound judgments in forward planning. There are too many unknowns and restrictions in the present Bill in critical areas. I set out below a few that worry me.

(a) ACCEPTABLE AUSTRALIAN PRICE

A Shipowner can be delayed at great cost in times of rapidly escalating costs whilst problems in this area are sorted out with Public Servants, and before the Minister is even aware of the problems.

(b) i. MODIFICATIONS

Bounty permitted on modifications is most uncertain and the procedures involved in obtaining Bounty is confusing and time wasting to Builders and Owners who cannot afford delays in this critical decision period.

ii.

It appears clear that no vessel other than the very large ones in the 40% Bounty range will have modifications eligible for Bounty, as Bounty is not payable in respect of modifications that do not exceed $500,000. This is most unfair to Shipowners of the smaller vessels who must carry out modifications if required to do so by Government Bodies or Unions.

iii.

The Bill as submitted appears to desire no subsidy on modifications to a new vessel under construction, but only to conversions of older or existing ships. However, I believe that in the Bill as written the Minister has to consider granting subsidy on modifications of ships under construction if such modifications in aggregate exceed $500,000.

But the complicated method of calling tenders to determine a "Bounty Price" on these modifications creates an almost unsurmountable hurdle to jump to obtain the Bounty which the Act would permit.

(c) BOUNTY PRICE

Because of the very wide discretion to be exercised by the Minister or his Public Servants, there are a great number of cost components that can be excluded from the "Bounty Price" of a vessel that cannot be excluded from the Owners final costs of the ship which, in fact, reduces the level of Bounty well below the published Bounty levels. A prospective Shipowner of such a vessel will have to waste months before he will know the level of subsidy on such a project.

(d) CALLING OF PUBLIC TENDERS

It is not normal practice in other overseas countries to call public tenders through the Government for a ship. Such a practice does in fact add months of delay to a project. An Owner is not allowed to know who the tenderers are and if he does find out he is forbidden to hold discussions with these tenderers until tenders close.

It is normal business practice for a Shipowner overseas to go from Builder to Builder negotiating and battling to obtain the best deal available to him both financially and technically. Government tendering is ponderous and restrictive to normal commercial activities and will add considerable cost to the Australian vessel.

It is my opinion that the administrative costs alone to run this Bounty Scheme as proposed will cost taxpayers well over $1 million and is too high a price to pay for a scheme which is not very acceptable to the industry. Over and above this Government administrative costs the added cost to both Shipbuilders and Shipowners will be well in excess of that figure.

My basic objection to the Bounty Act as proposed is that it is a complicated and costly scheme. I sincerely believe that any Bounty scheme should have three basic features:-

i. Administrative simplicity and economy.

ii. Bounty should be obligatory under clearly defined conditions.

iii. Public Service intrusion into the commercial operations of both Shipbuilder and Shipowners must be completely minimised.

B. MY PROPOSED BOUNTY SCHEME could be administered by five Public Servants at a cost less than $100,000 and meet the three features above. This proposal is set out hereunder.

1. A Ship Construction Bounty Act to be enacted to permit the payment of a "Ship Construction Bounty" to a Shipowner constructing a new vessel in an Australian shipyard, or converting or re-building a previously constructed vessel at an Australian shipyard, if that vessel is to operate in coastal trade or operate in trade to and from Australia using Australian manning.

2. The definition of a shipyard in each case must make it clear that new entry into the industry is permitted. The requirement of acceptance as a shipyard is for a shipyard to demonstrate that it has the technical ability to complete the contract by use of its own or sub contractors' plant and equipment; it has the financial capacity to meet the contract, or can provide a substantial "Garantor" willing to meet his financial requirements to complete the contract.

3. The receiver of the Bounty will be required to enter into an agreement to refund the Bounty or part thereof under specific conditions as in Clause 10 of the presently proposed Act.

4. The Minister shall determine "Initial Bounty" payable on

   (i) a new construction project upon production of a sworn statement by both the Shipbuilder and the Shipowner (supported by the necessary Naval Architect's statement and calculations) that a vessel is of a specific (L.S.D) light ship displacement tonnage measurement, and

   (ii) a conversion of an existing vessel upon production of a sworn statement by both the Shipbuilder and the Shipowner (supported by the necessary Naval Architect's statement) that the conversion is that as set out in the plans and specification forming part of the statement, and upon receipt of a "Statement of Shipbuilder's Costs" prepared by a Commonwealth Cost Investigator.

5. The Minister shall determine the "Final Bounty" payable

   (i) on new construction upon production of a certificate issued by a Surveyor of the Commonwealth certifying to the (L.S.D) light ship displacement tonnage measurement of the completed vessel, inclusive of all modifications built into the vessel prior to its completion, and

   ii) a conversion project upon production of a "Certificate of Completed Costs" prepared by a Commonwealth Cost Investigator and a Survey Certificate issued by a Surveyor of the Commonwealth.

6. The Bounty due and payable shall be that which is determined on the "Final Bounty" assessment by the Minister. The Bounty shall be paid progressively to the Shipowner over the building period of the new construction or conversion project in the following manner:-

When 20% of the contract price has been paid by Shipowner to Shipbuilder an amount equal to 10% of the "Initial Bounty" assessment shall be paid to the Shipowner.

Thereafter when each further 10% of the contract price has been paid by Shipowner to Shipbuilder a further 10% of the "Initial Bounty" assessment shall be paid to the Shipowner up to a payment of 80% of the "Initial Bounty" assessment when 90% of the contract price has been paid by the Shipowner to the Shipbuilder.

Upon completion of a vessel when the Minister makes his "Final Bounty" determination a final adjustment of Bounty payable shall be made equal to the difference between the payments made at that date, and his "Final Bounty" determination.

7. A Schedule of Bounty rates payable on new construction shall be varied from time to time by the Minister acting upon advice from a Special Advisory Committee appointed by the Government. Payment of the Bounty in accordance with the rates as stated in this Schedule is the right of every Shipowner who qualifies under the conditions set out in the Act. There shall be no administrative discretion exercised by Public Servants in this regard.

8. The "Schedule of Bounty Rates" shall be framed upon the following guide lines:-

There shall be SIX classes of vessels for the purpose of Bounty assessment.

(i) Cargo vessels including "Ro Ro" Vessels, Lash Ships, Heavy Lift, Container Ships and Landing Craft Cargo Ships.

(ii) Bulk Carriers (excluding Cargo Ships)

(iii) Gas, Petroleum and Oil Tankers including OBO Vessels.

(iv) Oil Drilling Vessels (including Drillships, Semisubmersible, Jackup Rigs) Dredgers, Derrick Barges, Pipe Barges.

(v) Tugs, Offshore Workboats, Fishing Boats, Ferries and Dumb Barges.

(vi) Passenger Ships.

Any vessel not clearly defind as belonging to a specified class for Bounty assessment shall have its class determined by the Minister upon application by a Shipowner.

9. The Rates of Bounty applicable to a vessel of a specific class shall be based on a formula using "light ship displacement weight" as the sole means of determination. It is considered that the value of a specific class of vessel is related to its "light ship displacement weight". Basic steel work, Main and Aux engines, deck machinery and all of the components incorporated into the construction of a ship have a weight ratio proportionate to the total size and weight of a ship and ultimately its final cost.

The basic ship design, e.g. the wartime "Liberty Ship" and subsequent post-war designs leading up to such a ship as the current "Freedom Ship" are well thought out economic ship designs adequate for the job.

There is enough cost information around from tenders on all classes of vessels to feed into a computer and ascertain the basic cost of an adequately designed vessel in each classification to arrive at a basic light ship displacement cost of any class of vessel built in the major shipbuilding countries of the world and also in Australia. It is thus possible to ascertain a level of Bounty needed in each classification of a vessel to equate the average overseas cost of a similar vessel at the base date of the scheme.

10. The scheme proposed calls for a set value in money in the form of a Bounty to be payable on the minimum "light ship displacement" set as the commencing level of eligibility for Bounty, for each classification in my table below rated as "Z" level. Commencing from this "Z" level I propose adding a further stated amount of Bounty for every further 10 tons of extra "light ship displacement weight" over and above the "Z" level. The stated amount of Bounty payable on this "Z" level of "light ship displacement" is called "Y", and this "Y" value will vary on each of the six (6) classifications of vessels, e.g. value "Y" for "Z" level on a tanker will be a higher value than on a Bulk Carrier, thus I show in my Schedule of Bounty Rates the notation Y(+ or -) to show the proposed variation.

11. It will be possible therefore for any Shipowner or Shipbuilder or any taxpayer to determine the exact amount of Bounty to which he is legally entitled as a right under the Bounty Act once he is notified or ascertains the proposed "light ship displacement weight" of his proposed ship. The Shipowner will be able to carry out all of his feasibility studies knowing the level of Bounty he can receive and with the aid of the Shipbuilder arrive at the final cost of his proposed ship. No one can do this now, nor will they be able to do so under the proposed Bounty Act now before Parliament.

The present Bounty Scheme will take well over 100 Public Servants to operate. My proposal will take only five (5) because of its simplicity and the lack of intrusion into the scheme by Public Servants as is needed under the present Bounty Bill. There can be no collusion between Owners and Builders to gain extra Bounty as the present Bounty Bill obviously expects under its arrangements.

12. The rate of Bounty payable to a Shipowner shall be as follows:-

Class 1: For vessels in excess of Z level light ship displacement but below Z + 10 tons light ship displacement, an amount equal to Y. For every 10 tons light ship displacement in excess of Z + 10 tons the level of Bounty shall be increased by X% of Y.

Class 2: For vessels in excess of Z level light ship displacement but below Z + 10 tons light ship displacement, an amount equal to Y (say -15%). For every 10 tons L.S.D in excess of Z + 10 tons L.S.D., the level of Bounty shall be increased by X% of Y (-15%).

Class 3: For vessels in excess of Z level L.S.D but below Z + 10 tons L.S.D, an amount equal to Y(+15%). For every 10 tons L.S.D in excess of Z + 10 tons L.S.D, the level of Bounty shall be increased by X% of Y(+15%).

Class 4: Ditto(3) above provided however that once the value of Bounty has been calculated under the above formula that value of Bounty shall be reduced by an amount equal to the weight in tons of the equipment incorporated in that vessel during construction, which is deemed not eligible for Ship Construction Bounty as listed in a schedule approved by the Minister being of a nature not normally built into a ship at an Australian ship-building establishment, multiplied by X% of Y(+15%) divided by 10.

Class 5: For vessels in excess of Z level L.S.D but below Z + 10 tons L.S.D, an amount equal to Y(-15%). For every 10 tons L.S.D in excess of Z + 10 tons L.S.D, the level of Bounty shall be increased by X% of Y(-15%).

Class 6: For vessels in excess of Z level of L.S.D but below Z + 10 tons L.S.D, an amount equal to Y. For every 10 tons L.S.D in excess of Z + 10 tons L.S.D, the level of Bounty shall be increased by X% of Y.

13. Variations and Non Eligibility

(a) Notwithstanding the levels of Bounty set out above for Classes 1 to 6, the final Bounty payable on any class of vessel in excess of ? tons L.S.D (approximating 92000 tons D.W shall not exceed ? .

(b) Bounty shall not be payable to a foreign Shipowner constructing a vessel in Australia for service under a foreign flag or using non Australian seamen or officers or for offshore trading.

(c) Floating docks and Naval vessels shall not be eligible for Bounty. The Minister may from time to time declare a specific class of vessel is no longer eligible for Bounty, but such vessels under construction or for which contracts have been placed in Australian shipyards shall be excluded from such Ministerial direction.

14. Conversions & Reconstruction

Vessels already constructed on which work is to be performed to convert them into another form of vessel, to extensively modify or jumboise them or to reconstruct them shall be deemed vessels eligible for Ship Construction Bounty.

The value of the new work to be performed inclusive of docking or slipping costs must exceed a value of $500,000. Both the Shipowner and the Shipbuilder must submit a sworn statement declaring the work to be performed, supported by plans and specifications certified by a Naval Architect (or approved Authority) declaring the true value of the work involved. This statement shall be called the "Initial Declaration of Work and Costs".

Upon completion of the work the Shipbuilder and the Shipowner shall submit a further sworn statement supported by plans and specifications certified by a Naval Architect (or approved Authority) declaring the extent of the completed works and the completed costs called "Final Declaration of Work and Costs."

The Shipbuilder shall submit a confidential cost statements to the Commonwealth Cost Investigator and such statements shall be checked and certified by the Cost Investigator. The Commonwealth shall pay progressive Bounty payments up to 80% of 25% of the value declared in the "Initial Declaration of Work and Costs".

Upon completion of the work and submission of the "Final Declaration of Work and Costs" and receipt of Builder's Cost Statement audited by the Cost Investigator, the Minister will determine a Final Bounty payment on work performed which shall not exceed 25% of completed costs and based on this final assessment an adjustment of Bounty payable to the Owner shall be made.

The Minister may from time to time nominate a type of work which shall not be eligible for Bounty.

15. Declarations

The Bounty Act shall provide for penalties against any Party wilfully making an incorrect declaration or sworn statement.

GOVERNMENT ASSISTANCE FOR SMALL SHIP CONSTRUCTION: ANALYSIS OF COSTS AND SUBSIDIES, JUNE 1972 TO MAY 1975

by

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INTRODUCTION

This paper looks at small ship construction under the Australian Government's shipbuilding assistance scheme during the period 1 June 1972 to 28 May 1975. For vessels under 1,300 gross (construction) tons, the paper provides some details of subsidy incentives and the sizes, numbers and basic prices of those vessels which have been built, are under construction or have been ordered in the period.

An indication is given of the proportion in subsidy terms, that these small vessels bear to the total subsidised shipbuilding program and within the small vessel category, the types, numbers and subsidy allocations but comprise the eligible, under 1,300 gross (construction) tons craft.

Consideration is also given to the value of the small vessel sector in terms of basic purchase prices and it should be noted that the basic purchase price is the (unsubsidised) price which the Government initially agrees to pay for a vessel before selling it back to an owner for a lesser (subsidised) figure. Generally, a basic purchase price is determined by deleting from the lowest tender, the cost of the various items ineligible for subsidy in terms of policy and adding any eligible items not forming part of the builder's tender.

BACKGROUND

Although various forms of Government assistance to the industry have been provided since 1942, and the minimum vessel size for subsidy eligibility eventually reduced to 200 gross tons, it was not until 1 June 1972 that the "recognised" shipyard system was discontinued. Additionally, on 18 December 1973, the Government reduced the minimum eligible level to 150 gross (construction) tons and extended subsidy to fishing vessels of 70' (now 21m) and above load water line length. At that time also, registration of shipbuilders was introduced, with registration being accorded automatically to builders who had built eligible vessels previously and to those new builders whose registration would contribute towards the orderly development of the industry.

On 20 June 1975, the Ship Construction Bounty Act became law. This Act gives legislative effect to the Government's shipbuilding assistance policy, with the previous systems of providing subsidy to shipowners by the Government buying and selling ships being replaced by a bounty payable direct to the shipbuilder. The rates of bounty and the conditions under which it is provided by the Act are the same as those contained in the Government's subsidy policy of 18 December 1973.

VESSELS, COSTS AND SUBSIDIES

During the period 1 June 1972 to 28 May 1975 the Australian Government paid out to owners, a total amount of $70,702,800 for shipbuilding subsidy on all classes of eligible vessels approved by the Minister for financial assistance. Of that figure, $8,447,157 was paid in respect of fishing vessels, dredgers, tugs, rig service vessels and so on, under 1,300 gross (construction) tons. In terms of subsidy paid, therefore, the smaller vessels represent about 12% of business transacted.

Taking another view, the Minister during the period approved the purchase of, and work commenced on, a number of vessels at basic purchase prices totalling $216,568,943. Included in that figure are basic purchase prices totalling $41,934,262 for vessels in the smaller category referred to above. Although the Commonwealth only makes subsidy payments, the figures tend to illustrate the value of work subject to Government assistance. It should be mentioned also that the basic purchase prices are themselves subject to increases arising from modifications, escalations and adjustments for prime-cost items and the final purchase costs are therefore somewhat higher. However, on a basic purchase price comparison, the small vessels account for some 19% of the total value.

To briefly consider the figures already presented, subsidy payments made in the period cover a range of vessels for which, in some cases, Ministerial approval was secured well before 1 June 1972 and construction was well under way. These vessels built under the "old" policy (policy prior to 1 June 1972) account for almost $20 million of the $70 odd million paid out and are almost exclusively big vessels constructed at what were formerly the "recognised" shipyards. Apart from stage payments of basic purchase prices for all vessels ("new" or "old" system), the total figure also covers subsidy payments for escalation, modifications and prime-cost adjustments.

On the other hand, the basic purchase prices are those figures approved by the Minister as the amounts on which subsidies at the appropriate rates are to be calculated and the total of $216,568,943 shown is the aggregate of such prices approved in the period for projects which proceeded. The individual amounts comprising the total do not cover vessels, approved under the "old" policy or approved projects which did not proceed. Moreover they do not contain variations for escalation etc. and in the main, do not represent final construction costs. The vessels concerned in the majority of cases have been completed or are under construction and relevant subsidy payments appear in the figure of $70,702,800. In other cases work is only at the preparatory stage.

Turning to the smaller vessels for which orders were placed in the period, a total of 74 craft under 1,300 gross (construction) tons were the subject of subsidy approvals. An analysis of that total reveals that prawn trawlers and fishing vessels predominated with 39, followed by tugs and barges, each with 11 vessels. The remaining craft consists of 6 oil rig service vessels, 4 passenger ferries, 2 dredgers and one "beach coaster" landing barge. In terms of subsidy paid out, the $8,447,157 total previously mentioned was shared in the proportion, fishing vessels $3,081,088, tugs $1,386,382, barges $472,450, oil rig service vessels $2,336,602, passenger ferries $534,173 and the others, $636,462.

Fishing vessels ranged in size from a 72 ft. load water line length craft to a 138 ft. trawler of 363 gross (construction) tons. The numbers and sizes

of this type of vessel are:

No.	LWL
1	72'
3	77'
1	78'
2	80'
17	85'
1	86'
5	87'
2	88'
1	90'
3	93'
1	97'
1	108'
1	138'

Individual building costs varied not only with size, but also with the vessel's sophistication.

Reflecting shorter building periods, thirty of the thirty-nine vessels were tendered and accepted on a fixed price basis, whereas all vessels over 1,300 gross (construction) tons approved in the same period were on variable price bases. Accordingly, while large shipowners claimed subsidy on escalation of $28,807,352, in the time in question, escalation claims from fishing boat owners only started to appear in very small amounts after May this year. Basic purchase prices for fishing vessels totalled $14,019,232 and the total approved basic subsidy is $3,404,811.

Tugs approved and commenced in the period are:

No.	Gross (Construction) Tons
1	204
2	206
2	221
2	298
1	308
3	310

Each of these vessels is subject to a fixed price contract with basic purchase prices totalling $7,505,115 and a total approved basic subsidy of $1,876,277. Unlike fishing vessels, where on 6 occasions owners selected other than the lowest tender, tug owners all placed orders on the basis of the lowest offers received.

Barges in the period were less complex and hence were generally the least expensive of the smaller vessels. Basic purchase prices totalling $3,246,503 and total subsidies of $811,625 were approved for the 11 barges concerned. In terms of size, these vessels are:

No.	Gross (Construction) Tons
1	223
1	350
1	587
3	591
1	641
2	730
2	758

With one exception, barge owners accepted fixed-price offers and on two occasions owners selected a tender other than the lowest.

Oil rig service vessels were the largest of the small ships approved and commenced in the period and they are:

No.	Gross (Construction) Tons
1	788
2	1198
3	1267

Basic purchase prices totalled $11,864,365 for these vessels and approved basic subsidy totalled $3,205,930. In each case the owner accepted a fixed price tender and that tender was the lowest for each project.

The remaining two small vessel categories, passenger vessels and other vessels, cover the following craft:

Type	No.	Gross (Construction) Tons
Harbour Cruise Vessel	1	360
Harbour Ferries	2	470
Paddle Wheeler	1	924
Landing Barge	1	696
Dredger	1	820
Dredger	1	432

Basic purchase prices approved for these vessels totalled $5,299,047 and total basic subsidy was approved at $1,324,761. All orders were placed on fixed price bases and the lowest tender was accepted in each case. Total subsidy paid to 28 May 1975 in respect of these projects was $1,170,635.

Looking briefly at owners' requirements for subsidised small vessels since 1 June 1972, the following schedule of tenders that have closed at the Department's offices indicates a fluctuating demand:

Tenders Closed	Type of Vessel
July 1972	- 2 fishing vessels
August 1972	- 1 dredger
September 1972	- 5 rig supply vessels
	- 1 tug
October 1972	- 2 fishing vessels
November 1972	- 2 fishing vessels
	- 1 tug
	- 2 barges
January 1973	- 2 fishing vessels
February 1973	- 1 cargo landing barge
	- 1 barge
	- 4 fishing vessels
March 1973	- 2 fishing vessels
April 1973	- 1 dredger
May 1973	- 1 rig service vessel
	- 2 fishing vessels
June 1973	- 7 fishing vessels
July 1973	- 2 tugs
	- 1 fishing vessel

Tenders Closed	Type of Vessel
August 1973	- 1 barge
	- 18 fishing vessels
	- 1 to 12 fishing vessels
	- 1 to 4 fishing vessels
September 1973	- 11 fishing vessels
	- 2 barges
October 1973	- 5 fishing vessels
	- 2 rig service vessels
	- 2 dredgers
	- 2 tugs
	- 1 barge
November 1973	- 1 fishing vessel
	- 1 cruise vessel
	- 4 barges
December 1973	- 2 fishing vessels
	- 1 barge
January 1974	- 1 tug
February 1974	- 3 barges
March 1974	- 3 fishing vessels
April 1974	- 2 fishing vessels
May 1974	- 5 fishing vessels
	- 2 tugs
	- 1 barge
June 1974	- 4 fishing vessels
	- 1 dredger
	- 2 tugs
July 1974	- 2 fishing vessels
	- 6 tugs
August 1974	- 1 fishing vessel
September 1974	- 2 rig service vessels
October 1974	- 2 rig service vessels
	- 1 fishing vessel
	- 1 survey vessel
	- 4 tugs
November 1974	- 1 tourist vessel
	- 1 fishing vessel
December 1974	- 4 fishing vessels
	- 1 rig service vessel
January 1975	- 1 barge
February 1975	- 2 tugs
	- 2 barges
March 1975	- 3 barges
	- 1 tourist vessel
April 1975	- 1 tug
	- 1 dredger
May 1975	- 1 tourist vessel
	- 3 tugs
June 1975	- 1 barge
	- 1 tug
July 1975	- 1 ferry.

It will be noted from the above, and from earlier information provided that there have been a significant number of projects in respect of which tenders were called twice or on the other hand projects which have simply not proceeded, particularly where fishing vessels are concerned. Prawn trawlers, tuna and other fishing vessels' requirements increased sharply in 1973 to reach note-

worthy proportions in August/September of that year. However, many owners did not proceed past the tendering stage and after a steady decline in 1974, no tenders have been called so far this year for that type of vessel. Tender prices for fishing vessels have been apt to vary markedly between builders on a particular tender closing date, although the band of prices does not appear to have risen greatly on 1972 figures. To illustrate, an 84' prawn trawler in respect of which tenders closed in later 1972 and a prawn trawler of the same size for which tenders closed in late 1974 received offers indicating escalation of only 6.46% for the period, based on a comparison of the lowest fixed tender prices. In terms of the highest fixed price tender in each case, the price actually fell by 7.31%.

Owners of other types of small vessels do not seem to have been so fortunate with building costs, despite some keen competition between builders on occasions. Any attempt to match successive tender prices for different barges, passenger vessels and the like would be meaningless without detailed vessel specifications, but some indication of escalating tender prices can be shown for tugs and rig supply vessels. From September 1972, to September 1973 for instance, the lowest fixed price tender for a 95' tug dropped marginally, but less than a year later a tug of the same length attracted a lowest fixed price offer representing escalation of some 49.71%. Still taking the same basis for comparison, in October 1974 the prices tendered indicated escalation of 127.70% on the September 1973 price and in April this year the increase was about 283.68% on the September 1973 price.

Rig service vessel owners appear to have encountered similar problems with increased building costs. A 190' vessel with a tender closing date in September 1972 and a similar vessel of the same length tendered for a little over a year later revealed an increase in the lowest fixed price offer of about 36.90%. In September 1974 a 170' rig service vessel was tendered for at a fixed price of some 91.07% higher than the September 1972 figure and in October 1974 builders responded with variable price tenders only for a 63 metre vessel at about 155.95% greater than the 1972 lowest fixed price. As far as increasing tender prices are concerned, rig service vessels and tugs are more apt to follow the trend of their elder brothers in the bulk cartage, general cargo and container business.

A final matter which may be of interest is the proportion of imported equipment costs in the basic purchase prices approved for subsidy purposes. For the bigger vessels outside the range presently being considered, imported equipment is prime costed at a basic total figure of $39,703,604, out of basic purchase prices totalling $174,634,681. The total cost of imported equipment can therefore be said, on initial figures, to comprise about 23% of the total basic purchase price for the large vessels. For vessels under 1,300 gross (construction) tons, the respective figures are $6,227,463 out of a total of $41,934,262, a proportion of about 15%. Individually, however, some of the small ships have a much higher ratio of imported content and some examples are a trawler with about 18%, a tug with some 25% and a rig service vessel with over 33%. In the case of dredgers, the ratio of imported equipment has been known to go much higher.

CONCLUSION

Despite the heavy capital expenditure involved in shipbuilding, the Australian Government is making a large financial contribution towards the continuation of the industry. The role played by small vessels in the industry's total output is significant, appropriate subsidy payments having brought orders to a wide spread of builders round the Australian coast.

Subject to owners' requirements, the demand for smaller vessels has been steady, although a tapering-off is noticeable this year. Apart from the less marked effect on fishing vessels, severe cost increases have been felt in the small ship building area as well as the large. However, unlike the trend for tenders for large ships, owners of small vessels are still able to secure fixed price offers for new buildings where building times are short.

SHIP CONSTRUCTION BOUNTY ACT - 1975

The Ship Construction Bounty Act 1975 came into effect on 20 June 1975. The Act gave legislative effect to the assistance arrangements announced on 18 December 1973 by the Minister for Manufacturing Industry.

The Second Reading Speech by the Minister introducing the legislation is set out below.

"The Bill gives effect to the Government's measures providing financial assistance to the Australian shipbuilding industry. The measures were announced by the Minister for Secondary Industry and Minister for Supply on 18 December 1973.

"It is the Government's objective to provide assistance which will assure the continuing development of a rationalised and efficient shipbuilding industry in Australia. The assistance will alleviate local shipbuilders' disabilities against prospective import competition while providing intending purchasers with the opportunity to source their requirements overseas.

"Honourable members will be aware that financial assistance has been provided to the shipbuilding industry since 1947. The assistance is currently provided under Section 47 of the Australian Coastal Shipping Commission Act 1956, as amended, under which Australian agrees to purchase a vessel from the shipowner on completion of construction and the shipowner agrees to re-purchase the vessel from Australia at the same price less the amount of the subsidy to be provided. The level and mode of assitance to the industry has been reviewed by the Tariff Board from time to time, the latest review being the Tariff Board report on Shipbuilding signed on 25 June 1971. The annual payments of subsidy have risen from about $2m in 1947 to about $30m in 1974.

"The legislation now being introduced sets out the assistance that will be available to shipbuilders and the procedures by which that assistance will be made available. The Bill is similar to other bounty legislation and brings the method of providing assistance to shipbuilders into line with other bounty assistance accorded to manufacturers.

"The Bill provides that bounty will be payable on the production in Australia, in registered shipyards, of vessels of 150 gross construction tons or more and fishing vessels 21 metres or more in length, where these vessels are for use in Australian waters or for use by Australian flag operators in international trade. Bounty is also payable on the modification in Australia of existing vessels where the cost of the shipbuilding type activity involved in the modification exceeds $500,000. There

is provision for pro-rata re-capture of bounty if the vessel is disposed of for use outside Australian waters by other than an Australian flag operator within ten years of completion of the construction or modification.

"The amount of bounty payable is as follows :

	% of bounty price
vessels of less than 1,000 gross construction tons	25%
vessels of 92,000 deadweight tonnes or more	25%
oil exploration vessels	25%
modifications of existing vessels	25%
other vessels	
up to 31 December 1980	25% to 40%*
on or after 1 January 1981	25%

*according to gross construction tonnage and date of keel laying specified in the building contract.

In determining the bounty price the cost of certain items such as purchase of designs overseas, miscellaneous stores, fees and specialised functional equipment not being part of shipbuilding activity may be excluded.

"The Bill also includes provisions for the registration of premises for the construction, or modification, of vessels generally or vessels of a particular kind. The provisions are similar to those provided in the Metal Working Machine Tools Bounty Act, 1972, and the Agricultural Tractors Bounty Act, 1973.

"The Minister for Transport will be responsible for the administration of the bounty legislation. "

Summary of Bounty Act

The Schedule to the Act sets out the bounty payable as a percentage of the adjusted price of the vessel as follows :

Period	Maximum Percentage
Up to 30 June 1975 to December 1975	40
1 July 1975 to 31 December 1975	37.5
1 January 1976 to 31 December 1976	35
1 January 1977 to 31 December 1977	33
1 January 1978 to 31 December 1978	31
1 January 1979 to 31 December 1979	29
1 January 1980 to 31 December 1980	27

The Act provides (Section 7) for a maximum bounty, to rise from 25% of vessels below 1,000 gross construction tons, up to a maximum amount set out above. The rate of increase is $2\frac{1}{2}\%$ for each 1,000 tons in excess of the first 1,000 tons.

Under the new Act shipbuilding bounty is paid direct to the builder whom it benefits. In other respects the bounty payable, the method of determining it, procedures to be followed and other aspects are similar to those which have been followed since 18 December 1973.

It should be noted that bounty is available on ships only if they qualify in respect of size (fishing vessels: load waterline length not less than 21 m) or gross construction tonnage (other vessels : not less than 150t), and are for use in Australian waters or in overseas Australian flag operations.

The Act provides for a smooth transition from the previous procedures. Shipbuilding contracts and Financial Assistance Agreements already executed or in immediate contemplation will continue in operation.

Procedure

Where a shipowner requires a new ship or the extensive modification of an existing ship and desires the ship to be built or the ship to be modified under the bounty scheme, the procedure to be following is as outlined below.

a. Tenders

May be called either by the owner or the Shipbuilding Division. Advertisements in the national press are essential and ensure that all builders have the opportunity to tender - a basic policy requirement.

Owners may request that tenders be called not only in Australia but also overseas.

In both cases all tender documents and conditions must be identical and all tenders must be called simultaneously. They must also close simultaneously and at the offices of the Shipbuilding Division. Two copies of each tender required.

Companies which are both shipowners and builders may tender for their own ships.

b. Indicative Bounty Price

If owner wishes, Shipbuilding Division promptly advise him an indicative Bounty Price on the clear understanding that the final Bounty Price will depend on detailed study of the lowest acceptable tender and the Minister's approval of the resultant Bounty Price.

c. Choice of Builder

Owner is free to discuss tenders with builders and selects tender he favours including those of the alternatives offered in it which he desires.

d. Draft Contract

Owner and builder negotiate draft building contract and forward copy to Shipbuilding Division.

e. Bounty Price

The Bounty Price is determined by the Minister on the advice of the Shipbuilding Board based on a detailed examination of the lowest acceptable Australian tender, and taking into account components of the tender which are not eligible for bounty (ineligible items are non-shipbuilding type items such as fishing nets, bunker oil, licence fees, etc).

The approved Bounty Price is advised to the owner and the selected builder.

If the Bounty Price for the modification of an existing ship does not exceed $500,000 the modification is not eligible for bounty.

f. Bounty

The bounty payable under the Act can be determined by the owner and the builder by applying the appropriate percentage to the Bounty Price -

e.g.	Assume gross construction tonnage	: 2,300
	Therefore bounty rate	: 30%
	Assume Bounty Price	: $3.2m
	Bounty payable	: $0.96m

g. Acceptance of Tender

For a project to qualify for bounty the owner must accept the selected tender within 60 days of receiving advice of the Bounty Price, and advise the Department of that acceptance.

h. Registration of Builders

For a project to be eligible for bounty the builder must be registered for the building of the relevant 'kind' of ship or the modification.

Builders whose applications for registration were approved prior to the Act will be accepted as registered under the Act.

i. Payment of Bounty

Under the present procedure subsidy is paid to the builder via the owner; now it is to be direct to builder.

As with other bounty legislation, bounty is strictly not payable until project completed. The Act however provides for advances of bounty and these will be payable at stages which will be stated in the tender documents.

These construction stages will be shown in the building contract and at each, builders will receive payments simultaneously both from the owner and the Government.

j. 'Modifications'

Changes to the specification on which tenders are based may be made by the owner up to closing of tenders. Such changes, if incorporated in the tenders, will be considered in determining the Bounty Price, i.e. they are eligible for bounty.

Changes to specification after the closing of tenders are not eligible for bounty unless related to decisions of a body concerned with safety aspects.

K. Escalation

Escalation in variable price contracts is eligible for bounty.

l. 'Keel Laying'

This traditional term has not been used in the Act because of the almost universal use of prefabrication of large units. The criterion for the determination of maximum percentage is therefore the setting up of a major unit on the construction site.

The building contract between the owner and builder must fix a date for this as it determines the maximum bounty rate.

m. Recapture of Bounty

If a vessel built under the bounty scheme is not used in accordance with prescribed aspects of the owner's expressed original purpose in having it built, e.g. for fishing if under 150t., or as Australian flag vessel in overseas trade, certain proportions of the bounty paid must be re-paid to the Government.

Owners will enter into agreements with the Minister to make such repayments.

n. Inspection

The Act provides for inspection of new buildings or modifications by departmental officers, as occurs at present. This is to ensure that projects proceed in accordance with the contract on which bounty was based.

Department of Manufacturing Industry,
Department of Transport,
CANBERRA. A.C.T. 2600

1 September, 1975

SOME FINANCIAL ASPECTS OF FISHING BOAT INVESTMENT

by

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Introduction

The fishing boat is the main item of capital expenditure in the establishment of a fishing venture. Generally in the major fisheries in Australia investment in the fishing boat comprises about 80 per cent of total investment. The decision to invest in a boat, whether as a replacement for an existing boat or new one is a very important one particularly in view of the substantial increase that has occurred in recent years in construction costs of fishing boats. It is proposed in this paper to briefly review some of more important considerations to be taken into account in purchasing a fishing boat and then to consider some of the financial problems likely to be experienced in financing and operating the enterprise.

Nature of the fishing operation

A fishing venture operated on a commercial basis is no different from any other economic activity. Inputs of labour, capital and raw materials (the fish resource) are combined to produce fish for consumption or fish for further processing. The rational fisherman is primarily concerned with maximising his profit by combining labour, capital and the raw material resources to produce the kind of goods required by consumers at minimum cost.

There is however, a major difference between a fishing enterprise and other types of commercial enterprise. Individual fishing firms do not have control over their raw material supplies as do, for example, manufacturing firms. The latter can, by paying a price for their raw material supplies exercise control over their current and future use. This is not possible in the case of the fishing firm; even though the owner may be concerned about the future state of the fish stocks there is little incentive for him to stop fishing since he knows that the fish he does not catch will be taken by other fishermen. He is thus intent upon taking as big a share of the catch as possible to maximise his profits.

Since this view is shared by other fishermen exploiting the fishery the end result is, if there is no restriction on entry into the fishery and as long as there is a belief that there is a profit to be made, additional fishermen will enter the fishery and the gross revenue from

the sale of the product will be shared by more and more fishermen until no profit remains to be distributed. For the fleet as a whole total revenue will equal total costs. It is possible of course that entrants will continue to enter the fishery until total costs exceed total revenue. In this instance many of the boats may be covering only their running costs.

Thus with a common property resource there is a tendency, in the absence of restrictions on entry into the fishery, towards excessive exploitation of the resource, accompanied by excessive labour and capital and low returns. This is particularly the case with those fisheries the products of which are in relatively high demand compared with their supply and fishing costs are low relative to the price. It is not necessarily a consequence in fisheries where costs are relatively high in relation to price or where the demand does not significantly exceed supply. In these circumstances the price mechanism tends to regulate the degree of exploitation.

The implication for the intending purchaser of a fishing vessel of the common property nature of the resource is that, because of his lack of control over the raw material supplies (the fish resource) he is unable to specify accurately the relationship between the inputs of labour capital and the output (the catch) of any particular investment project. The difficulty of forecasting with any degree of precision the future catch rate - and consequently the future stream of income presents a difficult task for the intending investor and is partly responsible for the relatively low level of capital attracted to the industry from external sources and the apparent reluctance of some lending institutions to finance the purchaser of vessels particularly for projects of a developmental nature.

Problems of investment

A major problem confronting the investor in the fishing industry is the future catch rate. The catch rate is a result of many factors including the biological and physical conditions in which the stock of fish live, the stage of development in the fishery, the management measures in operation, the skill of the akipper and the operational efficiency of his boat and gear. Changes in environmental factors may affect the availability of fish to a significant degree as in the case of the Southern bluefin tuna and the banana prawn fishery in the North. These fluctuations add to the risky nature of fisheries investment proposals. In addition the risk may be compounded in open access fisheries, where lack of restrictions on excessive exploitation of the fish stock may even accentuate fluctuations in the annual catch, and certainly reduce the catch rate to uneconomic levels.

Whilst it may be reasonable to assume that in the intermediate stages of development of an established fishery, catch rates in the immediate future will exhibit the same characteristics as in the recent past, it is important to take account of the effect of the entry of additional vessels on the probable catch rate. One excellent season can induce fishermen to replace their existing vessel with a larger one or attract new vessels to the fishery so that the individual investor has to consider not only the effect of the catch of his own vessl, but the overall effect of a number of vessels, e.g. Southern bluefin tuna fishery and the banana prawn fishery in the North.

The task of estimating likely catch rates for the next 10 to 15 years is particularly difficult in a previously unexploited fishery. It is probable that some exploratory fishing may have been carried out by isolated individual fishermen or Government fisheries authorities. It is also probable that some assessment of the total stocks and sustainable yield has been made. However, whilst these may provide a rough guide, likely future catch rates can only be established within reasonable limits by commercial exploitation. This again highlights the risk and uncertainty associated with investment decisions, particulary in unexploited fisheries. Furthermore, in the early developmental stages of a fishery catch rates are much higher than when fully exploited. Dr. Gulland has estimated that in a fully exploited fishery the catch per unit effort is likely to be no more than one-half to one-third of the size it would be when lightly exploited. This is of course only true of those long lived species of fish where the current stocks reflect the accumulated biomass of many years growth and does not apply to those species, e.g. prawns, in which most of the stock is replaced each year.

These initial catch rates often mean that the first vessels into the fishery can re-coup their investment in a few years of fishing. This tends to attract, in an open access fishery, a flood of new vessels into the fishery with the result that the fully exploited stage is reached in a relatively short period of time. Average returns per vessel are reduced substantially either as a result of declining catch rates or the same total catch being shared by a larger number of vessels, or both. Thus in the absence of management measures there is a tendency towards over-capitalisation in the fishery and lower returns to capital and labour. The situation becomes critical for the investor when there are limited opportunities for diversification to other fisheries, and his investment may become "locked in".

In considering an investment proposal, therefore, any projection of the catch rate should not be based solely on the recent past but should be based on a very careful evaluation of prospects in the future, taking into account the factors mentioned above. No mention has yet been made of the market for the product and the prices likely to be achieved. These are critical for the success of any fishing enterprise. It is self evident that if the catch cannot be sold at

reasonable prices there is little point in catching the fish then It is therefore important that a careful evaluation be made of market prospects before a final decision is made.

Problems of finance

The primary sector of the Australian fishing industry is comprised mainly of small to medium sized fishing enterprises. These enterprises have experienced difficulties in obtaining finance for the purchase of new or secondhand boats on reasonable terms and conditions. A survey on the availability of finance for fishermen undertaken by the Fisheries Division of the Australian Department of Agriculture was designed to obtain basic information on the sources of loans, the security required, terms of loans advanced and other relevant information.

Table 1 shows the number of loans obtained from various sources in each State. It also shows the average size of the loan from each source and the total amounts advanced by each lender.

TABLE 1.

SOURCE AND NUMBER OF LOANS

	Number of loans								Average size	Total advanced
Source	NSW	VIC	QLD	SA	WA	TAS	NT	TOTAL	$	$
Development Bank	3	3	12	3	4	7	0	32	13,272	424,704
Trading Banks	19	4	24	14	41	4	0	106	6,303	668,122
State Banks	7	1	0	5	5	12	2	32	6,364	203,648
Finance companies	17	8	34	15	19	7	0	100	7,783	778,303
Insurance companies	1	3	1	0	5	0	0	10	1,964	19,640
Fishermen's co-operatives	3	0	0	1	27	1	0	32	8,620	275,840
Other co-operatives	1	0	0	0	2	0	0	3	3,333	9,999
Fish processors	1	6	13	8	107	2	0	137	5,811	796,107
Accountants & Solicitors	2	3	3	0	1	2	1	12	11,206	134,471
Relatives & Friends	14	7	21	16	26	3	1	88	3,965	348,944
Previous owners	2	2	3	1	5	0	0	13	21,286	276,718
TOTAL	70	37	111	63	242	38	4	565	6,967	3,936,355

The table indicates that the banking system as a whole provided the greatest number of loans, followed by fish processing companies. It should be noted however, that the overall position of fish processing companies was influenced by the large number of loans made by them in Western Australia. In other States this source was found to be only of average importance. In New South Wales, Victoria, Queensland and South Australia finance companies were the important sources of loans. In Tasmania the State Bank was the most important source but elsewhere State banks were of limited importance.

The survey highlighted the fact that lending institutions, in particular banking institutions were reluctant to lend on the security of the fishing boat alone and required additional land based assets as security. Loan repayment periods were found to be generally short to medium term. Fishing organisations have stressed the need for longer term loans for the purchase of fishing boats in order to ease the burden of interest and capital repayments. For example a loan of $20,000 over a period of five years at an interest rate of 7 per cent reducing would involve repayments of $4880 per annum. If the term were increased to ten years at the same rate of interest the annual repayments would only be $2847.

The survey also indicated that finance was particularly difficult to obtain for boats designed to exploit under-developed fish resources or new fisheries. This compares with fishermen operating in limited licence fisheries where less difficulties were experienced in obtaining finance.

An insight into the requirements of lending institutions for the provision of financial assistance was given by a representative of the Commonwealth Development Bank at a seminar on fishing boat economics held in Adelaide in 1974. It was stressed that fishermen could enhance their chances of success in obtaining finance by presenting a well documented case. The Commonwealth Development Bank is a lender of last resort and in recent years has made substantial loans available to the fishing industry. Recently the lending functions of the Bank were extended to cover the refinancing of debt arranged on unsuitable loans and condition and the financing of the transfer of ownership of boats.

Operational costs

The costs of operating a fishing boat is broadly speaking a function of its size. The size of the vessel will depend upon many considerations including

- availability of the resource
- vulnerability of the resource to fishing gear
- storage and freezer capacity
- accommodation requirements
- method of fishing.

There are many other non-technical considerations including availability of crew, access to markets fueling and unloading facilities etc. All of these will have an influence on the final decision to be made about the size and type of boat to be acquired. The capital cost and operating costs are of course major considerations. Both of these costs increase with the size of the vessel. Fixed costs which include such items as depreciation, insurance or proportion of repairs and maintenance, and other fixed administrative expenses increase roughly in proportion to the size of the boat. Fixed costs of a 60 foot boat costing $150,000 could amount to about $25,000 and in the case of an 80 foot boat costing $300,000 somewhere in the vicinity of $300,000.

At the same time direct operating costs are higher because of higher fuel usage, and large crews. In a number of economic surveys undertaken by the Department it is evident that the quantity of fish products needed to be caught for larger vessels to break-even was substantially larger. For instance it was estimated the break-even catch (that catch required to equate total earnings with total cost) for prawn trawlers under 45 feet was 32,000lb. (given the cost/price relationship ruling at the time) compared with 160,000 lb. for boats above 65 feet. Due consideration should therefore be given to the higher operating costs of the larger vessels to guard against the danger of over-capitalisation.

REFRIGERANTS IN FISHING VESSELS - THEIR INFLUENCE ON DESIGN

by

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SUMMARY

The preservation of a catch of fish in current practice is either by chilling, superchilling or freezing method. The necessary primary refrigerant may be expendable, such as ice or solid carbon dioxide, or non-expendable such as ammonia, R12, R22 or R502 in order of cost.

Non-expendable refrigerants operate in a closed cycle, usually the vapour compression one. Much depends upon the compressor which is usually a reciprocating type but may be a screw type.

A freezing temperature of -40° C (-40° F) necessitates a compound system of mechanical refrigeration except where it operates with R502 which is therefore the preferred primary refrigerant.

Secondary refrigerants are necessary, especially to ensure an installation as simple and robust as possible.

NUMBERING SYSTEM OF REFRIGERANTS

The following system has been introduced by ASHRAE (American Society of Heating Refrigeration and Air Conditioning Engineers) to designate the "FREON" series of refrigerants which developed from the work of Midgley in the U.S. laboratories of General Motors. FREON is an original patent trade name. As many other trade names were later patented for the same material such as ICEON, ARCTON, FRIGEN etc. it was agreed to use the title Refrigerant by which to refer to them all, shortened to R, followed by a number based on their common origin - which is either methane (CH_4) or ethane (C_2H_6). This number depends upon how many hydrogen atoms are replaced by chlorine and/or fluorine atoms. The replacement atom can also be bromine but these resulting refrigerants will not be considered here.

The general formula for the resulting halogenated hydrocarbon is

$$C_c\ H_h\ F_f\quad Cl_{2c+2-h-f}$$

Its number is

$$R = (C-1)\quad (h+1)\ f$$

except that when $C - 1 = 0$ it is omitted

Thus R_{12} is $C\ F_2\ Cl_2$ and is named difluorodichloromethane, and R115 is $C_2\ F_5\ Cl$ with the name trichlorotrifluoroethane which mixed azeotropically with R22 ($CH\ Cl\ F_2$) forms R502, a recent (1962) and important refrigerant. To include the inorganic based refrigerants in this R system, the practice is to add the arbitary number 700 to their moleculer weights, thus Ammonia becomes R717 and Carbon Dioxide becomes R744.

The refrigerants of most concern to fishing vessel design are R717, R12, R22, R502.

Charts and tables of thermodynamic properties are available but not yet all in both systems of units - SI as well as Imperial.

I. INTRODUCTION

Ammonia and Carbon Dioxide are the classical refrigerants. Both have now disappeared together with such substitutes as sulphur Dioxide and Methyl Chloride in favour of one or other of the halogenated hydrocarbon series known popularly as the Freons. However, in very large shore plants and some fishing vessels ammonia has reappeared, briefly at least. It is a very good refrigerant thermodynamically and is relatively cheap but very toxic and for that reason has been generally outlawed. But what are these favourable thermodynamic properties, and how do they relate to the requirements of preserving the catch in a fishing environment?

The biological restraints of fish preservation have established three general methods of dealing with the catch until it is landed and despatched to market, with possibly a period in the shore based cold store.

(a) Chilling
(b) Superchilling
(c) Freezing

Chilling - is achieved usually by mixing the fish with ice. The temperature is reduced to that of the melting ice which is 0° C or a little lower due to the impurities present. BLAIN (1967) says that Australian boats' dependence upon ice alone restrict them to 3 days maximum at sea and MERRITT (1967) referring to Arctic cod (the species containing the least fat) states that the fish in melting ice at a ratio of fish to ice of 2 has a shelf life of about 14 days. Under Australian conditions this ratio would be nearer one, and the shelf life much lower.

Chilling only delays deterioration. It does not prevent it. Meltwater should be removed as soon as possible for general cleanliness and to avoid adverse stability effects on the vessel due to its free surface to which wet fish also add.

Superchilling - According to MERRITT (1967) good results were obtained with haddock stored at temperatures between -1° C (30° F) and - 3° C (26.6° F), but not if the temperature was lowered to - 15° C (5° F). Hence superchilling is defined as occurring when the temperature is lowered to -3° C (26.6° F). This can be easily arranged by the Refrigeration Sea Water method. The temperature in the evaporator would have to reach about - 6° C (21.2° F) to allow for heat transfer losses. Ratios of fish to water by weight of 3 to 4 are practicable.

Freezing - at sea implies considerably more sophisticated equipment as a temperature of - 40° C (- 40° F) is necessary in the evaporator to ensure - 30° C at the fish. This is achieved by freezing processes involving

- PLATES - Horizontal or Vertical
- IMMERSION AND SPRAY
- AIR BLAST

The freezing time is important and the above authority calculates time varying from 1 to 4 hours with a plate temperature of - 40° C (-40° F).

The technique of ultra-rapid freezing is also discussed by MERRITT (1969) page 110 and refers to the use of liquified gases which evaporate at temperatures below -80° C (- 112° F). This method employing expendable refrigerant, such as nitrogen and carbon dioxide is well established in other applications in Australia and warrants consideration. HUGGINS (1975) reports on it. In his earlier paper MERRITT (1967) quotes results which did not favour nitrogen, but carbon dioxide in concentrations of 30 percent was satisfactory except for some discolouration of the fish. There appears to be scope for re-consideration of this application.

Another area which merits attention is the storing of the catch in refrigerated containers which are commonplace in large cargo container ships but in a fishing vessel space would permit only the smallest standard size.

II. PRIMARY REFRIGERANTS

Non-Expendable

These refrigerants remain inside the closed cycle of the vapour compression system. Refrigeration is effected by phase change from liquid to gas at low pressure in the evaporator. To produce the liquid phase, the gas after leaving the evaporator must be compressed to a higher pressure at which its saturation temperature is greater than that of the cooling medium whose function it is to condense it to a liquid by cooling it. This is the reason for installing a compressor.

Compressors are usually of the reciprocating type for which such a standard text as THRELKELD (1970) defines the Clearance Volumetric Efficiency as

$$E = \frac{\{\text{Actual mass of refrigerant gas pumped per second}\}}{\{\text{Mass the compressor could pump if it handled the full piston displacement volume per second}\}}$$

$$= \left\{\frac{\dot{m}}{\dot{V}/v_s}\right\}$$

$$= \left\{1 + C - C\left(\frac{\text{Pressure of condensation } P_C}{\text{Pressure of evaporation } P_E}\right)^{\frac{1}{n}}\right\}$$

where v_s = specific volume of the refrigerant at the compressor suction

C = Clearance factor = $\frac{\text{Clearance Volume } V_C}{\text{Piston Swept Volume } V}$

= usually between 0.002 and 0.003

n = Thermodynamic Compression exponent peculiar to each refrigerant e.g. 1.16 for R22.

GOSNEY (1967) showed that the volumetric efficiency of a modern high speed compressor operating on R22 would become zero at a pressure ratio of 21, probably less.

In the case of ammonia the limiting pressure ratio is usually taken as 8, but for another reason. Ammonia tends to break down chemically and become a dangerous gas at temperatures of 148.8° C (300° F) and this temperature calculated on the elementary equations of thermodynamics for isentropic compression, or more sophistically, must not be exceeded. This temperature for other refrigerants used in fishing vessel applications are

R12	121° C	(250° F)
R22	135° C	(275° F)
R502	176.6° C	(350° F)

Clearly, the selection of the refrigerant plays a major part in the overall design of the installation, and of the ship.

SUNDERCOMBE (1968) compared past and present refrigerants used at sea for the carriage of refrigerant cargoes. Cargoes are usually delivered to the ship in a frozen state which has to be maintained during the voyage. This means it provides mainly the neutralisation of heat leakage through the insulation surrounding the cargo holds. In a fishing vessel this also applies, but in addition the temperature of the fish has to be reduced to that already stated as safe for preservation during the time available.

For freezing on board this temperature may be required to be -40° C (-40° F) which is low by average refrigeration requirements, such as those of air conditioning where evaporator temperatures are about +4° C (39° F) but with very large capacities - hundreds of times greater than the smaller, but more severe, capacities in fishing vessels.

The properties of refrigerants which must be considered can be divided into non-thermodynamic and thermodynamic.

The non-thermodynamic properties include toxity, explosiveness, flamability, solubility in water and oil, dielectric strength, corrosion tendencies et cetera. One or other of these properties have eliminated many of the 50 odd refrigerants which GOSNEY (1962) reports as having been tried. One of them, toxity, has almost eliminated Ammonia, one of the earliest classical refrigerants with still more thermodynamic advantages than many of its successors, in all application except very large ones, and, of interest here, in fishing vessels where no doubt the abundance of fresh air and moisture reduces its toxic potential. It also has the advantage of being cheap and soluble in water under usual conditions. If its cost is unity then approximately that of R12 is 1.9, R22 is 3.1, R502 is 5.8, and R11 is 1.6 (based on a bulk Ammonia price of 70 cents per kilogram). Despite this latter disadvantage, R502 is becoming more used especially in freezer applications, because of good thermodynamic properties which can be more important than the economic ones in the relatively small installation in fishing vessels.

The thermodynamic properties are usually arbitralily compared by reference to the ideal vapour compression cycle operating between condensing temperature of 30° C (86° F) and evaporating temperature of - 15° C (5° F) but the comparative figures in TABLE 1 (b) are based on an evaporating temperature of - 40° C (- 40° F), this being the most severe condition in a fishing vessel.

It will be seen that no one refrigerant is best on all points.

Attempts have been made to find a single measure for comparison with one of the physical properties

The following have been noticed and are useful, as guides -

(1) GOSNEY (1962) observed that the Coefficient of Performance increases with Critical Temperature.

(2) He also drew attention to the fact that the Volumetric Refrigerating Effect is directly proportioned to the Boiling Point. This can be shown by a neat piece of thermodynamics involving Trouton's Rule, which, being an approximate one, leads to some exceptions.

(3) The Heat of Evaporation (Latent Heat) should be relatively large. Ammonia owes many of its advantages to this fact. It implies a Critical Pressure high compared with working pressures.

(4) The Specific Volume at the compressor suction should be relatively low.

Points 3 and 4 concern properties which comprise the Volumetric Refrigerating Effect $\frac{\Delta h}{v_s}$.

That this quantity should be high, and is important, can be seen from the relationship - Refrigerating Effect per second Q

$$= \dot{m} \text{ (enthalpy rise in the evaporator } \Delta h)$$

$$= \frac{\dot{V}}{v_s} E\ (\Delta h)$$

$$= \dot{V} \{1 + C - C\ (\frac{P_C}{P_E})^{\frac{1}{n}}\ (\frac{\Delta h}{v_s})\}$$

$$= \begin{matrix} (\text{Properties relevant}) \\ (\text{to Compressor}) \\ (\text{dimensions and the}) \\ (\text{pressure ratio}) \end{matrix} \qquad \begin{matrix} (\text{Properties relevant}) \\ (\text{to the refrigerant}) \\ (\text{only -}) \\ (\text{Volumetric Refrigerant}) \\ (\text{Coefficient}) \end{matrix}$$

This simple relationship shows that both the refrigerant and compressor performance properties must be high and that although the latter can be isolated the former cannot - it involves the pressure ratio which depends upon the refrigerant.

However, it is required to select the best refrigerant to give the highest Volumetric Refrigerating Effect and the lowest Compression Ratio at an acceptable pressure in the evaporator (preferably above atmosphere to assist leak detection but not essentially so).

Investigation for improvements must involve such design matters as

The selection of the compressor type which can be RECIPROCATING as the foregoing assumes,
or ROTARY,
or CENTRIFUGAL
or SCREW.

The REFRIGERATION SYSTEM - which can be either SIMPLE or COMPOUND or CASCADE.

Selection of Compressor Types

Of the above available compressor types only the SCREW compressor has serious claims to replace the reciprocating compressor in fishing vessels. LUNDVIK (1967) published curves reproduced here as Figure 3 which show that at pressure ratios as high as 18 the Volumetric Efficiency of a typical oil injected screw compressor dropped only from 0.9 to 0.8 when compressing ammonia, whereas the limiting compression ratio for a reciprocating compressor of similar capacity is 8 when the Volumetric Efficiency was down to 0.6 and the discharge temperature was 160° C. The corresponding temperature for the screw compressor was 90° C. LUNDVIK (1967) sums up the advantages of screw compressors thus:

The Refrigerant System - Compounding

To reduce the pressure ratio and thus the maximum temperature and improve the volumetric efficiency in reciprocating compressors it is often necessary to resort to compounding in a multi (usually two) compressor system. There are several such systems and the best one to use depends upon the refrigerant which again plays a very decisive role.

GOSNEY (1967), in a classical paper, describes and analyses four methods of reducing the temperature of compression and the power requirement.

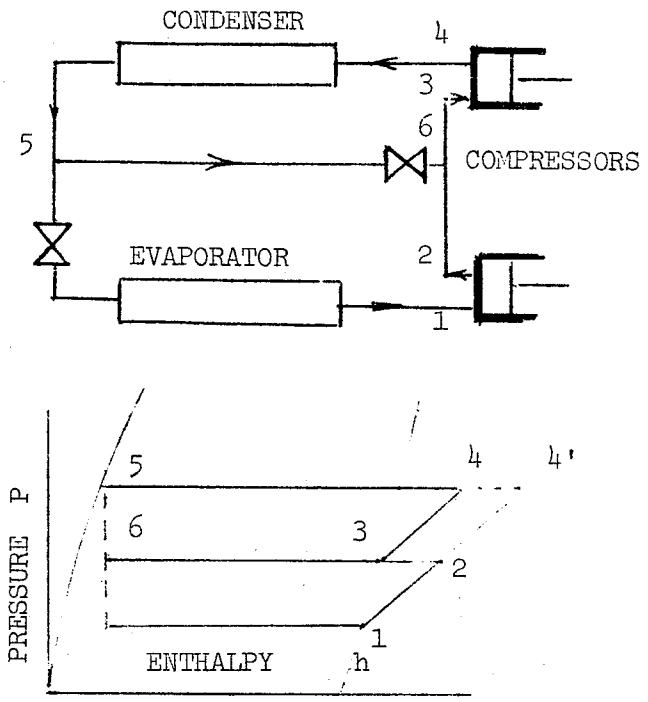
(a) Desuperheating (a preferable word in this work, to 'intercooling' which it resembles) by water or air cooling.

(b) Desuperheating by liquid refrigerant injection.

(c) Liquid pre-cooling.

(d) A combination of (b) and (c).

GOSNEY (1967) dismisses (a) as of little value compared with (b) which is reproduced here diagrammatically and on a Pressure - Enthalpy Diagram as Figure 2.



DESUPERHEATING BY LIQUID INJECTION
(GOSNEY 1967)

FIGURE 2.

GOSNEY (1967) proves that for this system to be beneficial, that is to produce a saving in power as well as a reduction in compression ratio for each compressor, then, referring to the numbering on Figure 2.

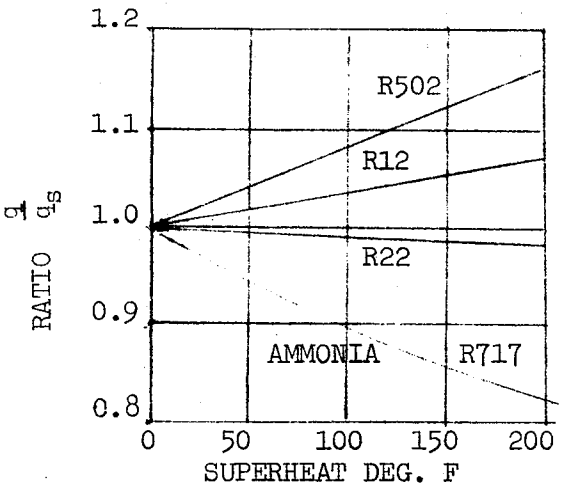
$$\frac{\left(\frac{h_2 - h_5}{v_2}\right)}{\left(\frac{h_3 - h_5}{v_3}\right)}$$ must be less than 1 (unity)

He reduces this ratio to $\left(\frac{q}{q_s}\right)$ where

$$q = \frac{h - h_5}{v_3}$$

q_s = the corresponding value at saturation,

and plots it against superheat temperature to produce Figure 3.



VARIATIONS OF VOLUMETRIC REFRIGERATING EFFECT WITH SUPERHEAT CONDITIONS - 15° C (5° F)/30° C (86° F)

(GOSNEY 1967)

FIGURE 3.

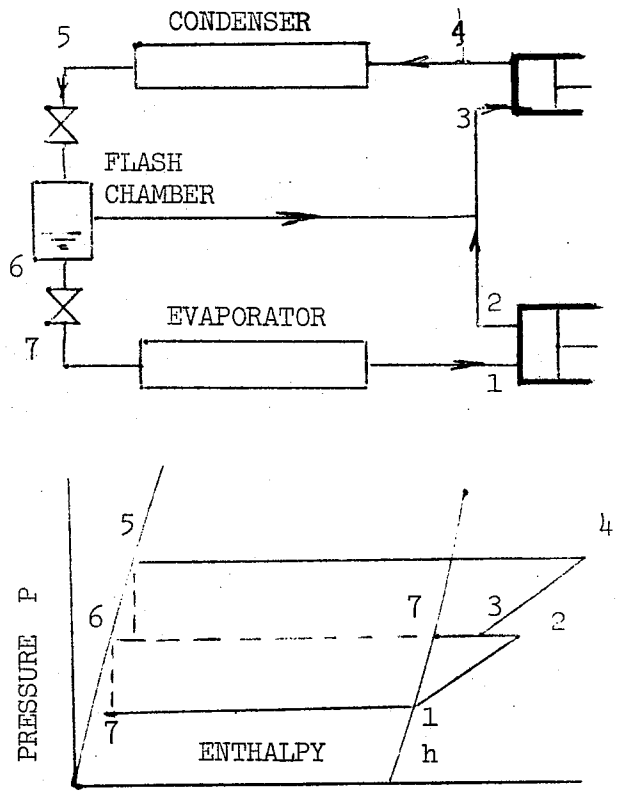
It will be noted that q is the Volumetric Refrigerating Effect for superheated vapour and q_s that for vapour near saturation. Hence the above result is also relevant to the decision whether or not superheating is beneficial in a single compression system although there are practical reasons why a little superheating is always advantageous, such as to avoid liquid particles entering the small clearance volume of the compressor.

GRAHAM (1968) also deals with these more complex systems showing calculations in some detail.

The conditions assumed for Figure 3 are a condensing temperature of 86° F (30° C) but a dry saturated suction temperature at 5° F (-15° C). For ammonia there is a marked decrease with superheat and hence desuperheating by liquid injection is beneficial. For R22 the effect is marginal, while for R12 and R502 the volumetric refrigerating capacity increase with superheat and hence liquid injection should not be applied in this case.

For the latter case the system should be that of

(c) Liquid Precooling which GOSNEY (1967) shows diagrammetically in Figure 4.



PRECOOLING OF LIQUID BY EXPANSION TO INTERSTAGE PRESSURE AND SEPARATION OF VAPOUR.

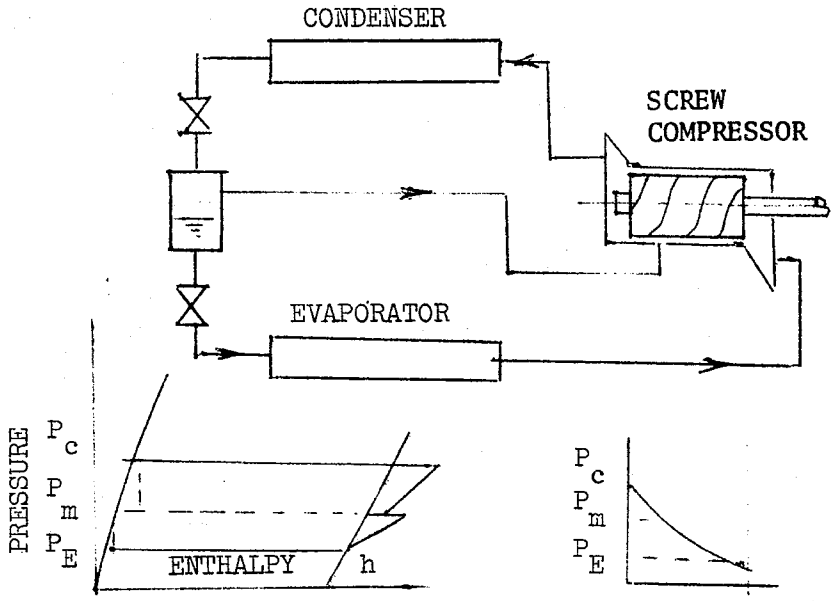
(GOSNEY 1967)

FIGURE 4.

For this system GOSNEY proves that small benefit occurs if the enthalpy at point 7 (h_7) is greater than the enthalpy at point 1 (h_1), as it is in all the refrigerants used in fishing vessels.

(d) The combination of (b) and (c) though adding to the complication of pipework is more usually adopted.

MUNNS (1975) analyses similar arrangements using screw compressors which lend themselves to a so called economiser connection permitting two stage expansion with a single compressor. One of Munns' diagrams is reproduced in Figure 5 modified to indicate the simplification of Figure 4 which a screw compressor permits.



ECONOMISER ARRANGEMENT WITH A SINGLE SCREW COMPRESSOR AND TWO STAGE EXPANSION.

FIGURE 5.

Expendable Refrigerants

These have been used for short time preservation of foodstuffs, especially in road transport, but not consistently at sea, except ice. ICE is such a refrigerant which can be active for periods of 14 days or more according to MERRITT (1969).

Others include liquid nitrogen and liquid carbon dioxide. MERRITT (1967) reports more favourably upon the latter than the former providing concentration of 30 per cent and some discolouration of the fish are accepted.

Solid carbon dioxide - also called dry ice - has also been tried but is not much used. It appears worthy of perserverence especially in conjunction with mechanical refrigeration and containers. HALES et al (1972) and ZIECIK (1973) describe systems applicable more to large container ships than to comparatively small fishing vessels, but the experiences are surely complementary.

Solid carbon dioxide sublimes at a temperature of -78.3° C (-109° F) at atmospheric pressure and in doing so absorbes 572 kj/kg (246 Btu/lb) of heat energy from its surroundings. This energy is nearly twice that of water ice which is 333 kj/kg (144 Btu/lb) but the cost of purchase of Carba Dry Ice is more than twice that of water ice, so that other advantages must be proven.

At a reported rate of sublimition of 5 per cent per 24 hours, solid carbon dioxide in boxes containing 4 blocks totalling a mass of 94 kg (200 lb) and requiring about 0.17m^3 (6ft^3) should not be difficult to stow before the catch, and last long enough to maintain it at freezing temperature.

II. SECONDARY REFRIGERANTS

PEARSON (1965) defines a secondary refrigerant as a fluid employed to transport heat energy away from the load, in this the fish, without evaporation, this heat being subsequently transferred to an evaporating fluid (the primary refrigerant) in a heat exchanger (the Evaporator).

The desirable properties are "low freezing point, low viscosity, high specific heat, low vapour pressure, low flash point, low toxity and low price".

Air is the most common secondary refrigerant. Others in common use with some of their properties are included in Table 2.

Water is also in common use but, of course, its freezing point limits it to chillers working at about 4.5°C (40° F). When water is mixed with calcium chloride the solidification temperature is lowered. For example 10 per cent by weight reduces this temperature to -5.0° C (21.4° F). This particular solution has been used for many years in refrigerated cargo ships. However to achieve a Eutectic temperature of -40° C (-40° F), a concentration of 30 per cent by weight is necessary. Trichlorethylene with a freezing temperature of -87.2° C (-125° F) is preferred despite its relatively high absolute viscosity and specific gravity.

Heat transfer properties of a secondary refrigerant have a vital effect on its system's design especially if it is in the gaseous phase such as in the blast air method of freezing (the heat transfer coefficient in the gaseous phase is of the order of 100 times less than in the liquid phase).

Tables of Refrigerant Properties

TABLE 1(A) - PRIMARY REFRIGERANT PROPERTIES

	REFRIGERANT PROPERTY			
REFRIGERANT R - NUMBER CHEMICAL FORMULA	AMMONIA R717 NH_3	R12 CF_2Cl_2	R22 CHF_2Cl	R502 R22+ R115
TEMPERATURE — BOILING (ATMP). Deg. C Deg. F	-33.3 -28	-29.8 -21.6	-35.2 -41.4	-45.6 -50.1
TEMPERATURE — CRITICAL Deg. C. Deg. F	168.3 271	147.8 234	131.7 205	125.6 194
PRESSURE — EVAPORATING AT ($-40^{\circ}C$)($-40^{\circ}F$) BAR LBF/IN^2 ABS.	0.7177 10.41	0.6417 9.32	1.034 15	1.31 19
PRESSURE — CONDENSING AT ($30^{\circ}C$) ($86^{\circ}F$) BAR LBF/IN^2 ABS.	11.67 169.2	7.449 108	11.92 172.9	13.0 189.8
SPECIFIC VOLUME — VAPOUR AT ($-40^{\circ}C$)($-40^{\circ}F$) KG/M^3 LB/FT^3	1.552 24.86	0.24 3.91	0.22 3.6	0.13 2.1
SPECIFIC VOLUME — LIQUID AT ($30^{\circ}C$)($86^{\circ}F$) KG/M^3 LB/FT^3	2.378 38.1	5 80.7	4.58 73.4	4.75 76.1
ENTHALPY DIFFERENCE — VAPOURISATION (LATENT HEAT) AT($-40^{\circ}C$)($40^{\circ}F$) KJ/KG BTU/LB	1390 597.6	171 73.5	232.6 100	174.5 74
ENTHALPY DIFFERENCE — REFRIGERATING EFFECT WITHOUT SUPERHEAT KJ/KG BTU/LB	1067.6 459	105.9 45.5	151.2 65	118.6 51
ENTHALPY DIFFERENCE — ISENTROPIC WORK KJ/KG BTU/LB	309.36 133	23.26 10	62.8 27	46.52 20
MAXIMUM TEMPERATURE COMP.DISCHARGE $^{\circ}C$ MAXIMUM TEMPERATURE COMP.DISCHARGE $^{\circ}F$	160 320	50 122	85 185	32 90 (APPROX.)

PEARSON (1968)

TABLE 1(B) - PRIMARY REFRIGERANT PROPERTIES

REFRIGERANT R - NUMBER CHEMICAL FORMULA	REFRIGERANT PROPERTY AMMONIA R717	R12	R22	R502
COEFFICIENT OF PERFORMANCE (THEORETICAL) COP.	3.45	4.55	2.4	2.55
VOLUMETRIC (ASSUMING) EFFICIENCY (C = 0.03)	0.7	0.77	0.78	-
VOLUMETRIC REFRIGERATING EFFECT $\left(\frac{\Delta h}{v_s}\right)_E$ KJ/M^3 BTU/FT^3	 927.7 24.9	 432.2 11.6	 674.4 18.1	 905.4 24.3
POWER PER TON OF REFRIGERATION Kilowatts - KW Horse Power - HP	 1.02 1.37	 0.776 1.04	 1.49 1.96	 1.39 1.85

TOXITY	YES - ABOVE 0.5% BY VOLUME	SLIGHT - ABOVE 30% BY VOLUME	SLIGHT	SLIGHT
FLAMMABLE OR EXPLOSIVE LIMITS IN AIR	16-25% BY VOLUME	NIL	NIL	NIL
ODOUR	STRONG	NIL	NIL	NIL
MISCIBILITY WITH LUBRICATING OIL	SLIGHT	COMPLETE	PARTIAL	PARTIAL
PRICES: $ PER KILOGRAM (Melbourne June 1975)	0.69 to 0.86	1.32	2.17	4.08

PEARSON (1968)

TABLE 2 - SECONDARY REFRIGERANT PROPERTIES

	NON-TOXIC SECONDARY REFRIGERANT PROPERTIES					
	WATER	$CaCl_2$ 30% WT.IN WATER	$NaCl_2$ 23% WT.IN WATER	TRICHLOR-ETHYLENE	PERCHLOR-ETHYLENE	R11
FREEZING (EUTECTIC)						
TEMP. °C	0	-55	-21	-87.2	-22.2	-111
°F	32	-67	-6	-125	-8	-168
VISCOSITY (ABSOLUTE) CENTIPOISE						
+40° F	1.55	15.5	2.5	0.69	1	0.5
-40° F	-	35.5		1.2	-	0.9
SPECIFIC GRAVITY						
+40° F	1	1.298	1.18	1.492	1.65	1.53
-40° F	-	1.318	-	1.552	-	1.625
SPECIFIC HEAT						
Kj/Kg(deg.C)						
+40°F	4.19	2.74	3.32	0.94	0.88	0.85
-40°F	-	2.65	-	0.85	-	0.83
Btu/(lb) (deg.F)						
+40°F	1	0.654	0.794	0.224	0.21	0.203
-40°F	-	0.632	-	0.204	-	0.198
VAPOUR PRESSURE						
mm H_s +40°F	6.35	<4.25	<5	30	4	364
GPM/TR						
+40°F	2	2.36	2.24	5.98	5.77	6.45
-40°F		2.41	-	6.31	-	6.23
FOR 10°F RISE.						

PEARSON (1968)

III. CONCLUSIONS

Ice is satisfactory for chilling for periods up to about 14 days, which means about 3 days at sea, assuming a fish to ice ratio of one.

The trend to mechanial refrigeration implies simple and very rugged equipment. As ashore, the vapour compression system is usual, although overseas the absorption and thermoelectric systems have been tried.

The refrigerant is either ammonia, R12, R22 or R502, but ammonia should be avoided due to its toxity.

R12 is a very satisfactory refrigerant for chilling (0° C) and superchilling (-2° C) temperatures in the fishhold.

For freezing temperatures (-40° C) the refrigerant must be either R22 or R502. There is little between these refrigerants technically and R502 is much more expensive. However R502 could ensure positive pressures in the system if that is considered important, and also the avoidance of the more complicated compound system.

The latter system can also be resisted by the use of a screw compressor, at a further price penalty at present.

For freezing, plate freezing through aluminium is reported by HALL (1975) as very successful in Western Australia, and air blast systems are popular in the Gulf of Carpentaria. The system of spraying circulating brine over the catch previously superchilled by a separate direct expansion system through pipe grids in the fishhold has advantages.

For superchilling the Refrigerated Sea Water system is popular and a reasonably cheap addition to, or replacement of, ice.

Refrigerated Sea Water containers are possible for the future, and, if insulated, could provide an economic use for solid carbon dioxide as an expendable refrigerant.

For the conversion of decisions based on the above to working drawings the ASHRAE GUIDE AND DATA BOOK (1971 et seq) and the BRITISH CODE OF PRACTICE CP406 (1952 et seq) are valuable references.

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SIZE CLASSIFICATION OF BOATS ENGAGED IN GENERAL FISHERIES, STATES AND NORTHERN TERRITORY AT 30.6.72

Length of Boat (feet)	N.S.W.	VIC.	QLD.	S.A.	W.A.	TAS.	N.T.	AUST.[1]
Under 20	2,197	258	736	..	513	108	45	3,857
20 and under 30	461	249	382	..	521	109	9	1,731
30 and under 40	153	152	173	..	273	138	8	997
40 and under 50	155	96	242	..	104	152	7	756
50 and under 60	81	44	124	..	64	60	13	386
60 and under 70	21	6	40	..	27	13	9	116
70 and under 85	5	3	16	..	5	3	15	47
85 and under 100	4	-	3	..	-	-	16	23
100 and over	-	-	12	..	1	5	8	26
TOTAL	3,077	808	1,828	1,652	1,508	588	130	9,591

Source: Commonwealth Bureau of Census and Statistics

1. - Incomplete: South Australian figures not available.

AUSTRALIAN GOVERNMENT FISHING BOAT LICENCES ISSUED DURING 1973

State	No.
New South Wales	651
Victoria	140
Queensland	1,096
Western Australia	1,095
South Australia	564
Tasmania	330
Northern Territory	22
TOTAL	3,898

Source: Department of Primary Industry

AUSTRALIAN FISHING VESSELS OF 200 TONS GROSS AND OVER

Vessels at sea as at 30.6.73	20
Vessels under construction as at 8.11.73	49
Vessels in respect of which tenders have closed but no order yet placed as at 8.11.73	21
Vessels which are at present out to tender as at 8.11.73	4
Total envisaged by 1976	94

Source: Department of Transport

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THE FISHERIES RESEARCH VESSEL - A COMPLEX SMALL SHIP

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SUMMARY

Although commercial stern-ramp trawlers of the size of the projected large CSIRO fisheries and oceanographic research vessel have not yet been built in Australian ship-yards, reference to the extensive literature of the twenty years development in Europe of this type of highly sophisticated prototype should provide solutions to most constructional problems. From the research staffs' point of view, however, the needs of the derived research vessel require a break with tradition. In particular, a planned fitting-out stage, controlled largely by the needs of research, is essential if an operationally effective vessel is to result. Some suggestions are offered in the hope that they may help to simplify the later stages of construction of a complex small ship.

INTRODUCTION

Research vessels tend to fall within the size range covered by this Symposium, although a number listed by the Food & Agriculture Organisation (Fujinami 1968) and several built since that first analysis of the international fleet, exceed the upper limit. One such vessel for example, planned for both fisheries and oceanographic research, is that projected for the C.S.I.R.O. Division of Fisheries & Oceanography, Cronulla.

Whilst oceanographic studies may be carried on from many different types of working platforms, the parentage of the hull form of research vessels concerned with fisheries should be derived, logically, from - in terms of naval architecture - that of the commercial fishing vessel type exploiting the fish populations which are the subject of the intended research. Superficially, too, the fisheries research vessel resembles its commercial prototype on account of their gear handling facilities, be they purse seiners, trawlers or oyster dredgers. Where practicable a combination of fishing methods may be present on one vessel, plus a comprehensive array of oceanographic equipment.

Since the advent of the ramped stern freezer-trawler (Lochridge 1950), the major commercial fisheries of the northern hemisphere have seen the progressive development of this type of vessel - not present in Australian fisheries - to the stage where some of the most recent examples have exceeded 100 metres overall and cost more than $A.6-7,000,000 (USSR has a class of French-built canning/freezer trawlers of 129 m and 8500 GRT (Hjul 1972)). Main engine powers of between 4,500-5,000 bhp are installed so that fishing with the largest nets (Scharfe 1969) can continue under the most severe weather conditions on the North Atlantic fishing grounds - eg the Barents and Greenland Seas, from Novaya Zemleya to Iceland, to Labrador and the Canadian Grand Banks. Trawling, from these stern trawlers, takes place regularly in winds of 10 & 11 Beaufort Scale under icing conditions and in the months of the Arctic winter darkness. The vessel type has gained a reputation for excellent seaworthiness, which has been improved by the careful attention to matching of bow and stern sections and to increased freeboard (Goodrich 1964). Stern trawlers now have a characteristically high focsle silhouette, which

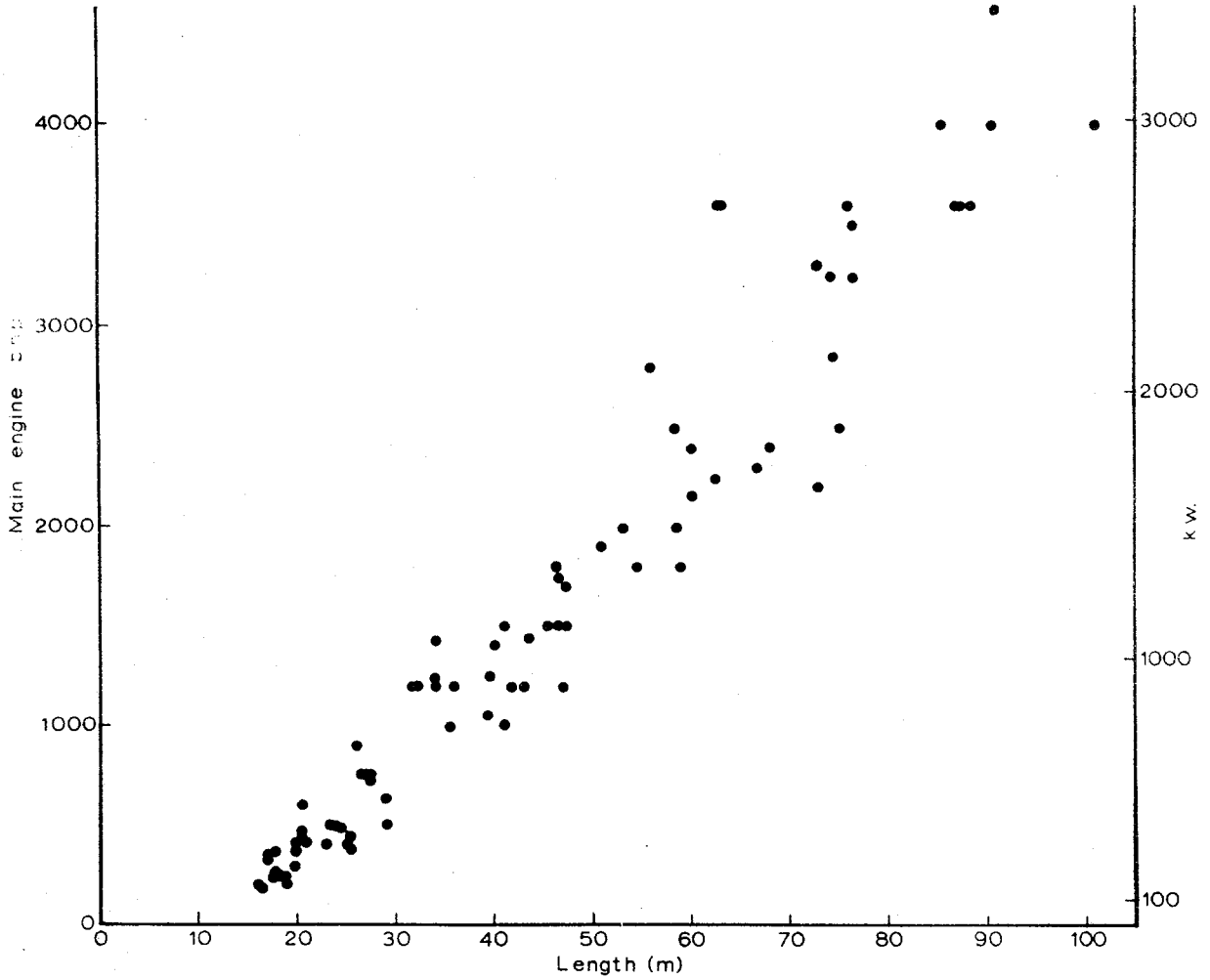

Fig. 1 Power length relationship for stern trawlers recently completed in Europe. (World Fishing, Vol. 23, No. 3, March 1974).

keeps the forepart of the vessel dry and hence delays the onset of icing, which has caused so many losses amongst the low-freeboard side trawlers.

Design developments of the larger stern trawler and their gear handling equipment are well documented in the international fisheries periodicals and technical press; in FAO special publications (Traung 1955, 1960, 1967 and Kristjonsson 1959) and by the White Fish Authority of the United Kingdom (WFA 1964 and Hjul 1972); Lloyd's Rules & Regulations (1973) detail minimum scantlings, some of which are often exceeded in practice, and constructions, and Holland-Martin (1972) dealt with all aspects of trawler safety. The literature is extensive. It is specialised because, traditionally, the design and construction of fishing craft has remained in the hands of a relatively small number of shipyards concerned almost wholly with trawlers and tugs. Few problems should arise therefore, during the construction of the C.S.I.R.O. vessel, which has an important fishing element, which cannot be resolved by reference to earlier experience. Obviously any technical managements' or drawing office personnels' direct experience of building the larger range of European trawler, would be an advantage.

Modern trawlers possess design features which are characteristic of the class, irrespective of size or country of origin. They are also amongst the most highly specialised and mechanised small ships afloat. Thus the recent

Tomago-built 'Trident Aurora' (Anon. 1974) of some 30 metres, and the largest built so far in Australia, includes many characteristics of the stern trawlers of the northern hemisphere. Differences, apart from size, are due to her specific needs as a prawn trawler, which processes, packages and quick freezes her entire catch at sea, so that it may be landed in prime condition without further handling ashore.

Other design features which characterize commercial trawlers, are also shared by the derived fisheries research vessel, if normal bottom and mid-water trawling are to form a serious part of her multi-discipline research programmes. Major differences occur, however, as a result of the fundamentally different operational needs of research and its wide variety of equipment, expensive and often fragile, which must have special access for easy replacement as research develops and equipment needs change.

This paper is an attempt to outline some suggestions for simplifying the shipbuilder's task of constructing a major research vessel. No new technology is required, but, by means of a team approach, involving consultants, shipbuilder and user, a more rational and detailed planning of both ship and research systems is proposed for the fitting out stage. The criteria for achieving the final design aims may differ from those normally used. They are, essentially, those which confer upon the resulting vessel the flexibility of future needs, and ease of maintenance which are basic to the requirement of the user research staff.

The areas covered, therefore, include (i) the initial planning philosophy; (ii) special measures, involving construction specifically associated with some research needs; (iii) communication problems within the shipyard; (iv) the consultants', users' and shipyard's interrelationship in planning for the crucial fitting out stages for ship and research systems.

(i) INITIAL PLANNING

A research vessel is a seagoing laboratory in which many disciplines must operate year round under all practicable sea states for biological, and for physical and chemical oceanographic research programmes. The C.S.I.R.O. vessel will be expected to work from the equator to high latitudes in the Southern Ocean and thus to experience extremes of weather conditions as a matter of course. Internal environment can be controlled by cooling and heating cycles of the air conditioning plant, which has been an accepted method over several decades of enabling crews to live and work in reasonable bodily comfort, in most climates,

Shipboard computers whether for navigation systems or research may require their own refined type of air conditioning, which incorporates appropriate filtering equipment for the removal of dust and fine salt particles taken in by the normal ships air intake system.

The almost universal use of diesel machinery has led also to the inclusion, over the past decade and more, of measures to limit noise and vibration on board commercial, non passenger carrying, vessels (Walter and Witt 1965). This practice is growing in order to provide acceptable living standards in accommodation and to minimise fatigue and loss of working efficiency due to high noise levels inside and outside the engine room. For some research, underwater noise limitation measures adds to the complexity of the vessel.

The progressive introduction of automation in fishing gear handling, (Hjul 1972) and changes in ship propulsion from watched engine rooms to varying degrees of centralisation of control and automation - has led to an

increasing complexity of trawler engineering, (Hatfield (1970) describes a computer-based 'electronic watchkeeper' built, experimentally, into a 68 metre (LOA) commercial stern trawler). The trawler building industry in Europe is, therefore, well used to its own advanced technologies. Major differences, however, are brought about by the introduction of research requirements. These are so fundamental that the ship and the contained research equipment can no longer be treated as separate entities but must be designed as an integrated concept and as a research tool in which research requirements will take priority and dictate layout, operational capabilities as well as content. Often this requires non traditional shipbuilding practices to be introduced. Only the user organisation can determine the priorities, scope and probable degree of permenance of a research facility, hence the user must be responsible for the basic planning of the vessel, aiming to achieve simplicity and precision of both research and ship operation and to do so with a maximum inbuilt convenience for research staff and crew. At the same time, flexibility of layout and provisions for future research facilities must be considered during the planning stage.

It follows that the users must have access to naval architect and marine engineer consultants at an early stage in the planning process so that their concept can progress realistically on the basis of their research programmes. It follows, too, that the final decision on the suitability of a ship/engineering design proposal must lie with the users and their experience of research at sea. To achieve this, an understanding of the problems facing both the user and the design team must be reached by the fullest possible discussions. Furthermore, any constraint likely to be imposed by a design proposal on a particular field of research, requires reference back to the specialist group concerned, so that designs may be developed until the constraint imposed is either acceptable or a new solution can be found. In some cases solutions may be sought from outside the shipbuilding industry. Furthermore each research requirement should be scrutinised, in turn, in relation to each ship design decision, so that any possible interaction may be assessed, and, where simultaneous operation of two conflicting systems is seen to occur, redesign must continue until the interference is minimised or eliminated.

The large modern fisheries research vessel derives characteristics from the stern trawler. These include deep draft, to accommodate the largest practicable slow running and well immersed single screw for bad weather operation; a moderate rake of keel or design trim for free running and the ability to increase that trim materially for fishing; high power and speed in comparison with other draft of similar size ($\frac{V}{\sqrt{LBP}} = 1.0$ is often exceeded as a service speed); position of the LCB aft of amidships; high rise of floor; and fine entrance to water line to minimise pitching and slamming in bad weather; high freeboard forward to keep the foredeck - a working area - dry.

Differences to be found between the commercial and research vessels reflect, naturally, their entirely different aims. Thus fishing operations from the research vessel are aimed primarily at identifying the species present during acoustic surveys of fish resources. Quite frequently entirely different sizes of nets are required. Whereas commercial craft use the largest nets possible - Schärfe (1969) quotes midwater trawls of 2100 m^2 mouth opening and over 200 metres in length - surveys of young fish, eg of less than one year old, required for mortality or recruitment estimations, are carried out by scaled down midwater trawls of approximately between 1/10 and 1/3 the dimensions of those used commercially. Thus power requirements for such and similar low drag research conditions cannot be met economically by the single large diesel, normally provided in commercial craft. The tendency to select diesel-electric or other form of multi-engined diesel installations

for research vessels, despite higher first cost, provides more effectively for the wide variation of propulsion powers needed under research conditions. Trawl winch powers, too, tend to be lower.

Much research is undertaken whilst lying stopped "on station" at sea, and using a succession of relatively low power winches for the lowering and recovery of sampling devices - water bottles, vertically hauled plankton nets or sensing instruments recording in laboratories via slip-ring winches. As many stations may take several hours to complete, particularly if related to tidal cycles, flexibility of power available to the main screw is essential, plus some form of bow propeller.

These and similar considerations can only be decided by the user staffs and all must be put forward to the consultants as a very complete and detailed statement of operational, layout and content requirements for transcribing into the hull and machinery specifications.

As far as problems of hull design are concerned, the research vessel benefits from the knowledge of the trawler's naval architecture but tends to present some departure from the commercial trawler in the vertical distribution of main weights. Thus, pressure for laboratory space on the main (fishing) deck may require the main trawl winch, weighing, together with its two 4/5,000 m warps, between 50 and 60 tonnes, to be sited on the boat deck above main deck and only the light net storage drum winch for midwater trawl handling, to be sited on the main deck in its place. In addition several research winches and gantries, totalling some 30 tonnes with their wires and cables, and sited also on the boat deck, could present a stability problem for a vessel which will not be carrying the 6-700 ton fish cargo of her commercial counterpart. Beam can be increased, however, with advantage and without resistance penalty, in view of the, probably, finer hull form. Beam of commercial stern trawlers in Europe tends to be determined by lock gates and not by optimised design.

Whilst several trawl winch configurations are available which permit considerable flexibility in trawl deck layout, the overall space requirements for the many other forms of research and sampling equipment can be resolved only by the users assessment of relative priorities of fishing and other research programmes. These, together with the physical, spatial relationships between laboratories and their associated deck equipment and working areas, underline the peculiar complexity of designing a research vessel. It also emphasises the extent to which the user staffs must be involved, at all times, to ensure that design compromises still permit research to be undertaken with the maximum effectiveness and convenience under all conditions. The user's involvement must also continue into the preconstruction planning at the shipyard and throughout all the building stages.

(ii) SOME SPECIAL DESIGN PROBLEMS

(a) Underwater Noise

One of the primary needs of fisheries research vessel operation is to be able to undertake large scale acoustic survey "grids" - often covering several thousand square miles, over sea areas which may contain fish resources of potential interest. Acoustic techniques enable fish to be detected and the size and density of the shoals determined without the need to spent time fishing. Naturally, sample trawl hauls will be taken at suitable intervals to identify the species present, but the distances involved in even quite modest grids - parallel lines so arranged that fish density may be contoured to determine the area(s) of maximum concentrations - are great enough to require

that the highest practicable ship speed be used, which should be not less than about 12 knots. The factor upon which this speed most depends is underwater noise, not power - the CSIRO vessel will have sufficient power available from two of the three generators.

The transducers of the acoustic survey instruments, sounders and sonar, transmit and receive sound pulses of frequencies ranging from 30 to 100 or 200 kHz and are susceptible to interference from outside sources producing noise within these frequencies. The two main sources of interference arise from propeller cavitation and from flow noise over the hull, its openings and appendages. The former must normally be the subject of a specialist design study, but the success of the hull flow is dependent upon the hull form and the quality and finish of the plating.

The hull form optimisation technique developed by Doust for side trawlers (Doust & O'Brien 1959; Doust 1963), aimed at minimising resistance. It also has the effect of minimising hull turbulence and hence flow noise. The design technique used for the newer stern trawling research vessels has had the same effect (Trout 1974, 1975). Thus one of the critical factors in building is the production of a hull which will take advantage of this potential by ensuring a well faired and uncorrugated hull surface and also by grinding off surplus weld material from butts and seams to produce a smooth finish. Hull openings should be of type which will also minimise flow noise.

(b) Appendages

Bilge keels have been eliminated from several fisheries research vessels because of their tendency to affect adversely the performance of hull mounted acoustic transducers installed on the plate keel, lying between them. Passive roll-stabilising tanks have been substituted (Trout & Downham 1968; Trout 1974, 1975) so that the hull could be kept smooth and free of appendages which might cause cavitation. Good streamline finish of the stern frame and rudder are also prerequisites.

Although some comparisons of rolling characteristics of hulls with bilge keels and anti-roll tanks have suggested that the presence of normal bilge keels make little contribution to roll limitation (Giddings & Wermter 1965), Yokoyama et al. (1968) have shown,however, that 1 m deep bilge keels of triangular section improved an 82 m vessel's roll performance by 20%. By critical siting of these extra deep keels, danger to other vessels coming alongside or to the keels themselves when lying alongside a quay, could be minimised without undue increase of resistance.

Further research, however, is required to arrive at a bilge keel section which will cause minimal flow noise, together with a robust construction capable of avoiding the distortions, so often seen in dry dock, to those of normal crude "plate and bulb" type. Here again the importance of considering all interactions with research requirements cannot be overstressed. To reduce rolling by an additional 20% by means of extra large bilge keels but at the expense of increased flow noise, by an uncontrolled design of the appendages, would be an unacceptable penalty.

(c) Hull

Hull construction must be expected to be heavy, primarily to reduce the chances of plates becoming corrugated during fabrication. To reduce the risk of such corrugations developing also with age and service in high head sea states, as is common on northern hemisphere fishing grounds, the recent Lowestoft Laboratory's research vessel 'Cirolana' (62.5 m LBP) was built with

19 mm (¾ inch) thick bottom plating. Doubled frames were also provided forward, plus additional fore and aft frames over the area of maximum slamming forces.

(d) Raft Mounting

Machinery noise is primarily at the lower end of the frequency spectrum. Raft mounting all diesel engines and other noise producers, eg compressors, pumps, as on the 'Cirolana', is an effective method of controlling this high energy noise. Airborne noise, which might stimulate other structures of the hull and so by conduction generate underwater noise, was also limited by means of an acoustic hood (Trout & Downham 1968). One other highly valuable result of raft mounting the diesel machinery was the reduction of vibration in the laboratory accommodation, which has enabled high magnification optical microscopy to be used routinely at sea, even in moderate weather. In part this is also due to the effectiveness of the passive roll stabilisation tank designed by the Ship Division of the National Physical Laboratory, Feltham.

Although the construction of the raft may raise some problems for the smaller yards, with small crane lift capabilities, planning of the correct sequence of assembly of the raft components in relation to unit fabrication of the rest of the shipwork should not be difficult to achieve. These are essentially problems related to the overall design of raft and the essential access for the welding of the thick steelwork.

Planned access routes to and in the areas below the raft, once 'in situ', are vital to the operation of the vessel for the rest of her life. Access should take account of all structures and services between the underside of the raft and the tank top. Of these it is probable that pipework; double bottom tank entry points; main engine holding-down bolts are the more important. In particular, whatever form of resilient mounting system or material is to be adopted, clearance around each support must be adequate to permit easy access for inspection and also for replacement as required. Comprehensive and fully detailed sectional drawings are essential to ensure this ease of access and it is advisable that clearances should not be restricted to the theoretical minima.

Raft mounting requires the provision of flexible connections onto and off the raft, for fuel, cooling water, lubricating oil etc. If the diesel generator units are themselves resiliently mounted on the raft, a second set of flexibles will be required. From experience, the major difficulty with the installation of flexibles is to ensure that the off-raft flange connections should be lined up with the on-raft flanges, so ensuring that the flexible sections inserted are not under stress and that no distortion is permitted during installation. Whilst this is a simple and obvious precaution it is one which appears difficult to achieve with certainty.

(e) Stabilisation Tank

The importance of roll stabilisation for a vessel in which developments of land laboratory techniques are to be used is evident. In order to derive maximum benefit from the tank - a simple structure in itself - "tuning" is essential for the sea state selected (Lewison 1975). Perhaps of even greater importance is the method of determining the quantity of liquid in the tank. Here the normal, central sight glass, usually advocated by tank designers, takes no account of the almost invariable slight angle of heel taken up by ships when in port. From experience the author would recommend twin sight glasses, with the maximum possible separation, so that depth of liquid may be assessed with greater accuracy. It should also be checked against the delivery of a

calibrated pump whilst in port. Sight glasses are, of course, unusable at sea and the same calibrated pump will be used to pump out the required weight of liquid at intervals throughout the voyage as displacement changes demand. A normal flow meter on the discharge side of the pump will be an additional useful check on the tanks contents.

(f) Trim

The ability to standardise trim is highly desirable for comparability of results of successive quantitative acoustic resource surveys, irrespective of state of loading during a cruise. Whilst rake of keel, or design trim, by the stern, under free running conditions is one of the characteristics of the stern trawler, it becomes necessary when fishing to increase the trim to permit immersion of the lower end of the ramp to facilitate hauling the trawl in rough weather without risk of damage to the net. R.V. Cirolana's designed free running trim is 0.45 m. This can be increased to 1.5 m maximum for fishing and these figures are roughly the average for commercial vessels of between 60 and 75 m LBP.

As fishing is certain to be required for species identification at intervals during an acoustic survey, the ability to make rapid changes of trim is essential. When on purely fishing surveys, short distance movements may be made without reverting to free running trim, but for acoustic survey conditions at 12 knots, approximately, the drag of the immersed transom would be unacceptable.

Two problems arise from these considerations: (i) the trimming system should be provided with pumps having centralised control - possibly even bridge control - and with a high rate of flow which will permit trim changes to be achieved in the shortest practicable time in view of the weight of water required to effect thoses changes; (ii) the angle at which the hull mounted transducers are installed may require to be different for the two conditions of survey and fishing, for optimum reception of the returned signals, particularly when operating in deep water.

(iii) COMMUNICATION WITHIN THE SHIPYARD

The inclusion of drawing office personnel at all detailing meetings at the shipyard is not a universal management procedure. From experience it is, however, invaluable for several reasons and is common sense during the development of preparatory and working drawings of a complex vessel because it provides direct contact between user and draughtsmen actually responsible for translating the former's wishes. Transmission of the user's intent, given in the inevitable verbal amplification of any written specification, is therefore, not dependent upon chance loss of clarity, or incompleteness of transmission at each 'hierarchical interface'.

In the same way attendance at those same meetings by the hull and machinery inspectorate, provided by the consultants, will be of greater service to the user organisation if their mandate can be expanded from their normal 'building practices approval' and examination and testing of materials and equipment. Their presence at the yard will normally be more frequent than that of the user personnel and thus they should be fully briefed on all requirements. Any organisational change which improves the chances of achieving the objective of the specification correctly and at the first attempt is worth the innovation.

(iv) PLANNING FOR FITTING OUT

In some shipyards the traditional way in which a ship is fitted out after launching is unsatisfactory for the number and type of research and ship systems contained in the large modern research vessel. Too often installation of ship services is still dependent upon an unplanned availability of 'trades'. Installation of much complex equipment is thus carried out in an unpredictable and unplanned sequence. Delays in arrival of subcontracted items aggrevate this situation and wastage of manpower and material can be high if earlier installations are burned off and resited to provide space for the equipment of trades arriving later at the ship. Too often, however, badly sited equipment is not removed but allowed to remain whilst successive services are looped around it, resulting in a poor utilisation of space and poorer access for maintenance for those who must operate the ship. In the writer's opinion the traditional piecemeal pattern of fitting out should be replaced by the planning of all services - ship and research - in which all three parties must be involved. Once steelwork drawings have been approved, the dimensions of all spaces bounded by steel are defined. Three dimensional, for example, isometric drawings of 'tight spots' can be produced which permit all services going to or passing through each space, or each piece of equipment, to be sited for the maximum convenience of installation, for maintenance of the user research staff and ship operator. The siting and run of service may sometimes differ from what is easiest and cheapest for the shipbuilder to construct and could include, for example:- air trunking; ducting from laboratories to data logger/computer complex; research winch cabling - both power and for the returned signal - requires separate duct systems. Once so planned, the sequence of arrival of the different trades becomes unimportant. All services may then be fitted without interference to or from the next to be installed. For a research vessel, where equipment must be capable of being modified or replaced throughout the ship's life, at minimum cost, this approach is essential. Nor is this of academic interest or applicable to research vessels alone. The method would confer on commercial craft an ease of operation and simplified maintenance, contributing to the popularity of a builder's products and reputation and is thus a worthwhile target in itself.

CONCLUSION

It is probably true to say that solutions to most of the technical and technological problems likely to be met during the construction of a research vessel based upon the stern ramp trawler of the northern hemisphere, such as that proposed for C.S.I.R.O., are already available in the extensive literature - a fragment of which is listed. Most of the remaining problems will be found to be human ones!

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ALUMINIUM CONSTRUCTION.

CAN IT IMPROVE THE SAFETY OF FISHING VESSELS?

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1. INTRODUCTION.

Time has arrived to reconsider the merits of aluminium alloys for the construction of fishing vessels.

1.1 Reasons for delay in wider adoption of aluminium alloys in Australia for fishing vessel construction.

1.1.1 Conservatism of fishermen.
Tendency to follow proven types associated with local areas, with a continued preference for wooden hulls.
Until recent years, where steel construction has been accepted, the same conservatism tends to retain the new 'Status Quo' holding to accepted types of vessel.
There has been a tendency to wait until someone else makes the adventure.

1.1.2 Cost of aluminium alloy per unit quantity compared to the price of steel for same unit has made the initial vessel cost appear to be uneconomical.

1.1.3 Costs quoted for building an aluminium vessel have been higher in relation to labour and overhead charges than for steel vessels of comparable size.
These charges have reflected the shipbuilders concern that the working of this new material will involve him in problems arising from lack of experience on the part of his operatives as well as added time and cost in experimentation with new methods of fabrication and welding.

1.1.4 The sparsity of data from reliable sources for the guidance of designers and the lack of recognised rules for construction in aluminium alloy, which would be parallel to the rules for other materials. Rules for steel vessels have been issued by both Government authorities and registration societies for a long while; rules for G.R.P. and ferro cement have been available for a number of years, but only in very recent times have rules been published for marine aluminium alloy construction.

1.2 Reasons for suggesting that now is the time for the reconsideration of the use of aluminium alloy for fishing boat construction.

1.2.1 The awakening of the fishing industry to the need to improve and modernise vessels, methods of fishing and equipment, in order to obtain greater economical and more reliable returns of fish and profits.

1.2.2 The increased cost of steel and the tendency toward a corresponding reduction in the differential between

aluminium alloy and steel prices.

1.2.3 Shipbuilders who have experimented in the building of aluminium alloy vessels, more particularly in the pleasure boat field, have found that real costs of production are not as high as were originally expected.
The experience of workers with aluminium alloy in other fields, such as the building of road tankers for the oil industry and the wider use of Argon Arc welding, with the consequent increased availability of welders trained in this technique, can reduce the uncertainty of the shipbuilder and improve his production methods for aluminium construction.

1.2.4 The available data on the experience overseas, both in the operation of aluminium fishing vessels, and in design and building, make it possible for the Australian naval architect to produce designs for vessels, with more confidence that the finished vessel will meet the owner's requirements and prove that the choice of aluminium alloy, has been justified.

1.2.5 The present intention on the part of the Australian Government to provide assistance to the fishing industry, gives the fishing vessel owner an opportunity to recover some, if not all, of the possible increased costs in purchasing an aluminium alloy vessel.

2. COMPARISON OF QUALITIES OF ALUMINIUM ALLOY.

2.1 What are the known merits of aluminium construction for fishing boats?

2.1.1 The metal as currently developed for marine applications is:-

a) Non rusting.

b) Self protecting by oxidisation.

Each of these qualities result in greatly reduced maintenance costs.

2.1.2 The marine alloy possesses the virtue of a high strength to weight ratio, leading to a lighter basic hull structure with consequent advantages to the fisherman of one or more of the following alternatives:-

a) Lighter load displacement, leading to possibility of smaller draft, if required.

b) Increased dead-weight for the same draft.

c) Improved stability due to greater freeboard and better values of righting arms, (G.Z.value) in 'overload condition'.

d) Better speed for same engine power.

e) Smaller engine power for same speed.

2.1.3 The aluminium alloy has the quality of greater ductility. In service, it will bend or deflect more easily than steel, but resists the tendency to tear or fracture on impact. The hardness of the metal improves with cold working, a quality not present in steel.
The marine alloys can be readily formed into quite complex shapes even with hand tools. Annealing becomes necessary only after the more severe cold working.

2.1.4 Aluminium alloy construction sections are generally extruded from a cast ingot. A facility which can greatly assist the skilled designer to experiment with new forms of structure and consequent improvements in his design. The present limited range of aluminium alloy structural sections for marine use exists mainly due to the lack of demand for special shapes on the part of the designers, rather than to any inherent problem in manufacture.

2.1.5 Aluminium castings may be welded without loss of strength, provided the weld metal has a similar constitution to the casting.

2.1.6 Rivetting and bolting of aluminium alloy are acceptable and good methods of joining aluminium exist provided compatible rivet material is used.

2.1.7 Adhesive bonding, using epoxy and similar type adhesives, have been developed for bonding aluminium alloy to itself or other metals or non metals.
Sheer strengths, ranging from 1800 to 5500 p.s.i. at room temperatures, are offered.

2.2 What are the known detriments associated with the use of aluminium alloy for construction of fishing vessels?

2.2.1 The aluminium alloy has a Young's modulus of about 10,000,000 LBS/in^2 approximately only 1/3 of the value for mild steel.
This quality results in greater deflection under stress necessitating closer support by framing, either longitudinal or transverse, to reduce panel sizes and to increase resistance to buckling.

2.2.2 Fusion welding of marine aluminium alloys is possible, but because the metal oxidises very rapidly, oxygen must be excluded from the weld during the fusion process, hence the necessity for the Argon Arc equipment.
This involves specialised equipment and requires skilled welders.

2.2.3 Aluminium alloy has a high thermal conductivity rate resulting in the rapid spread of the heat of fusion welding.
This tends to increase the risk of plate buckling and necessitates special procedures to reduce the heat flow from the area of the weld.
Buckling may be reduced by a heating and quenching process.

2.2.4 Endurance under fluctuating loads can become an important factor in some aspects of ship design.
For example, in high speed small craft, the stiffened panels of shell plating within the forward bottom area subject to slamming pressures, are a potential area for the cracking of the weld-metal joining stiffeners and shell plating, due to fatigue.

2.2.5 High susceptibility to corrosion by galvanic action when in electrical contact with dissimilar metals in a salt atmosphere or if immersed in salt water.
This requires careful choice of metal other than the main aluminium alloy. It is imperative that such metals be separated from the alloy by a non conducting insert between the metals.

3. SOME PUBLISHED COMMENTS ON ALUMINIUM CONSTRUCTION OF FISHING BOATS.

3.1 Colin B. Jagger, in the paper entitled "Aluminium in Shipbuilding", presented this year to the Australian Branch of Royal Institution of Naval Architects, surveys, very thoroughly discusses the general application of aluminium alloys in the marine field.

In regard to fishing vessels, he says, "Fishing boat design must be firmly based upon purely commercial considerations and although owners are traditionally very conservative, more and more fleets are turning towards aluminium construction. Light planing hulls capable of lifting up to two tonnes of catch have been in service in the in-shore fishing industry for some years and a comprehensive economic study sponsored by the Aluminium Association of the U.S.A. several years ago demonstrated a substantial financial gain for aluminium trawlers engaged in a wide variety of fishing. The investigation showed that aluminium hulls made possible higher cargo/hull weight ratios with savings in fuel consumption, allowed larger vessels to be powered by the same unit or gave increased speed and greater range thus cutting down 'dead time' moving to the fields. There is negligible cleaning and maintenance in the fish holds in which no linings need to be provided".

3.2 In a paper by C. W. Leveau, entitled "Aluminium and It's Uses in Fishing Boats", presented to the third F.A.O. technical meeting on fishing boats, Göteborg, 1965, gives figures supporting most of the claims made in the introduction to this paper:-

"We have, then, the following economic advantages when using an aluminium fishing boat: (1) reduced maintenance, practically nil; (2) reduced fuel consumption per mile of travel due to lower weight; a 65-ft. (19.8-m) aluminium boat, for instance, weighs about 54,000 lb (24,494 kg), 24,000 lb (9,886 kg) less than the 78,000 lb (35,380 kg) of a steel boat with the same dimensions; (3) reduced draft; (4) constant weight of the hull, no water absorption as with a wooden hull; (5) possibly better manoeuverability due to less hull weight; (6) no dry or wet rot and no painting, caulking or puttying needed as with a wooden hull and no rust as with a steel hull; (7) greater speed with the same hp. due to less weight; (8) better sanitation, keeping the fish in good marketable condition".

Considering the Australian scene, he reports a fishing boat built of aluminium by Engineer and Marine Services, Fremantle, W. A. in 1960 for crayfishing. At the time of his paper, 1965, this boat was operated by the Australian Aluminium Co. He gives the following particulars:-

L - 64 ft. (15.5 m)
B - 17 ft. 6 in (5.2 m)
D - 8 ft. (2.4 m)
T - 4 ft. 6 in (1.4 m)
Power - one 230 hp Deutz engine with 2:1 reduction gear.
Speed - 11.3 knots.
Range - 500 - 600 miles.
Hull plating - 5/16 ins. (8 mm)
Deck plating - 3/16 ins. (4.7 mm)
Frame spacing - about 18 ins. (.457 m)

The owners report that this vessel has been very successful and that there is a complete absence of either pitting or

corrosion. The hull is left unpainted".

3.3 From the published information on the use of Aluminium Alloy for fishing boat construction, a saving in hull weight of the order of from .3 to .5 of the steel weight may be anticipated.

In the book "Aluminium Afloat" published by the Aluminium Company of America, figures are quoted from an investigation made by the Harbour Boat Building Company comparing aluminium against steel construction for a 110 ft. fishing vessel. The other particulars are as follows:-

Length overall.	110 ft.
Length on DWL.	108 ft.
Moulded beam.	26.5 ft.
Moulded depth.	14.0 ft.
Propulsion Diesel Engines.	800 HP.
Speed.	12 knot.
Range (total).	8,000 nautical miles.
Fuel consumption.	1,100 galls/day.
Total fish load capacities.	247 tons. (including brine coils)
Maximum fuel capacity.	32,000 galls.
Maximum fresh water capacity.	4,600 galls.

Weight Analysis comparing steel and aluminium vessels:

	Steel Tons.	Aluminium Tons.
Hull and deckhouse structures.	146	77.5
Outfitting.	50	50
Main engines and auxiliary machinery.	50	50
Sub-total weight:	246	177.5
Ballast allowance 7½%	18	14.5
Light-ship weight.	264	192
Displacement.	450	450
Deadweight.	186	258

The following cost summary is given:

	Steel.	Aluminium.
Labour @ $3 per hour.	164,673	165,168
Material.	147,742	223,560
Overhead at 75%	123,505	123,876
	435,920	512,604
Profit 10%	43,592	51,260
Insurance.	3,424	4,181
TOTAL:	$482,936	$568,045
Aluminium excess cost:	$85,109	
Equivalent to:	17.6% of steel.	

The Report states that due to a combination of increased earning capacity and an annual saving on painting and dry docking of $4,104 an annual saving of $32,454 could be expected.

On this basis, the extra cost of aluminium construction is wiped out in 2.6 years.

Reviewing the weight given above, there is a saving of 46.9% in the hull and deck house structure by using aluminium.

The overall saving in light-ship weight is 27.3%.

4. THE EFFECT OF WEIGHT SAVING UPON STABILITY.

4.1 The advantage of using aluminium alloy in construction of superstructures as a contribution to improved stability in ocean going passenger vessels, has long been established.

The saving in top weight in these vessels together with increase in beam enabled them to meet the stability requirements in the 1960 Convention 'For the safety of life at sea'.

The requirements for the safety of fishing vessels, which emerged as the result of the recommendation of the Stability Committee of Imco, some established fishing boats have found difficulty to meet these aspects of stability in some loading conditions, particularly the requirements associated with the maximum value of righting arms.

In these vessels, the maximum value of GZ tends to occur at about 25° and sometimes lower, that is the bare minimum value.

In such vessels, the initial GM may be satisfactory. However, when the vessel is fishing successfully among a plentiful supply of fish, there is a tendency to fill the holds and often the decks, and under these circumstances of overload, stability could be materially reduced to the danger point.

4.2 An examination of the hydrostatic particulars of a number of fishing vessels, reveals that in the loaded condition, the displacement is such that the corresponding value of KM is approaching its minimum with the increased displacement.

The KM curve has receeded in value, reducing the corresponding value of the GM. An examination of the cross curves drawn for a height of G approximating to that which would be established at this point of loading shows at the higher displacements, a general reduction in righting arms. The maximum GZ values are lower and occur at a smaller angle of heel, frequently less than the values required by the Imco recommendation, and approaching a level of increased risk.

The Imco values are set out as follows - see "Recommendation on Intact Stability of Fishing Vessels" page 5, section 5.1, Recommended Criteria:

5.1 The following criteria are recommended for fishing vessels:

a) The area under the righting lever curve (GZ curve) should not be less than 0.055 metre-radians (10.399 Ft. Deg.) up to $\theta = 30°$ angle of heel and not less than 0.09 metre-radians (16.918 Ft.Deg.) up to $\theta = 40°$ or the angle of flooding θ_f* if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40°, should not be less than 0.03 metre-radians (5.639 Ft.Deg).

b) The righting lever GZ should be at least 0.20m (.6562Ft.) at an angle of heel equal to or greater than 30°.

c) The maximum righting arm should occur at an angle of heel preferably exceeding 30° but not less than 25°.

d) The initial metacentric height GM_o should not be less than 0.35 m (1.1482ft.).

5. STABILITY GAIN BY CONVERTING STEEL TRAWLER TO ALUMINIUM CONSTRUCTION.

5.1 The original stock design provided for a vessel to be built as a combination trawler with the following particulars:-

Length overall.	56' 0"
Beam.	18' 3"
Depth amidships.	9' 5"
Mean draught.	7' 0"
Engine power.	230 S.H.P.
Speed estimated.	9 knots average.
Fuel capacity.	3,200 galls.imp.
Freshwater.	1,740 galls.imp.
Fish hold capacity.	1,350 cub.ft.
estimated at	30 tons fish.
Accommodation.	4 m.

Master's cabin adjacent to wheelhouse.

The vessel which was built by the owners, was modified in wheelhouse structure and an upper wheelhouse added. The engine room layout was modified, heavy fendering was added at deck level. The additions tended to increase the weight of the vessel and raise its C.G.

The estimated weight of steel in the vessel was of the order of 34 tons.

5.2 Assuming that the same vessel was designed to be constructed in aluminium in place of steel, a saving of 15 tons would be expected, calculated as approximately 45% of total steel.

An investigation of the anticipated effect upon the performance of the vessel by this substitution has been made under the following conditions.

The hull form is unchanged, the distribution of the weight of aluminium is such that its centre of gravity is at the same height as the steel structure.

The stores, fuel and fresh water capacity is the same and at the same C.G.

All other weights on board remain the same as the steel vessel.

From an inclining experiment on the steel vessel, a light ship weight and K.G. was obtained, namely - 61.88 tons with K.G. of 9.175 above the basic reference line.

The steel structure if replaced by aluminium, would make a saving of 15 tons assumed to be removed from the estimated K.G. of steel, namely 8.0 ft. above the reference line.

This resulted in a new light ship weight of 46.887 tons with K.G. = 9.551 ft. above reference line.

5.3 First consider the overall effect of this change upon the stability of the ship.

A number of conditions of loading are estimated both for the steel vessel and the aluminium vessel for comparison under identical distribution of fuel, water and stores etc. as well as fish caught.

These are as follows:-

1. Departure conditions:-
   Full fuel, water and stores.

2. Fishing conditions:-
   Half fuel, water, stores and half load of fish in hold (15 tons).

3. Arrival home:-
   10% fuel, no water or stores, with hold full of fish (30 tons).

4. Overload condition:-
   10% fuel, no water or stores, hold full of fish (30 tons), deck full of fish (7.807 tons).

The hydrostatic particulars and cross curves for an assumed K.G. of 9.0 ft. were computer calculated and are presented herewith.

The detail of weights and their K.G.'s are given and a set of curves drawn showing G.Z. values and W. x G.Z. values for each type of vessel in all four conditions.

In all cases, no adjustment frd. trim has been made. The stability characteristics being for direct comparison of the vessels under identical conditions, floating at levels generally parallel to the designed L.W.L.

The results of these investigations are summarised in the following table.

5.4 Analysis of Stability Results.

From the table shown, it can be seen that in all the conditions investigated, the maximum value of the righting arm - G.Z. was greater with aluminium than with steel.

The maximum values occur at higher angles of heel in all conditions.

The area under the G.Z. curve up to 30° is greater for aluminium than steel.

A calculation of the values of area under the curve between 30° and 40° was in all cases greater for the aluminium vessel than for steel.

In the overload conditions it is interesting to note that the area under the curve, G.Z., between 30° and 40° for steel ships is 5.368 Ft. degrees or 0.0286 Metre-radians, which is less than the value required by I.M.C.O., namely 5.639 ft. degrees or 0.03 metre-radians. The value for the aluminium vessel is 7.075 ft. degrees or 0.0376 metre-radians.

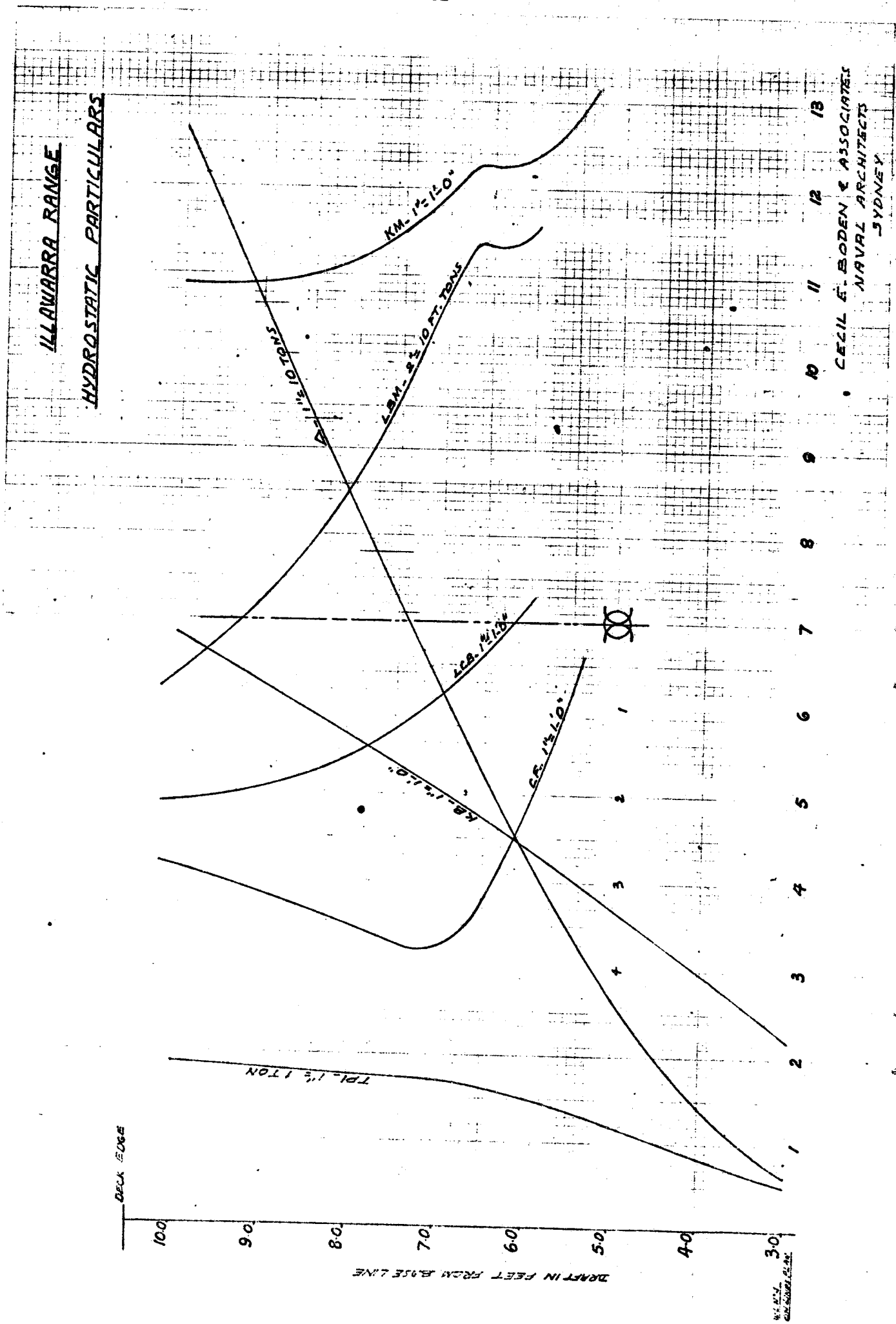
5.5 The overall result indicates that whereas the steel vessel has satisfactory values of maximum G.Z. and area under the G.Z. curve in normal loading conditions it becomes marginal should the skipper overload his ship. By comparison in the same situation, the aluminium vessel has an extra margin of safety.

5.6 It is interesting to note that the righting moments in condition 1 and 2, are smaller for aluminium than the steel vessel but show a progressive improvement with the greater loads of fish.

56' 0" COMBINATION TRAWLER.

COMPARISON OF STABILITY FOR STEEL AND ALUMINIUM CONSTRUCTION.

CONSTRUT-ION	CONDIT-ION	DISPLACE-MENT	K.M.	K.G.	G.M.	MAXIMUM VALUES			FREE-BOARD	AREA UNDER G.Z.CURVE TO 30°	
MATERIAL	NUMBER	TONS	FT.	FT.	FT.	θ	G.Z.	WxG.Z	FT.	FT.DEGREES	METRE RADIANS.
STEEL	1	79.69	11.30	8.475	2.825	27.5	1.072	85.60	2.67	20.253	0.1077
ALUMINIUM		64.728	11.78	8.594	3.291	30.5	1.175	77.00	3.37	21.651	0.1152
STEEL	2	85.777	11.13	8.377	2.753	27.0	1.020	88.00	2.37	19.778	0.1052
ALUMINIUM		70.777	11.58	8.46	3.120	30.0	1.180	83.60	3.08	21.819	0.1161
STEEL	3	93.040	11.02	8.41	2.61	27.0	.892	82.6	2.05	17.843	0.0949
ALUMINIUM		78.040	11.35	8.465	2.885	29.0	1.088	86.0	2.75	20.511	0.1091
STEEL	4	100.849	10.93	8.68	2.25	23.0	.652	65.5	1.68	13.851	0.0737
ALUMINIUM		85.849	11.12	8.80	2.32	26.0	.835	72.0	2.37	16.495	0.0877


ILLAWARRA RANGE
HYDROSTATIC PARTICULARS
CECIL G. BODEN & ASSOCIATES
NAVAL ARCHITECTS
SYDNEY
KM. 1"=1'-0"
Δ 1"=10 TONS
LBM. 1"=10 FT. TONS
LCB. 1"=1'-0"
KB. 1"=1'-0"
LCF. 1"=1'-0"
TPI. 1"=1 TON
DECK EDGE
DRAFT IN FEET FROM BASE LINE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
1
2
3
4
5
6
7
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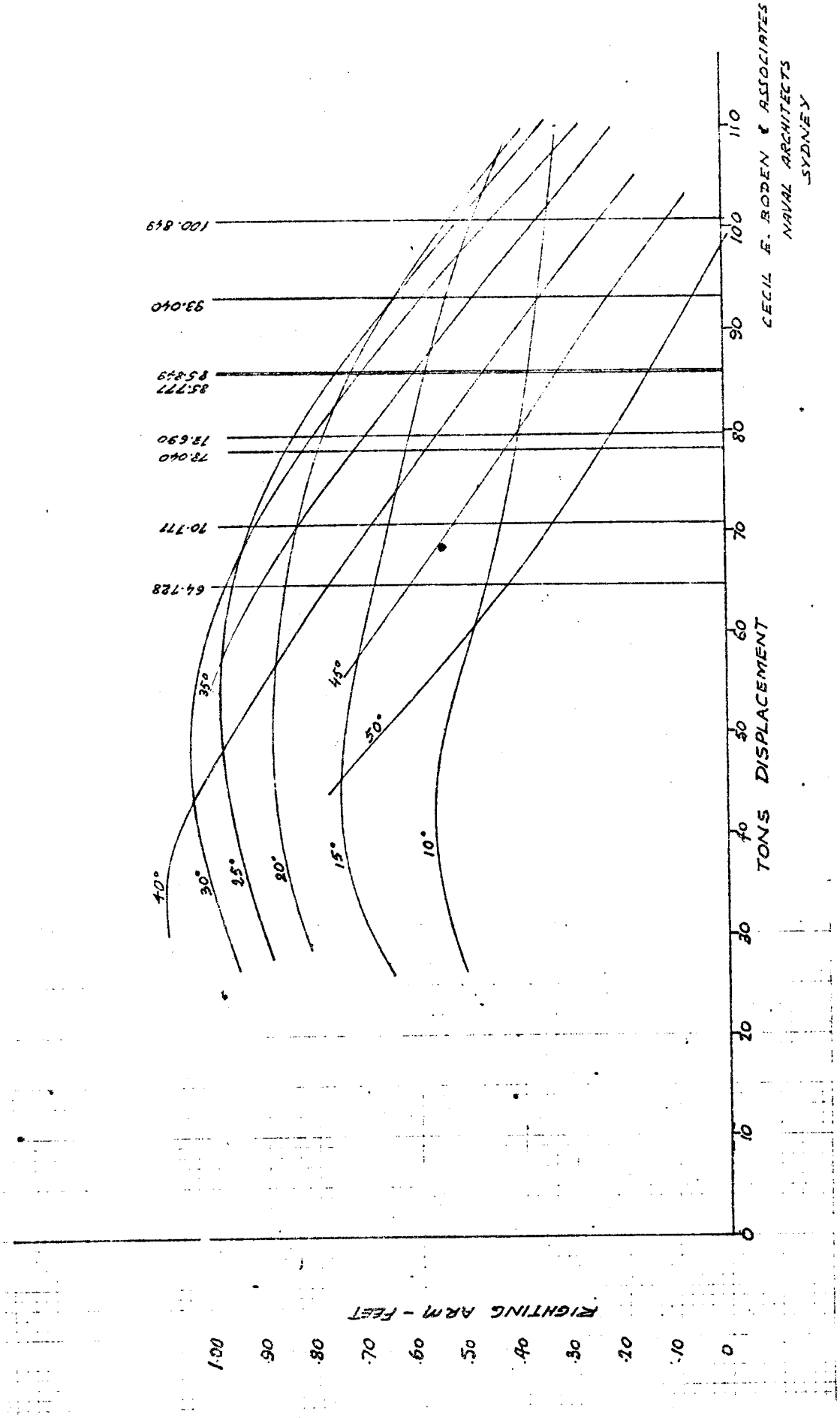
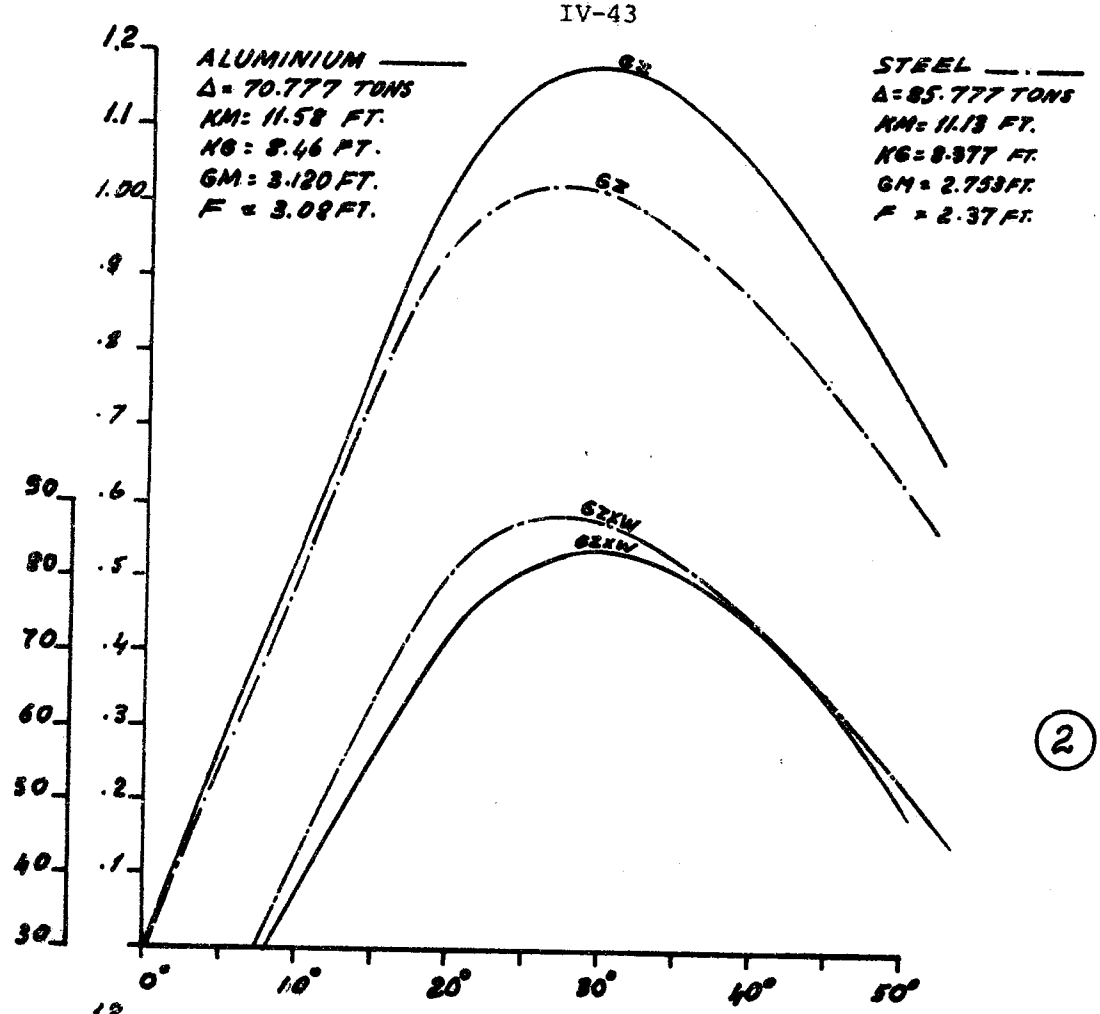
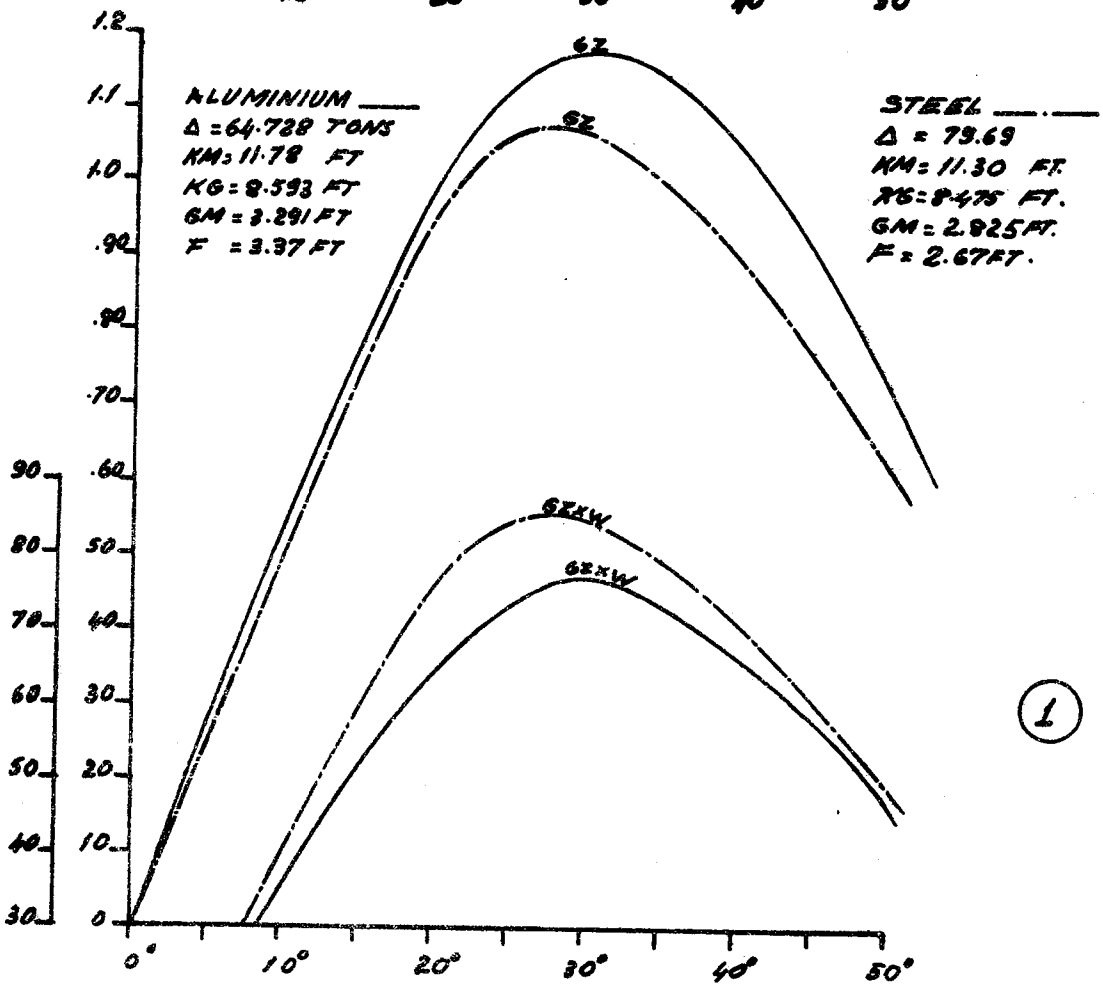
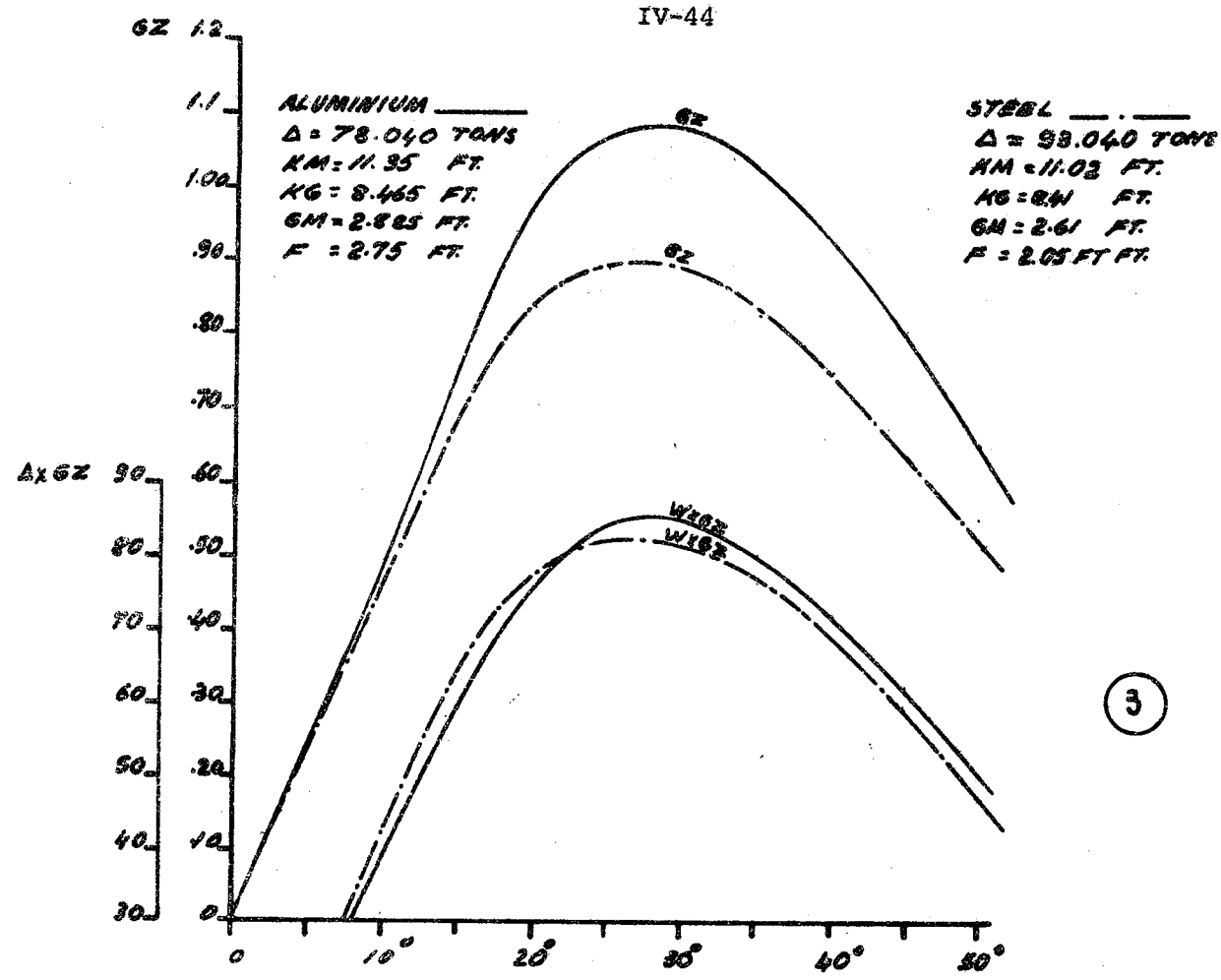
10
11
12
13

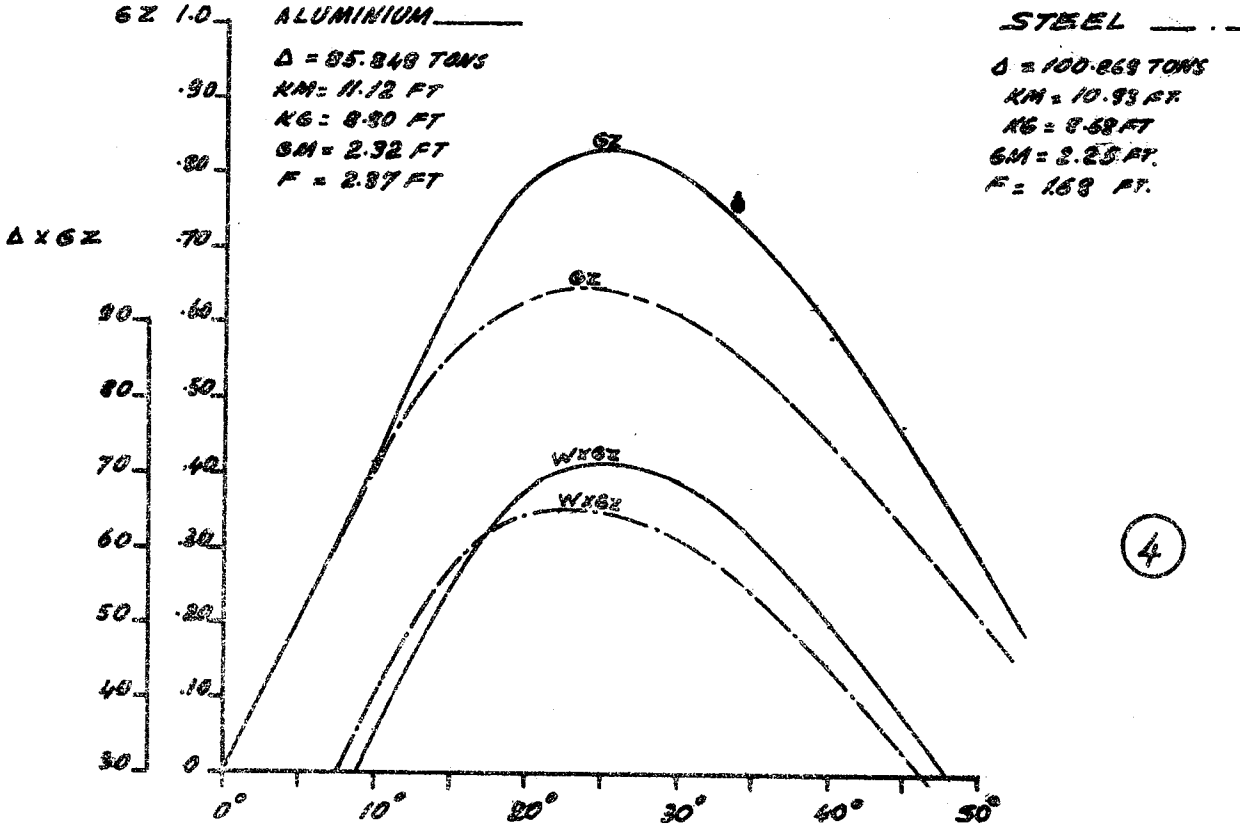

ILLAWARRA RANGE
CROSS CURVES
KG ASSUMED 9'-0 ABOVE BASE LINE
CECIL E. BODEN & ASSOCIATES
NAVAL ARCHITECTS
SYDNEY
100.849
93.040
85.777
85.849
78.690
78.040
70.777
64.728
40°
35°
30°
25°
20°
15°
45°
30°
10°
0
10
20
30
40
50
60
70
80
90
100
110
TONS DISPLACEMENT
RIGHTING ARM - FEET
.00
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00


ALUMINIUM
Δ = 70.777 TONS
KM = 11.58 FT.
KG = 8.46 FT.
GM = 3.120 FT.
F = 3.08 FT.
STEEL
Δ = 85.777 TONS
KM = 11.13 FT.
KG = 8.377 FT.
GM = 2.753 FT.
F = 2.37 FT.
GZ
GZ
GZKW
GZKW
1.2
1.1
1.00
.9
.8
.7
.6
.5
.4
.3
.2
.1
90
80
70
60
50
40
30
0°
10°
20°
30°
40°
50°
2


ALUMINIUM
Δ = 64.728 TONS
KM = 11.78 FT
KG = 8.593 FT
GM = 3.291 FT
F = 3.37 FT
STEEL
Δ = 79.69
KM = 11.30 FT.
KG = 8.475 FT.
GM = 2.825 FT.
F = 2.67 FT.
GZ
GZ
GZKW
GZKW
1.2
1.1
1.0
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
90
80
70
60
50
40
30
0°
10°
20°
30°
40°
50°
1


GZ
ALUMINIUM
Δ = 78.040 TONS
KM = 11.35 FT.
KG = 8.465 FT.
GM = 2.885 FT.
F = 2.75 FT.
STEEL
Δ = 93.040 TONS
KM = 11.02 FT.
KG = 8.41 FT.
GM = 2.61 FT.
F = 2.05 FT FT.
GZ
GZ
WxGZ
WxGZ
Δ x GZ
0
10°
20°
30°
40°
50°

3


GZ
ALUMINIUM
Δ = 85.848 TONS
KM = 11.12 FT
KG = 8.30 FT
GM = 2.32 FT
F = 2.37 FT
STEEL
Δ = 100.269 TONS
KM = 10.93 FT.
KG = 8.58 FT
GM = 2.25 FT.
F = 1.63 FT.
GZ
GZ
WxGZ
WxGZ
Δ x GZ
0°
10°
20°
30°
40°
50°

4

5.7 These results raise an interesting question. To what extent are authorities justified in expressing standards of stability in terms of righting arms (G.Z.) values and areas under G.Z. curves, without some reference to the actual righting moments which are effective.

6. PRESENT ACTION NECESSARY TO ENABLE AUSTRALIAN FISHING INDUSTRY TO OBTAIN THE BENEFITS OF THE WIDER USE OF ALUMINIUM CONSTRUCTION.

6.1 It should be recognised that it is a matter of national importance rather than a matter of private benefit, to encourage the use of aluminium construction for the construction of fishing vessels.

The establishment of the fishing industry to meet a national necessity is recognised by the expressed willingness of the Government to provide financial assistance by means of a bounty in some form or other.

Collaterally with this, it should be recognised that the development of the fishing fleet should be along lines of the greatest economical benefit to both the community and the fisherman. Methods of construction which ensure that these benefits are of a long term effect should have precedence.

6.2 The fuller development of the use of these aluminium materials, which have so much to offer the fishing industry, in cleanliness of operation, reduced maintenance cost, better performance at a lower cost and a contribution to added safety, should be encouraged by the establishment of a source of adequate technological assistance of a similar character to that provided by C.S.I.R.O.

6.3 Further, assistance should be given to the research into new and better techniques in the fabrication of aluminium alloys, in ship construction, in the production of more suitable types of extrusions for ship building uses, and in the provision of technical guidance to the smaller ship building yards who could be encouraged to build in this metal.

DEVELOPMENT OF A CLASS OF RIG SUPPLY, ANCHOR HANDLING & TOWING VESSEL

by

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Chatswood, N.S.W.

SUMMARY

The design development presented in this paper is a 190' twin screw rig supply boat of 4000 shp with two engines per shaft designed to supply an oil rig with about 1000 tons of cargo, tow it and handle its anchor system during rig shifts.

To illustrate the development of the 190' Sarah Class supply vessel, the designs originating from the author's firm since 1965, are briefly examined in this paper. The approach to small ship design and construction evolved and practised by the firm over the ten years preceding the involvement in supply vessels is explained. The development is discussed within the context of this way of working, whereby the consultant designs, technically and financially assesses equipment, scale lofts and provides detail plans for the builder and this approach is put forward as a main contributing factor to the successful development of this class of supply boat.

For the purpose of this paper, the vessels are named and given the abbreviated titles as follows:-

	Title
Austral & Tasman Tide *	Austral Class 1
Victoria & Sydney Tide *	Austral Class 2
Sedco Helen & Sedco Anne	Sedco Class
Lady Lorna & Laurie	Lorna Class
Lady Sara, Vilma, Rachel, Cynthia, Vera, Gay, Jane	Sarah Class
AOS LA10 new design	Super Sarah

* Tasman & Sydney Tides fitted with nozzles.

The following Table 1 gives the principal characteristics of the above vessels and Fig. 1 shows comparison of the curves of areas.

INTRODUCTION

Although separated in time and basic concept, all three prior designs contributed to the Sarah Class in some way and for that reason pertinent points of Austral, Lorna and Sedco designs are reviewed.

The design of the Sarah Class rig supply anchor handling and towing vessel came about from the point of view of the author's firm's participation, because a way had been established to construct small ships in Australia at an economical

TABLE 1

	Austral Class 1	Austral Class 2	Sedco Class	Lorna Class	Sarah Class	Super Sarah approx.
Length O.A.	166.4'	166.6'	200.4'	161.7'	190.0'	198.6'
Length Designed W.L.	160.0'	160.0'	186.5'	155.0'	180.0'	186.1'
Length B.P.	154.2'	154.2'	179.0'	148.8'	172.8'	178.7'
Beam Mld	38.00'	38.00'	38.94'	33.00'	42.00'	43.14'
Depth Mld	13.50'	14.00'	16.67'	13.50'	16.00'	18.01'
Designed Draft	10.00'	10.00'	13.50'	11.00'	13.00'	16.01'
Dispt. at Designed Draft	1054 tons	1054 tons	1528 tons	1153 tons	1729 tons	2202 tons
Max. Draft	11.50'	12.00'	14.33'	11.54'	14.37'	16.01'
Dispt. at Max. Draft	1258 tons	1358 tons	1680 tons	1218 tons	1986 tons	
Dwt/Dispt. Max. Draft	0.55	0.59	0.47	0.47	0.48	0.54
Cb Design Draft	0.607	0.607	0.552	0.717	0.623	0.600
Cp Design Draft	0.646	0.646	0.596	0.730	0.649	0.620
Cm Design Draft	0.940	0.940	0.926	0.982	0.951	0.968
½ angle of entrance at Designed LWL	31.8°	31.8°	25.0°	34.0°	24.5°	22.5°
L/B,/B/L (L=DWL)B/L	4.21/.238	4.21/.238	4.79/.209	4.70/.213	4.29/.233	4.31/.232
L/D	11.85	11.43	11.19	11.48	11.25	10.33
B/H	3.80/3.30	3.80/3.17	2.88/2.27	3.00/2.86	3.23/2.92	2.69
Dispt. ÷ $.01L^3$ Designed	257	257	236	310	269	342
Dispt. ÷ $.01L^3$ Maximum	314*	332*	259*	327*	341*	
Horsepower	2 x 850bhp		2 x 2150bhp	2 x 1600bhp	4 x 1000shp metric	6400shp metric
Speed	12.78 open propeller	11.98 nozzles	15.0	12.54	13.2	14.0
Bollard Pull		24.70 nozzles	40.0	43.7	53.0	80.0
Propeller Dia.	6.75"		7.5'C.P.	6.68'	8.37'	---
" Pitch	5.35'		---	6.68'	8.27'	---
" Area Ratio	.646		---	.601	.605	---
Nozzle Fitted	No	Yes	No	Yes	Yes	Yes

* These figures require adjusting for the greater length at the water line corresponding with the maximum displacement.

level compared with the traditional approach through the 'recognised' subsidised shipyards.

At the commencement of Australian Offshore activity in 1965 the author's firm had had ten years of experience as marine consultants in evolving a new approach in Australia to the design and construction of small ships whereby ships of acceptable quality could be built economically by low overhead engineering firms and small shipyards not equipped with drawing offices.

Encouraged by successful wartime production of small ships, through necessity by firms of limited or no shipbuilding background, the method was based on designing simplified developable hull forms and marrying to this, from the German optical marking off methods, the scale lofting of lines to produce all detail planwork for the builder.

The potential builder of small ships was no longer confined to the ranks of those firms with the expensive facility of a mould loft and the specially skilled loftsman, which had performed the ancient but antiquated art of laying out the lines of a vessel full size from the naval architects 10 or 20 station preliminary lines plan. In effect, the loftsmen were brought into the drawing office, where the fairing of the lines could be properly controlled as a design function.

Apart from the faired offsets allowing the hull to be precisely detailed, other areas of ship design could be detailed and advanced in the consultant's office ahead of the traditional procedure which waited upon the shipyard to be chosen and work progressed beyond the lofting stage. With the hull form accurately defined, detail complex pipe layouts could be laid out, shaft lines and their components, shafts, bearings, sterntubes detailed for sub-contractors pricing.

The hull structure was closely studied to establish simplicity in the basic geometry so that construction could be arranged and detailed in a manner suited for prefabrication and this generally entailed a form of longitudinal framing, backed by transverse webs. This procedure left the shipyard management free of design responsibilities and able to concentrate on developing efficiency in building techniques by creating the organisation to schedule the building procedures and by giving its full attention to directing the multitude of trades towards common purpose of building a ship.

To obtain the confidence of the smaller firms considered suitable for the small ship construction and encourage them to tender, it was necessary to provide more information for tendering than was the case with the larger traditional shipyard. The practice was evolved of providing, additional to the specification, the following five design plans defining the design:-

1. General Arrangement
2. Structural Plan (incorporating profile & decks, bulkheads & framing sections)
3. Propeller, Shaftline, Sterntube & Engine Arrangement
4. Schematic Pipework (incorporating valve & fitting lists)
5. Schematic Electrical

In some instances of special type vessels, additional planwork is provided to illustrate special duties. In supply boats an instance is the bulk handling system for pneumatic blowing of cement and barytes. This system can warrant an arrangement plan.

Technical design cannot be divorced from cost, so the procedure was developed during formation of a design to obtain prices for various items of equipment - main engines, auxiliaries, pumps, winches, valves, etc. - a constant testing of the market to measure value for money, availability and delivery in keeping with the required construction period. This information was made available to all tenderers overcoming the need for the smaller firms to provide additional staff to chase quotations. The enquiry by the designers ahead of the actual tendering also serves to overcome the time lag in obtaining quotes.

At the time of the first enquiries for supply boats, it had been well established that small ships could be built at prices considerably below those obtainable through the subsidised 'recognised' shipyards of that time (refer to Table .2.. Tender Prices). Consequently, we had no doubt that our procedure for small ship design and construction was the correct approach for obtaining economical building of supply boats.

Supply boat hulls were not that refined as to be unsuitable for design with a developable form. In fact, it could be submitted that the developable form was an improvement on some of the less attractive straight frame forms, both in appearance and economy. Whilst simplicity of hull form was the starting point, simplicity had to go on into hull construction, machinery choice and installation and in fact the word simplicity is a desirable aim of the whole concept of the design.

From the foregoing, it can be seen that this design and construction approach could require more time for design thinking in the office prior to tendering and construction, because it had in effect transferred to the office the detail/design skills previously relied upon from the craft tradesmen in the shipyard. This procedure was no more than had been developed in the European shipbuilding industry since pre-World War II and unhampered by the multitudinous British union system, was well and efficiently established in the immediate post war years.

To obtain the most satisfactory results from this unconventional approach to shipbuilding, the owner has to understand and support the procedure. The owner has to accept that this way of working places the design responsibility on the consultant and acknowledge that the construction is assured of success, proportionate to the time allowed to develop the initial design in detail, prior to tendering. The owner has to have confidence, not only in the consultant's design ability to interpret his technical and operational performance requirements into a practical working vessel, but also that the consultant has the ability to expand the design into detail planwork, providing economical construction in sympathy with shipyard's capabilities and to meet the construction programme.

Table 2

110' PEARL SHELL CARRIER - 'MERINDAH PEARL' - Tenders Received, June, 1966

Price Excludes Main Engines & Auxiliaries valued at $32,790

	Tender	Price Excluding Delivery	Quoted Delivery Time
Carrington Slipways	$180,735	$177,485	29 weeks
Steel Tank & Pipe	184,900	180,900	25-30 "
G.H. & J.A. Watson	193,100	189,100	39 "
Dillingham Shipyards	197,800	192,330	40 "
A.B. Rea & Co.	199,551	194,201	35 "
M.R. Hornibrook	202,576	192,294	43 "
Central Iron & Steel	250,800	243,470	50 "
Fairmile Construction, U.K.	252,500	233,750	70 "
Evans Deakin & Co.	539,750	527,750	66 "
Hakodate Docks Ltd., Japan		173,000	10 months

70' SINGLE SCREW TUG - A.D. 'YARRA' - Tenders Received

Carrington Slipways	98,764		26 weeks
A.B. Rea & Co.	119,252		28 "
Adelaide Ship Construction	169,260		45 "
Evans Deakin & Co.	191,700		32 "

83' TWIN SCREW TUG - 'MYALLA' - Tenders Received

Price Excludes Main Engines & Ancillary Equipment valued at $54,517

Carrington Slipways	215,848		39 "
A.B. Rea & Co.	230,188		39 "
Evans Deakin & Co.	238,490		34 "
Adelaide Ship Construction	306,530		54 "

Above are typical Tenders received in period 1963 - 1972 showing ability of unsubsidised yards to underquote 'recognised' shipyards.

The preceding material illustrates the background in which the author's firm undertook the first supply boat designs. The review of the three early designs is intended to show how experience gained in their design, detail planning, construction and performance contributed, in conjunction with the owner's supply boat operational experience, to the development of the Sarah Class.

The purpose of the paper is twofold:

Firstly, it is intended to show that the development of the Sarah Class has resulted in a practical vessel, capable of attending to its duties efficiently.

Secondly, that the way of working whereby a consultant, under instructions from the owner client, prepares the design drawings in the manner and detail previously set out and follows through with supplying the detail drawings to the successful tenderer, has the potential for a successful and economic solution to the construction of small ships.

AUSTRAL CLASS

The first supply boat enquiry was a commission from Esso Exploration to provide a design of a 153' x 36' x 12'-6" supply boat and produce specification and plans for tendering. This design was not proceeded with, since Esso had evidence as the year progressed that the industry's requirement for supply boats would be met without their participation. The design bore a strong resemblance to an American vessel of typical Gulf of Mexico design.

The Austral Class originated in an enquiry in December,1966 to A.B.Rea, Newcastle; Carrington Slipways, Newcastle and Central Iron & Steel, Bundaberg on behalf of Port Jackson & Manly Steamship Company who were desirous of being in a position of having vessels to charter to Esso for the Bass Strait operation. The American company, Tidewater, had also asked us for assistance in obtaining Australian-built vessels, so we suggested that the two companies might join forces. With the intention of expediting the project and minimising expense to the client, who had no commitment from Esso, the prospective builders were requested to tender on the 153' Esso design. During tendering the vessel grew to 160' x 38' x 13'-6" as a result of Esso's specification indicating their preference for a larger vessel.

After the contract was let with A.B.Rea in early February, 1967 and during the formation of Tidewater Port Jackson Marine in the early months of 1967, the vessel grew to 165' to be in keeping with Tidewater's then current design experience. Following completion of a 160' 1/12 scale faired lines plan and a 165' scale lines plan to Tidewater design, we were then instructed in April to produce our own 165' lines following disappointing trial results of a Canadian-built vessel for Tidewater. The lines were based on a single chine hull of developable form with the very slightest suspicion of a flare in the bow. Two different engine installations were under consideration during the design and tender stage, but Tidewater's influence provided the third and final choice at the time of con-

tract in the form of the then American near standard of two V-12 D398 Caterpillars at 2 x 865 bhp. However, some doubt was expressed by Tidewater that this power would achieve twelve knots. The owners were resigned to being approximately one knot short of Esso's desired thirteen knots, in the interests of economy of power and experience with the chosen installation. Calculations on our 165' lines encouraged us to believe that thirteen knots at design displacement and trial conditions was not a pipe dream.

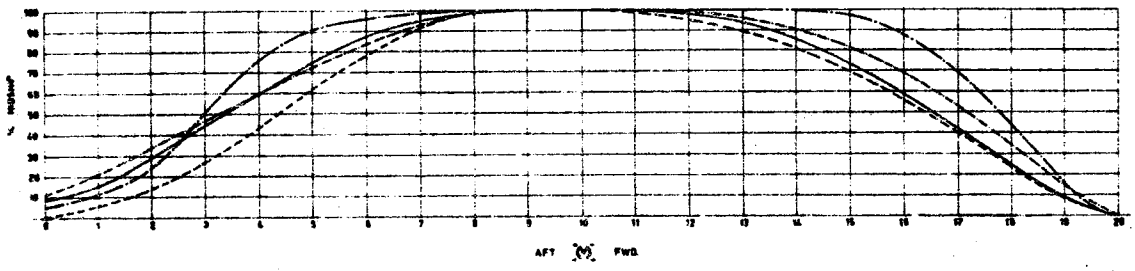
The project had not exactly moved off to a start in keeping with the procedure advocated in the Introduction. The cancelled and delayed planwork over the first three months of the contract caused strain in the drawing office and placed the builder's completion time in jeopardy. The organised production of detail plans comfortably ahead of construction, known from our other small ship experience to be desirable, by mid-year and mid-contract was beyond hope of achievement.

July 1967 saw the third vessel contracted at Central Iron & Steel, Bundaberg, but this vessel was given an extra 6" depth of hull to the main deck, as was the fourth vessel ordered from C.I.S. in November 1968.

As the contract progressed, offshore activity in Bass Strait and Sedco's experience with the 135G rig on the Australian coast revealed the poor situation in respect to tug availability for rig towing. Consequently, rig operators were hinting at the need for towing ability in the supply boats. This resulted in us being required to design nozzles of Wageningen 19A form for the second vessel from A.B.Rea and the fourth from C.I.S. The open water propellers were fitted with the tips cut back a fraction of an inch.

In the light of Tidewater's anticipated results, the Austral Tide's trial of May 2nd, 1968, producing 12.78 knots at 1068 tons was satisfying. The Sydney Tide with nozzles achieved 11.98 knots and a bollard pull of 24.7 tons.

Reference to the General Arrangement, Fig. 8 shows a layout with no great departure from the typical Gulf of Mexico supply boat. Table 1 gives the principal particulars of the Class and Fig. 1 the curve of areas.



LORNA CLASS
SEDCO CLASS
AUSTRAL CLASS
SARAH CLASS

FIG. NO.1 CURVES OF AREA

SEDCO CLASS

Sedco had experienced some tense moments with their 135G rig on the Australian coast through lack of ready availability of tugs and consequently, their insurance company insisted - for the projected drilling operation in the Joseph Bonaparte Gulf at the end of 1968 - that two 4000 hp supply boats, capable of towing the 135G rig be in attendance.

The Sedco marine superintendant presented us in September 1967 with Sedco's outline specification for a high powered oil rig supply vessel. The following precis of this specification illustrates the magnitude of the step forward from previous experience in supply boat design.

Outline Specification

Class ABS Registry Panama

Length O.A./BP	200'/165'
Beam O.A./Mld	40'/ 38'
Depth Mld	17'
Draft	13'-6"
Speed Max.	14 knots
Speed Cruising	12 knots

Capacities:-

Rig Fuel	200 tons
Ships Fuel	60
Drill Water	415
Potable Water	50
Deck Cargo	400
Bulk Cement	120

Winches:- Towing winch - two drum 2500' x 2" dia. wire Two Catheads - 40 ton pull. Heavy duty work winch 1000' x 2¼" wire - 125 ton pull

Propellers:- CPP 7'-6" dia. 3 blade for 2000 hp

Bow Thruster:- 350 hp 4 tons thrust electric

Main Engines:- 2 EMD/16-567 2000 hp each 3/1 red.

Generators:- GM-71 Series 2 x 125 kw 440 VAC 60 Hz 3-phase 1 x 320 kw 220 VDC for bow thrust. 1 x 20 kw AC 60 Hz 3-phase Harbour set.

Bridge Crane:- Electric 25 ton SWL transverse and longitudinal travel with load. Hoist 4' beyond stern. Hook to clear deck by 14'.

Resulting from experience with towing and supplying of their 135G rigs by vessels of European design, Sedco was aware that the design characteristics of the Gulf type boat had their limitations and with the emphasis on towing, the funnels had to be removed from the aft position. Furthermore, for better sea keeping in the more adverse sea conditions found beyond the Gulf of Mexico, coupled with increased power and speed potential, more freeboard was necessary forward. The new vessels were to have an extra deck in the forecastle.

The time schedule, taking design as well as construction into account, was already tight when the project was first discussed in mid-September 1967. Official instruction to proceed did not come till November 6, at which time it was acknowledged that the normal procedure of preparing design plans, specification and calling tenders would not obtain the two supply boats in the 13-14 months available. The design and detail planning had to proceed concurrently so that steel and machinery orders could be placed and this planwork and information had to be supplied to a builder or builders as it became available. The

builders had to be chosen without the more usual benefit of the estimating and quoting procedure. Such a procedure was not viewed enthusiastically, however, time allowed no alternative and our estimate of cost, developed over the three months from September, showed that the somewhat sophisticated supply boats contained a large amount of bought-in equipment, making up a considerable percentage of the ship cost. Furthermore, from the design calculations, hull steel weight was available with reasonable accuracy. Consequently, if the owner had control over the choice, price and delivery of bought-in machinery and equipment and at the same time the steel hull cost was based on an agreed fabricated steel cost, then the overall project had a reasonable measure of control. The estimated cost break up was machinery & equipment $740,000, hull $300,000 and outfitting $320,000.

Two firms were chosen as builders - Central Iron & Steel, Bundaberg and Carrington Slipways, Newcastle. On the 7th February, 1968 the letter/agreement setting out rates for hull construction, known and estimated bought-in equipment and targets for installation, became the basis of the contract which resulted in the Sedco Helen departing Newcastle for Darwin in February, 1969 and the Sedco Anne leaving from Bundaberg in August, 1969.

An interesting development in the lines of the Sedco Class was the departure from the developable form chine hull to incorporate a round bilge strake of constant radius amidships to forward, but decreasing towards the stern to a 5" solid round. Some flare was introduced into the bow sections above the DWL. The propellers and rudders were required to be well tucked under and forward of the stern to provide maximum protection from the ropes and cable that these vessels are required to work at the stern.

Since controllable pitch propellers and power chosen were adequate to provide the 40 ton bollard pull required and the owners preferred open propellers for manoeuvrability, no nozzles were fitted, however, we were required to design a rope guard frame as a measure of protection for the C.P. propeller. Subsequent events were to show that the loss or damage of a C.P.P. is to be preferred to loss of a ship through rope guards being torn out.

The General Arrangement, Fig. 7 shows the engine room forward under the accommodation. The bulk tank compartments moved aft of the engine room and in the centre of this compartment an unusual feature for a supply boat was installed, namely a moonpool and above this the ship was designed to carry a regular drilling rig. The provision of a flume tank and C.P.P. control compartments, aft of the bulk compartments, made for a complex structure and difficulties in maintaining continuity.

In Table 1, comparison of hull coefficients shows the marked departure from the fuller hull forms.

The technical results generally proved satisfactory,

however, they were marred by vibration found in service in light stern trim conditions when moored at the rig stern quarter to the sea. This was due to slamming in way of the flat stern sections and to eliminate the problem, it was necessary to re-shape the stern providing V sections. This modification was completed at the end of 1969 early 1970, just prior to the loss of the Sedco Helen, probably due to the rope guard being torn from the hull.

LORNA CLASS

About November 1968, P & O's new company, Australian Offshore Services (AOS), entered the scene in respect to Australian construction of supply boats with an order placed with Carrington Slipways for two vessels based on an early Dutch design. The specification from AOS defined the length, breadth and depth, but whereas the original design had encompassed two engines of about 800 hp each, the new construction was required to have two totalling 3200 hp.

Newly developed high performance V8 engines overcame the designer's space problem and allowed this massive power increase in the same dimensions, but in reality it proved to be a case of diverting the space problem into operation problems. I believe the original concept of these designs was a European equivalent of the American Gulf Boat, but in this case the box, under the probable influence of the European canal system, had little beam. We were given scope within the dimensions set to create basically developable lines, with circular bilge strake and adopt our normal form of construction, but whilst this allowed the builder to construct economically, the pregnant fullness of form could not be disguised and benefit of the power installed was not capable of being fully utilised.

It is interesting to compare the Lorna & Austral Classes in Table 1, since both these designs were fitted with the same diameter 6'-9" Wageningen 19A nozzles.

Whilst construction of these vessels provided no advancement in technical development, the operation was a useful exercise in the consultant-builder-owner relationship - in this particular instance, the consultant being employed by the shipyard.

SARAH CLASS

At the end of 1970, P.& O considered we had sufficient experience to be allowed more license in the design of a new supply boat under their guidance and in December we received their first instructions which were as per Table 3. This Table also shows in the second column the final design particulars.

Table 3

	Owner's Initial Requirements	Final Design
L.O.A.	172' to 180'	190'
DWL	165' max.	180'
Beam mld	42' to 43'	42'
Depth	up to 16'-6"	16'
Draft	13' max.	14.37'
Block coefficient	.62	.623
Midship coefficient	.90	.951
Prismatic	.68 approx.	.649
Lloyd's, Solas Developable all welded hull with round bilge		
Speed:	14.5 knots	13.2 knots
Pull:	40 tons	50 tons
Bow Thruster	Diesel driven	Electric
Cement	4000 cu.ft.	4500 cu.ft.
Air Compressors	2	2
Double Drum Winch Split Windlasses	200,000 lbs.	224,000 lbs.
Propellers in nozzles		
Liquid Cargo - Fuel	450 tons	497 tons
Deck Cargo	350 tons	570 tons
Main Engines	2 x 2000 hp @ 900 rpm 3:1 red.	4 x 1000 @ 720/3:22 & 4 x 1050 @ 750/3:22
Alternators	3 x 180 kw 415 VAC	2 x 200 kw + 1 x 60 kw later 2 x 250 kw + 1 x 99 kw

The initial specification for this vessel in December 1970 followed the previous AOS ship to a considerable degree, however, in March of the new year, operational experience and direction from AOS set principal factors on which the design was to be developed, namely, two engines per shaft and a cost not to exceed $1,325,000. At that time the other requirements still stood and the emphasis was still on speed rather than power. Open propellers were still a proposition on the bollard pull speed requirement of 40 tons and 14.5 knots.

The insistence on two engines per shaft followed the European sister company's (IOS) inclination and was considered a must by AOS, following machinery failures in the Lorna Class, placing these vessels off hire for long periods. Another consideration was the increasing concern in respect to economy with larger horsepowers involved in supply boats.

The 13' draft restriction was still with us as a result of Welshpool channel, however, with a potential 16'-6" of depth, the design had to be kept flexible for possible deeper loading. Scantlings definitely had to be determined for minimum freeboard and the lines aft also had to be thought of with the possibility of deeper draft and nozzles - in mid-1971 still undecided.

Experience with the straight sided, single chine TPJ vessels had shown the chine on these vessels to be vulnerable working against rigs and platforms and our immediate reaction was to

slope the sides. This had to be balanced against higher resulting prismatics and adverse resistance coefficients, which became increasingly unattractive when looking for lower level speed performance with one engine per shaft. Subsequently, the early chine damage on the TPJ vessels has been overcome through experience in handling. The round bilge, furthermore, is less vulnerable than a single chine and safety, from the flooding aspect, is appreciably improved by providing a double bottom throughout the machinery and non-tank spaces with a depth in excess of the bilge radius.

Fig. 5 illustrates the preliminary lines of the Sarah Class, the extent of conical development, the round bilge, simple geometry of no camber or sheer on the main deck and straight line camber, straight line sheer on forecastle deck. Following Sedco slamming experience, care was exercised to minimise the area of flat section over the propellers and rudders, whilst at the same time providing an overhanging stern shape to protect these vulnerable parts. After the towing ability gained precedence over speed once more and nozzles were decided upon, their associated fairing assisted in further breaking up the flat surfaces.

Study of the General Arrangement, Fig. 6 shows some marked changes in layout for a supply vessel.

This supply boat design was the first occasion on which we had sufficient freedom to give consideration to the arrangement in respect of the costly and difficult structural fire protection requirements. To minimise structural fire protection, out of consideration of noise and to reduce shaft line lengths, the engine room was moved aft and interchanged with the bulk cement compartment. This eliminated the costly insulation of the engine room deckhead. A combined deep tank and rig chain locker was interposed between the engine room and the bulk compartment as a further means of insulating the engine room from the accommodation.

To achieve a reasonable freeboard at the stem, and to avoid waste space through excessive tween deck height in the forecastle, the main deck was stepped up half a deck height, 4'-0", at the break of the forecastle. The overlapping structure of the scarphing of the two decks provides a strong base for the 100 ton towing and work winch and also the tank space for daily service fuel on the centreline and lubricating oils in the wings.

The aft end of the forecastle superstructure was continued aft in two wings, forming a recess for the winch, which, because of being on the raised foredeck 4'-0" above the main deck, has some measure of protection from the sea on the normally wet supply boat deck. At the aft end of the forecastle wings, small engine room casings lead from the engine room to the funnels, which are placed rather further aft than on some supply boats.

This was done to provide space so that lifeboats could be fitted between the funnels and the deckhouse, to minimise the arc of lost vision from the wheelhouse and to minimise structural fire protection. The small engine room casings were

not considered a serious handicap, since with the engine room being under an open unobstructed deck, it was possible to fit a flush hatch for removal of equipment and in the event of a major main engine failure, there is the minimum of impediment to cutting open of the main deck. The funnel-engine room casing area constitutes the most difficult section to lay out, since the air intakes, main and auxiliary exhausts and engine room access are all confined in the one restricted space.

The long forecastle contributes to the stability characteristics of the vessel, which are well illustrated by the two extracts from the Stability Book reproduced in Fig.No.2a and Fig. No.2b. The first extract gives the typical full load departure condition and the second the maximum deck load arrival condition.

With the mainmast mounted on the frame between the funnels in this aft position, there was still sufficient spacing for mast lights to allow the foremast to be placed on the wheelhouse top, instead of a flimsy and vulnerable mast on the stem head.

The accommodation was arranged to provide single berth cabins for four seamen, a technician and five officers. Passenger cabins for five and seven respectively were disposed forward of the crew accommodation on the raised foredeck. The toilet washplace was placed at the forward end of the vessel to insulate the accommodation from windlass and chain locker noise. Forward of the bulk compartment and below the raised foredeck, a lower foredeck of short length was laid out to provide for two refrigerated spaces, air conditioning machinery, stores and access to the bow thruster compartment. This lower foredeck had access by a stores trunk from the forecastle deck.

The design was developed over a relatively long period compared with previous supply boats, starting seriously in March 1971 and proceeding through to early September, before finance was approved for construction. This time allowed a thorough technical and cost review of the principal components of installation. It was also long enough to establish, before construction commenced, that the owner's requirements, to be comfortably obtained, needed a longer vessel. Since confined construction space in shipbuilding seriously affects efficient use of labour and is consequently very costly, it was considered a reasonable risk to increase the design WL by 15' to 180' without breaking the budget figure. This was nearly but not quite true, since Carrington Slipways estimate of the 30th September gave $1,387,500 for the first of two and $1,318,125 for the second. These prices, probably higher as much through equipment costs as extra length, became the basis of AOS's letter of intent to Carrington on the 14th October, 1971. Final contract price was of the order of $1.4 million without subsidy, which was not available, nor at that time required, by the 'unrecognised' Carrington Slipways, as is well established by reference to Table 4 . This Table represents a thorough pricing of a high powered tug supply vessel by an international operator.

With the engine arrangement of two engines per shaft decided upon, the initial thought was that controllable pitch propellers would provide the only satisfactory answer, particularly since it

CONDITION No. 2 ~ FULL LOAD DEPARTURE ~ "SARAH" CLASS

ITEM	WEIGHT TONS	K.G	VERT. MMT	LCG	LONG. MMT AFT	LONG. MMT FWD	FREE SURF.
LIGHT SHIP	929·64	15·15	14084·05	3·97		3686·68	
CREW & EFFECTS	200	25·0	50·0	47·0		94·0	
FOOD STORES	5·0	15·0	75·0	56·0		280·0	
ENG. ROOM STORE	3·0	4·0	12·0	-35·0	105·0		
No. 2 ℄ BALLAST	23·4	7·35	171·99	74·25		1737·45	
No 4 P+S. DRILL WATER	65·0	2·28	148·2	29·83		1938·95	
No 4 ℄ FRESH WATER	52·92	2·0	105·84	33·0		1746·36	210·89
No. 5 P+S. DRILL WATER.	90·12	11·52	1038·18	18·0		1622·16	
No. 6 P+S. LUBE OIL	5·74	18·0	103·32	5·0		28·7	2·0
No 6 ℄ DAILY SERVICE	7·27	18·0	130·86	18·0		130·86	28·61
No 7 ℄ FUEL	40·41	2·0	80·82	-9·0	363·69		
No 7 P+S. FUEL	76·76	2·17	166·57	-7·62	584·91		
No 8 ℄ CARGO OIL	108·35	7·95	861·38	-38·98	4223·48		
No 8 P+S. CARGO OIL	114·4	10·24	1171·46	-37·9	4335·76		
CEMENT ~ 80 lb/ ft³	120·0	12·0	1440·0	35·0		4200·0	
CEMENT	39·0	12·0	468·0	40·0		1560·0	
DECK CARGO	303·13	18·5	5607·9	-35·0	10609·55		
DISPLACEMENT =	1986·14	12·94	25715·57	-1·6	20122·39 3197·23	17025·16	241·5

TRIM CALCULATION

			AFT	FWD
1	DISPLACEMENT TONS Δ	1986·14		
2	CORRESPONDING DRAUGHT F.T.	14·37 A.B.		
3	L.C.B. ABOUT ~~20~~	-1·23		
4	L.C.G. ABOUT ~~200~~	-1·6		
5	M.C.T 1"	241·3		
6	TRIM (T) = (LCB-LCG)Δ / 12 MCT 1" FT.	0·2538	BY STERN.	
7	½ L.B.P.		90·0	90·0
8	L.C.F. ABOUT ~~20~~	-10·39		
9	DRAUGHT MARKS FROM PERPENDICULAR		-17·0	STEM
10	TRIM FACTOR (K)		62·61	100·39
11	DRAUGHT CORRECTION KT/L		0·0883	0·1416
12	CORRECTION FOR DESIGN TRIM		0·0365	0·0365
13	FINAL DRAUGHTS		14·4948	14·2649
			14'~6"	14'~3 1/8"

STABILITY CALCULATION

14	K.G.	12·94			
15	FREE SURFACE MOMENT	241·5			
16	FREE SURFACE CORR^{N}. = MMT/Δ	0·12			
17	K.G. CORRECTED = KG + CORR^{N}.	13·06	K.G. CORRECTED	13·06	20
18	K.MT.	20·32	KG. ASSUMED	10·0	21
19	G.MT. = KMT - K.G. CORRECTED.	7·26	GG1	3·06	22

RIGHTING LEVERS

θ	SIN θ	GG1 SIN θ	GZ	G1Z
15°	0·2588	0·7919	1·99	1·1981
30°	0·5	1·53	3·17	1·64
45°	0·7071	2·1637	4·276	2·1123
60°	0·866	2·65	4·463	1·813
75°	0·9659	2·9557	3·968	1·0123

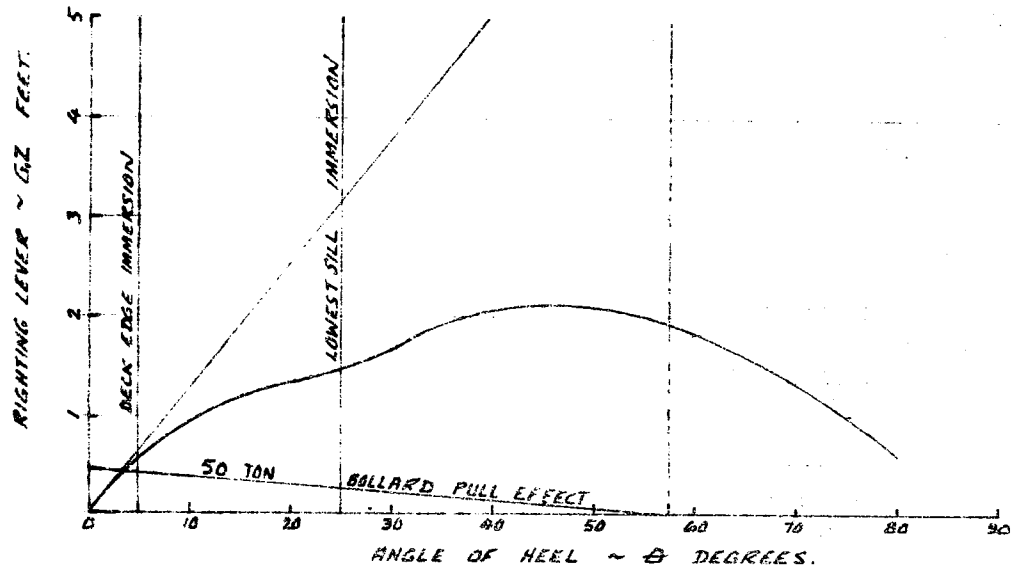


FIG. NO. 2a

"SARAH" CLASS

CONDITION No 7 ~ MAX DECK CARGO ARRIVAL

ITEM	WEIGHT TONS	KG	VERT MOMENT	LCG	LONG. MMT AFT	LONG. MMT FWD	FREE SURF.
LIGHT SHIP	929·64	15·15	14084·05	3·97		3686·68	
CREW & EFFECTS	2·0	25·0	50·0	47·0		94·0	
FOOD STORES	0·5	15·0	7·5	56·0		28·0	
ENGINE ROOM STORE	3·0	4·0	12·0	-35·0	105·0		
No. 4 P&S. DRILL WATER	65·0	2·28	148·2	29·83		1938·95	
No 4 ℄ FRESH WATER	5·3	0·2	1·06	33·00		174·9	210·89
No. 5 P&S. DRILL WATER	90·12	11·52	1038·18	18·0		1622·16	
No. 6 P&S. LUBE OIL	3·0	17·0	51·0	5·0		15·0	2·0
No 6 ℄ DAILY SERVICE	7·27	18·0	130·86	18·0		130·86	28·61
No 7 ℄		FREE	SURFACE	ONLY			153·28
No 1 F.P. BALLAST	9·0	15·06	135·54	86·06		774·54	
No 2 ℄ BALLAST	23·4	7·35	171·99	74·25		1737·45	
No 3. P&S. BALLAST.	102·0	6·56	669·12	58·0		5916·0	
DECK CARGO	573·88	19·5	11190·66	-35·0	20085·8		
DISPLACEMENT =	1814·11	15·26	27690·16	-2·24	20190·8	16118·54	394·78
					4072·26		

TRIM CALCULATION

			AFT	FWD.
1	DISPLACEMENT Δ TONS	1814·11		
2	CORRESPONDING DRAFT ~ FT.	13·455		
3	L.C.B. ABOUT ✕	-0·374		
4	L.C.G. ABOUT ✕	-2·24		
5	M.C.T. 1"	232·4		
6	TRIM (T) = (LCB-LCG)Δ / 12 MCT 1" ~ FT.	1·2138	BY STERN	
7	½ L.B.P.		90·0	90·0
8	L.C.F. ABOUT ✕	-10·865		
9	DRAFT MARKS FROM PERPENDICULARS.		-17·0	STEM
10	TRIM FACTOR (K)		62·135	100·865
11	DRAFT CORRECTION = KT/L.		0·413	0·6802
12	CORRECTION FOR DESIGN TRIM.		0·0365	0·0365
13	FINAL DRAFTS.		13·9105	12·8113
			13'-10 7/8"	12'-9 3/4"

STABILITY CALCULATION

14	K.G.	15·26			
15	FREE SURFACE MOMENT	394·78			
16	FREE SURFACE CORRECTION = MMT/Δ	0·22			
17	K.G. CORRECTED = K.G. + CORRECTION	15·48	K.G. CORRECTED	15·48	20
18	K.MT.	20·66	KG1 ASSUMED	10·0	21
19	G.MT. = K.MT. - K.G. CORRECTED	5·18	GG1	5·48	22

RIGHTING LEVERS

θ	SIN θ	G. G1 SIN θ	G Z	G1 Z
15°	0·2588	1·4182	2·15	0·7318
30°	0·5	2·74	3·5	0·76
45°	0·7071	3·8749	4·62	0·7451
60°	0·866	4·7457	4·73	-0·0157
75°	0·9659	5·2931	4·13	-1·1631

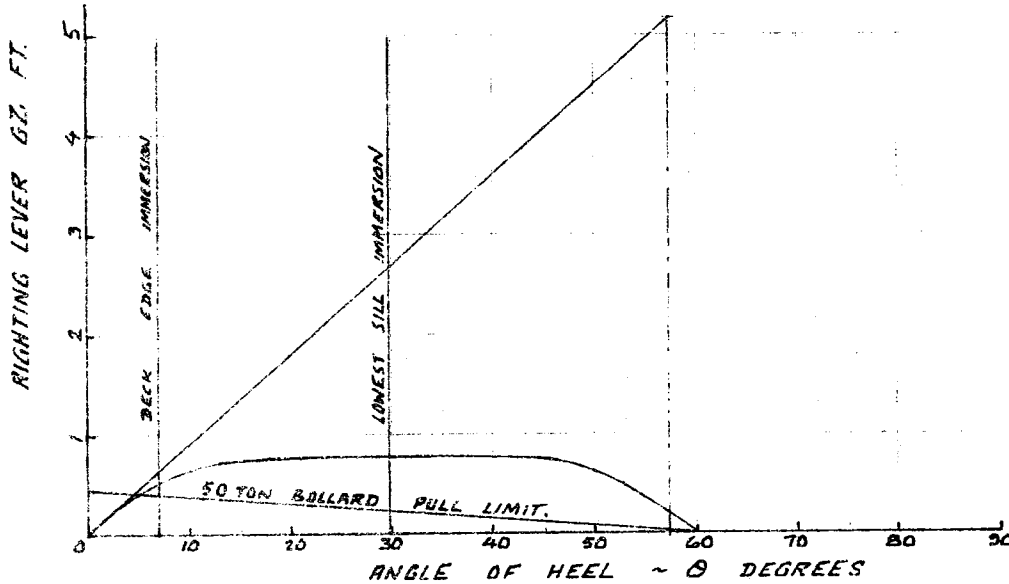


FIG. NO. 2b

Table 4

Offers on Two Tug Supply Vessel - 191' x 42' x 19'-8" - 4 x 1050 bhp @ 750 rpm with CPP

July, 1972

		Delivery	Price approx. in Pounds Stg.	Aust. Dollars @ Stg.1.00 = A$2.0617
1	Kramer & Booy N.V.	11/14 months	Stg.1,069,000	A$2,203,957.3
2	Verolme	12/14.5 "	1,062,000	2,189,525.4
3	Conoship	1 year	1,127,000	2,323,535.9
4	Rijn-Waal	10/1973 12/1973	1,128,000	2,325,597.6
5	SMS	For discussion	1,134,000	2,337,967.8
6	Nieuwe Noord Nederlandsche	9/1973 12/1973	1,089,000	2,245,191.3
7	Euroshipbuilding Association (Ysselwerf)	15 months	1,093,000	2,253,438.1
8	'Piet Hein' (Groep Exporthevording)	14/17 "	1,132,000	2,333,844.4
9	Schichau Unterweser A.G.	12/1973	1,237,000	2,550,322.9
10	Elsflether	8/1973 10/1973	967,000	1,993,663.9
11	Broedrene Lothe	1973	1,023,000	2,109,119.1
12	Falkenbergs Varv.	12/1973	1,056,000	2,177,155.2
13	Duro - Felguera	end 1973 mid 1974	1,002,000	2,065,823.4
14	Beliard Murdoch S.A.	4/1974 10/1974	1,053,000	2,170,970.1
15	* Hall Russell & Co. Ltd.		970,000 986,000	1,999,849 2,032,836.2

* This offer dated 9th August, 1972 included Government subsidy.

was a requirement that the vessel run in service on one engine per shaft. The adoption of CPPs was not considered with enthusiasm since it was becoming apparent that the area of operation would at sometime be the northwestern and northern areas of Australia, far distant from docks and engineering facilities.

Experience with CPPs on the Sedco vessels had not been reassuring in respect to reliability and the thought of going through the experience with the new vessels of docking on the Darwin sandbanks between tides as in the case of Sedco, did not appeal. The second factor that made an alternative solution imperative, was doubling of CPP prices between 1969 and 1971, largely due to customs duty imposed in the meantime - for 4000 hp, a lift from $80,000 to $160,000.

With the decision to emphasise towing ability, the cost of the fixed blade propeller solution lay in the 'unusable' power, when the towing propellers were free running. This cost situation did not look so unattractive after tenders for main machinery showed a range from a variable $353,000 down to a fixed $221,000 with the engine manufacturers at the lower level prepared to accept a penalty for the vessel going off hire due to engine failure. The lowest priced engines 4 x Daihatsu 8PSHTEM - 26EL totalling 4000 shp were chosen for the installation and at 720 rpm and 9.19 kg Cm^2 BMEP were the most conservatively rated of engines offered.

Mikado Propeller Works submitted several propeller design proposals and these as per the following Table 5 were considered.

Table 5

Design No.	Prop RPM	Dia x Pitch x P/D	Type	Bollard Pull/RPM	Free Running Speed
1	224	2550 x 2320 x .91	K4-60	53.7/225.7	12.9/230.7
2	286	2200 x 1990 x .904	K4-75	48.9/290.5	13.1/194.6
3	224	2550 x 2670 x 1.047	K4-60	49.5/196	14.0/230.7
4	286	2200 x 3230 x 1.014	K4-75	45.8/259	14.0/294.6
5	224	2550 x 2520 x .988	K4-60	51 /209	13.5/230.7
6	286	2200 x 2100 x .954	K4-75	47.5/275	13.5/294.6

The Design No. 5 was considered the most suitable compromise.

Reference to Fig. 4 shows that, in accordance with our resistance curve based on initial hull design coefficients, the Mikado propeller chosen by our estimation could be expected to produce about 13.2 knots four engines free running and just short of 11.2 one engine per shaft free running. The trial results for the first two vessels, Sarah and Vilma, were as per the following Table 6 and Fig.3.

Table 6

	Speed 4 Engines	Corres. RPM	Speed 2 Engines	Corres. RPM	Displacement Tons
Sarah	13.20	750/229.8	10.88	570/177	1680
Vilma	13.25	750/229.8	11.35	600/186	1520

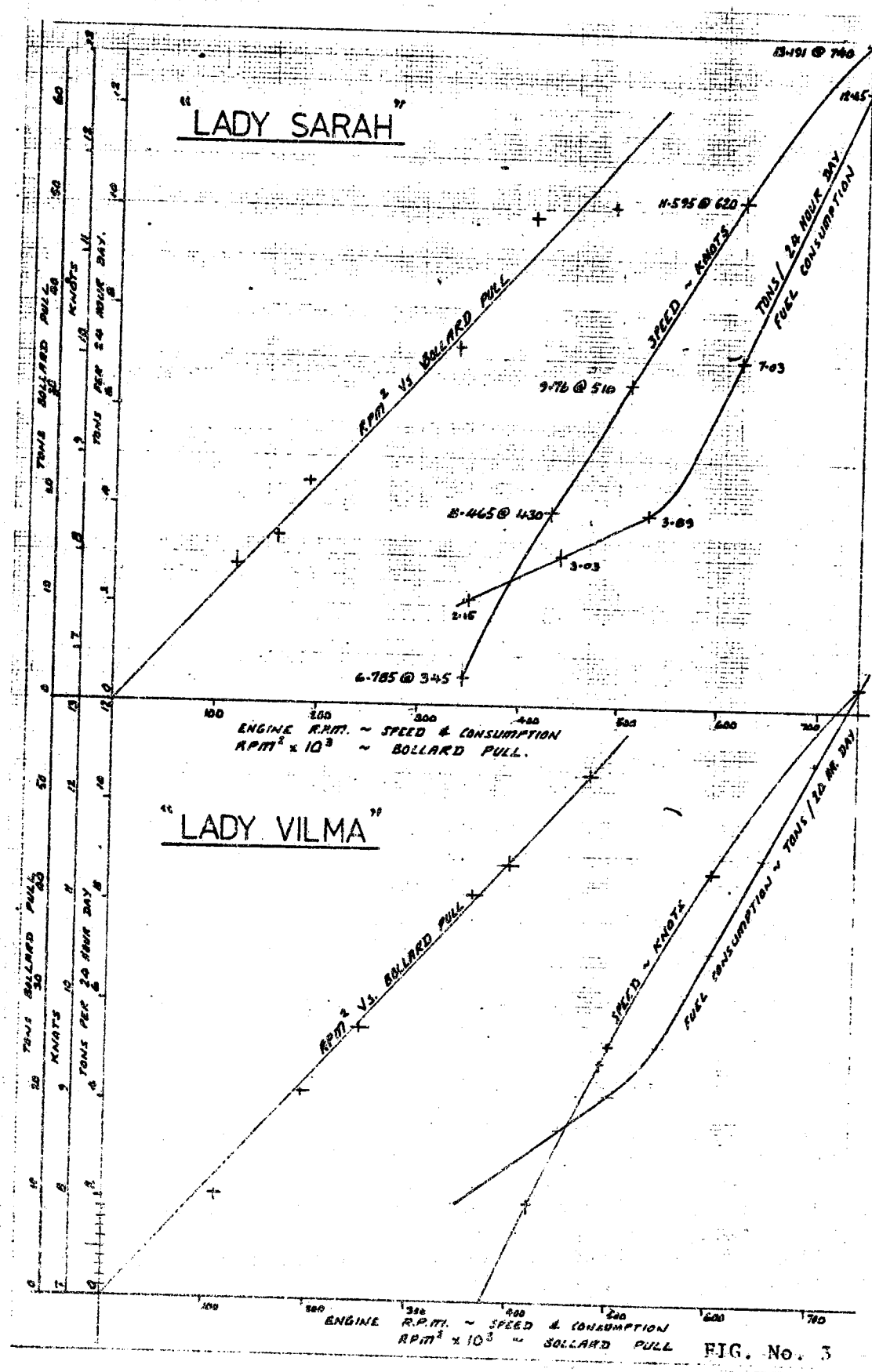


FIG. No. 3

FIG. NO. 3

On the Sarah trials, the rpm were restricted to 570 for the one engine per shaft trial as a precaution, since there was an anticipated critical speed at about 600 rpm and on this first trial the engine manufacturers were reluctant to push through the barred speed range too quickly.

Too much credit for the proximity of the trial result to the calculated cannot be placed on the soundness of the calculations. In the final drawing of the 1/12 scale lines plans, the hull coefficients changed from the preliminary design due to the draftsman being instructed to err on the higher side of the required displacement in the final lines to ensure weight margins were not compromised.

The resistance calculation for the final hull coefficients is illustrated by the higher curve in Fig. 4. Two pairs of propeller thrust curves are drawn in for Ka 4.60 propellers in Wageningen 19A nozzles on two assumptions of thrust deduction and these serve to show the possible spread of speed obtainable and a truer perspective of the value of resistance propeller calculations, when model data is not available. In an endeavour to assess the loss of speed performance through not having a CPP, a propeller calculation for a fixed blade speed propeller was carried out and the plot of this is also shown in Fig. 4. This propeller calculation was based on absorbing 90% of available engine power and shows a gain of about .3 of a knot. The small potential gain is not surprising in view of the steepness of the resistance curve and provides further thought as to the merit of CPP.

Apart from the weakness of data on appendage resistance, wake and thrust deduction factors for supply boats, it must also be acknowledged that commercial pressures do not always support accuracy in trial measurements. Despite the usual endeavour for a deep water trial, it is often found necessary, in order to see the northern marks off Newcastle through the BHP haze, to come in under 10 fathoms.

With engines at 10% overload, the Lady Sarah on bollard pull trial gave 50 tons pull and the Lady Vilma 53, as per Fig. 3 illustrating trial results.

The vessels were designed with a small bilge radius of 2'-0" with the intention that no bilge keel be fitted. However, the high GM of this type of vessel, with consequent quick roll of six or seven seconds, required for comfort the subsequent fitting of bilge keels 9" in depth, which was the limit to keep within line of side and bottom plating. These have been reported as moderately effective, but no quantitative results are available.

The four vessels following the first two had few changes. One change was an increase in main engine power from 1000 to 1050 per unit or to a total of 4200 metric shaft horsepower and the engine rpm, free running, went out from 740 to 750. The first vessel with the increased power, Lady Rachel, recorded 13.48 knots at 750 rpm with four engines free running and 11.6 knots at 600 rpm with one engine per shaft, however, the vessel was lightly loaded at 11'-9¼" mean draft on this trial.

Another change was the installation of a triple drum Beck & Jonas winch of 100 ton capacity in lieu of the two drum waterfall type. The triple drum winch with two working drums speeds up retrieving of rig anchor pendants, but with the trend to deeper water rig operations and longer pendants, it is difficult to obtain adequate capacity in the two work drums and find room for the winch, let alone pay for it at the current price of $240,000. The requirement to stow rig chain in the supply boat first came on the Australian scene with the Sarah Class and this presents further complication to the winch design, particularly 3 drum and the physical problem of installing on the vessel the mammoth size of the cable lifters involved in 2-3/4" - 3¼" cable. Experience with stowing rig chain in the first two vessels resulted in another change of the subsequent vessels - a strengthening up of the stiffening and plating in the No. 5 deep tanks utilised for this purpose.

Another change of more import was the increase in power of the bow thruster which took with it the auxiliary power units. The Sedco Class were equipped with 350 hp units and there was little confidence that the 240 hp units, specified for the Sarah and Vilma, would prove adequate for this design, which at full load displacement would be 306 tons heavier, however, this is where the budget drew the line. Subsequent vessels were fitted with Kamewa CPP bow thrusters of 300 hp and the two main auxiliary power units were increased from 200 kw to 250 kw.

As a result of the design modifications, the lightship increased from 930 tons of the Sarah to 990 tons on the Rachel amd with the Lady Gay equipped with a gantry, the lightship became 1025 tons, reducing the deadweight/displacement ratio from .53 to .48.

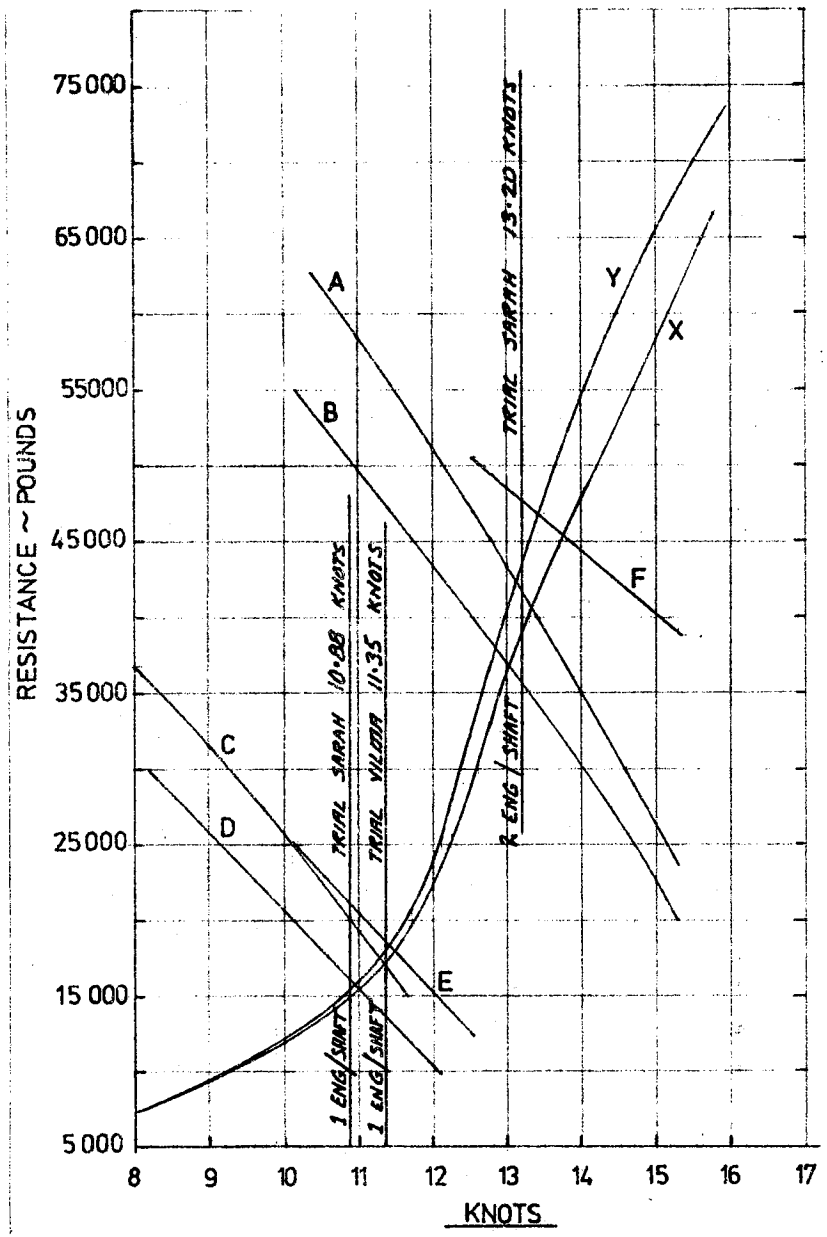
The last vessel of the Series, Lady Jane - at time of this writing, some weeks away from trials - has the further modification of being equipped with Daihatsu 6DSM-26 of 5200 metric shaft horsepower and we anticipate that trials will confirm the estimated 64 ton bollard pull of the Stone Marine propeller and speeds of 13.7 knots - 4 engines, 12 knots - 2 engines.

Following the first two, subsequent vessels became eligible for a subsidy. The pattern of price growth through the Class, disregarding subsidy, was as set out in Table 7.

Table 7

Vessel	Tendered Price	Contract Date	Delivery
1 & 2	$1.4 million	Oct.71	7.11.72/24. 2.73
3 & 4	#1.75 & $1.68 million	Oct.72-Jan.73	24. 8.73/26. 2.74
5 & 6	$2.2 & $2.4 million	Nov.73-Mar.74	17. 5.74/ 4.12.74
7	$2.8 million	June 74	

The above shows that in a period of two years five months, representing the time between the 1st and 6th vessels, these virtually identical vessels had increased in price in the order of 70%.



Curve x Resistance Curve based on prismatic coeff. .635

y Resistance Curve based on prismatic coeff. .649

Both these Curves are based on Roach's tug coefficients extended for grain size K_s = 0.25 according to Prandtl-Weitbrecht. Wetted surface of rudders, propeller brackets, nozzles added to bare hull. Appendage resistance taken as additional 10% on total resistance coefficient. Wind resistance allowance 3% on total resistance.

Curve A Propeller Thrust Curve K_a 4.60 rpm 740/3.22 w = .111, t = .138

B As for A, but t = .26

C Propeller Thrust Curve K_a 4.60 rpm 570/3.22 w = .111, t = .138

D As for C, but t = .30

E Propeller Thrust Curve K_a 4.60 rpm 600/3.22 w = .111, t = .30

F Propeller Thrust Curve, H/D varying for 90% power absorption - w = .111, t = .138

w = Taylor wake

t = Thrust reduction

FIG. NO. 4

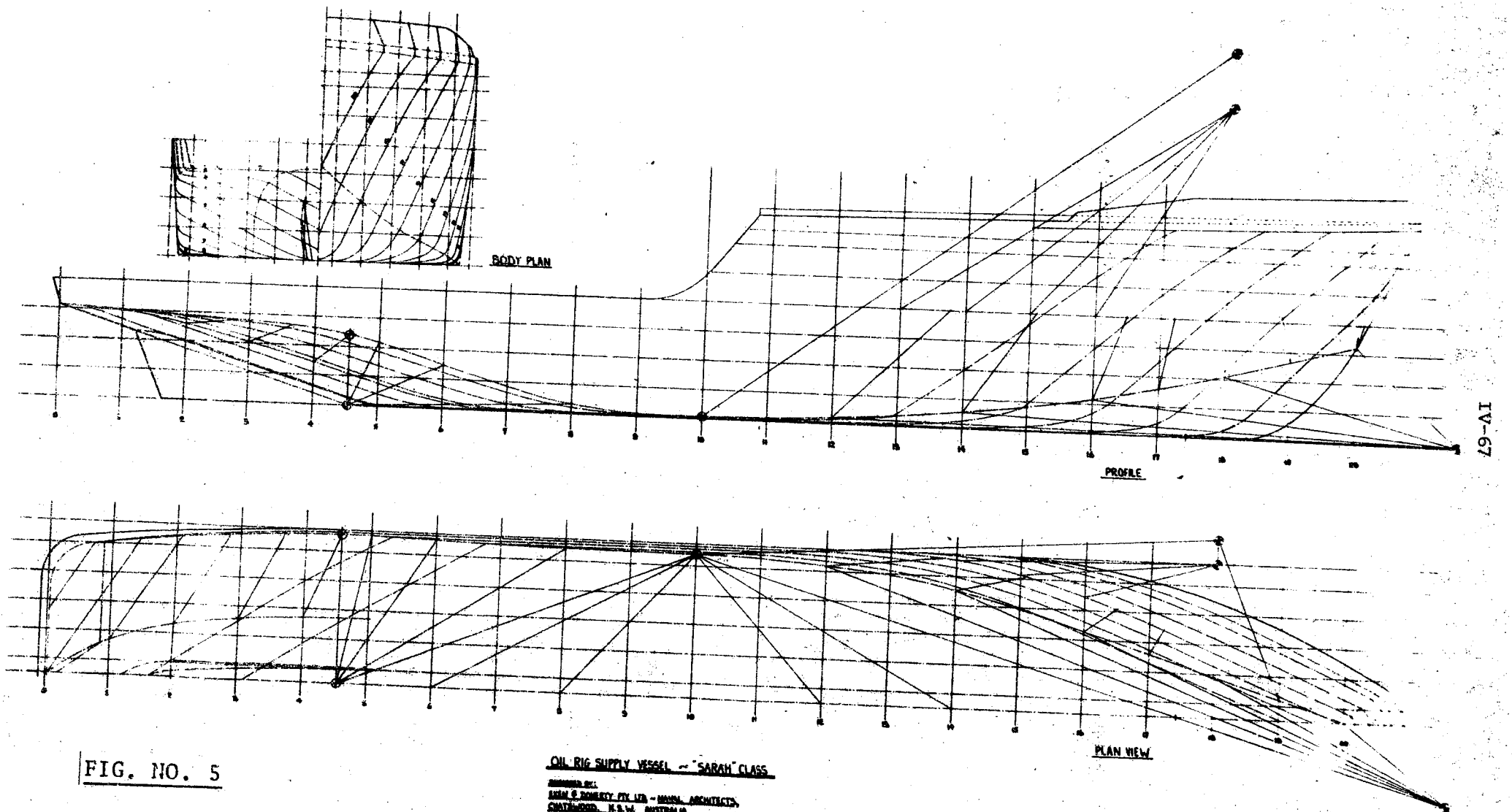


FIG. NO. 5

OIL RIG SUPPLY VESSEL – "SARAH" CLASS

DESIGNED BY:
ALAN B. ROBERTS PTY. LTD. – NAVAL ARCHITECTS,
CHATSWOOD, N.S.W. AUSTRALIA

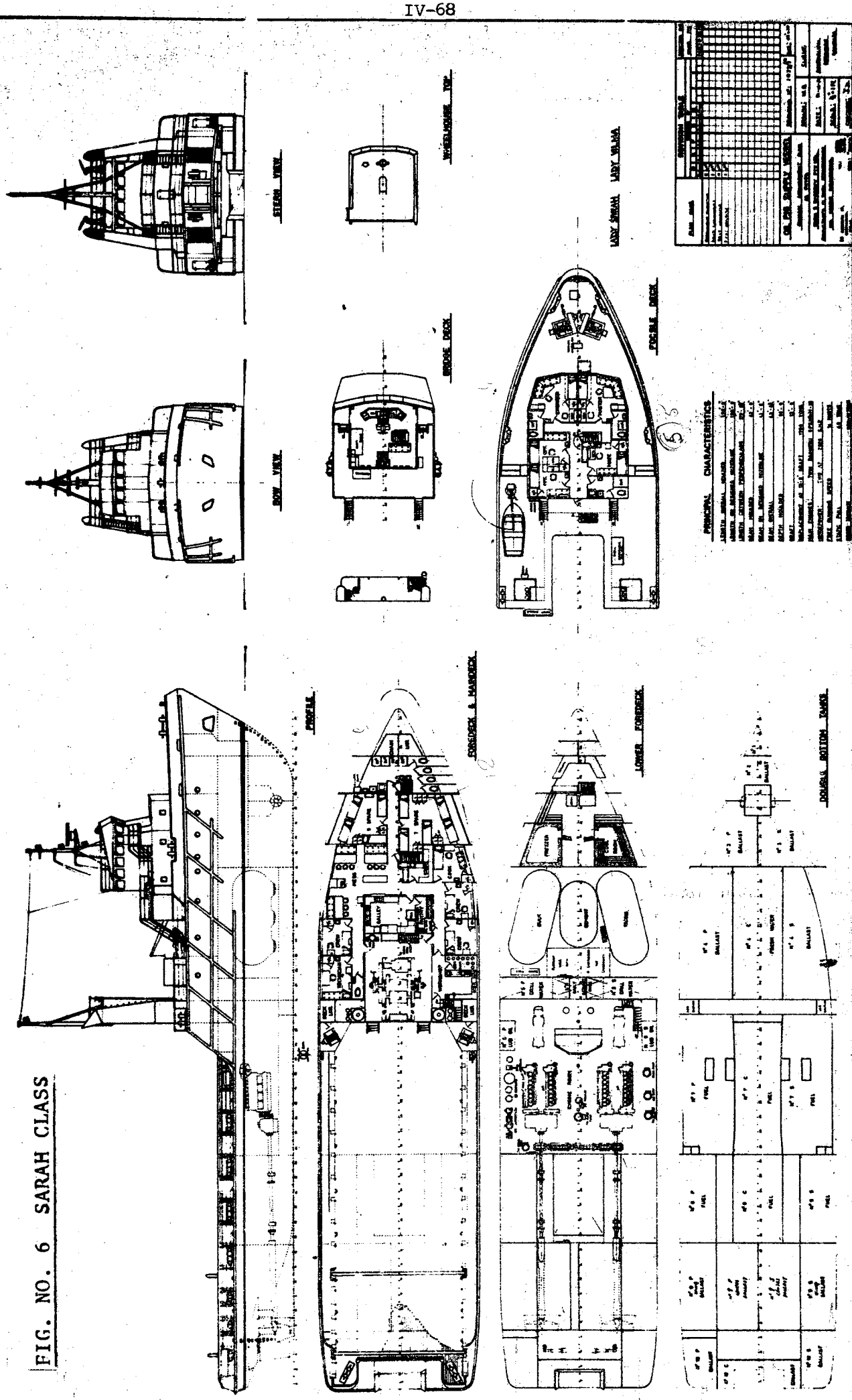


FIG. NO. 6 SARAH CLASS

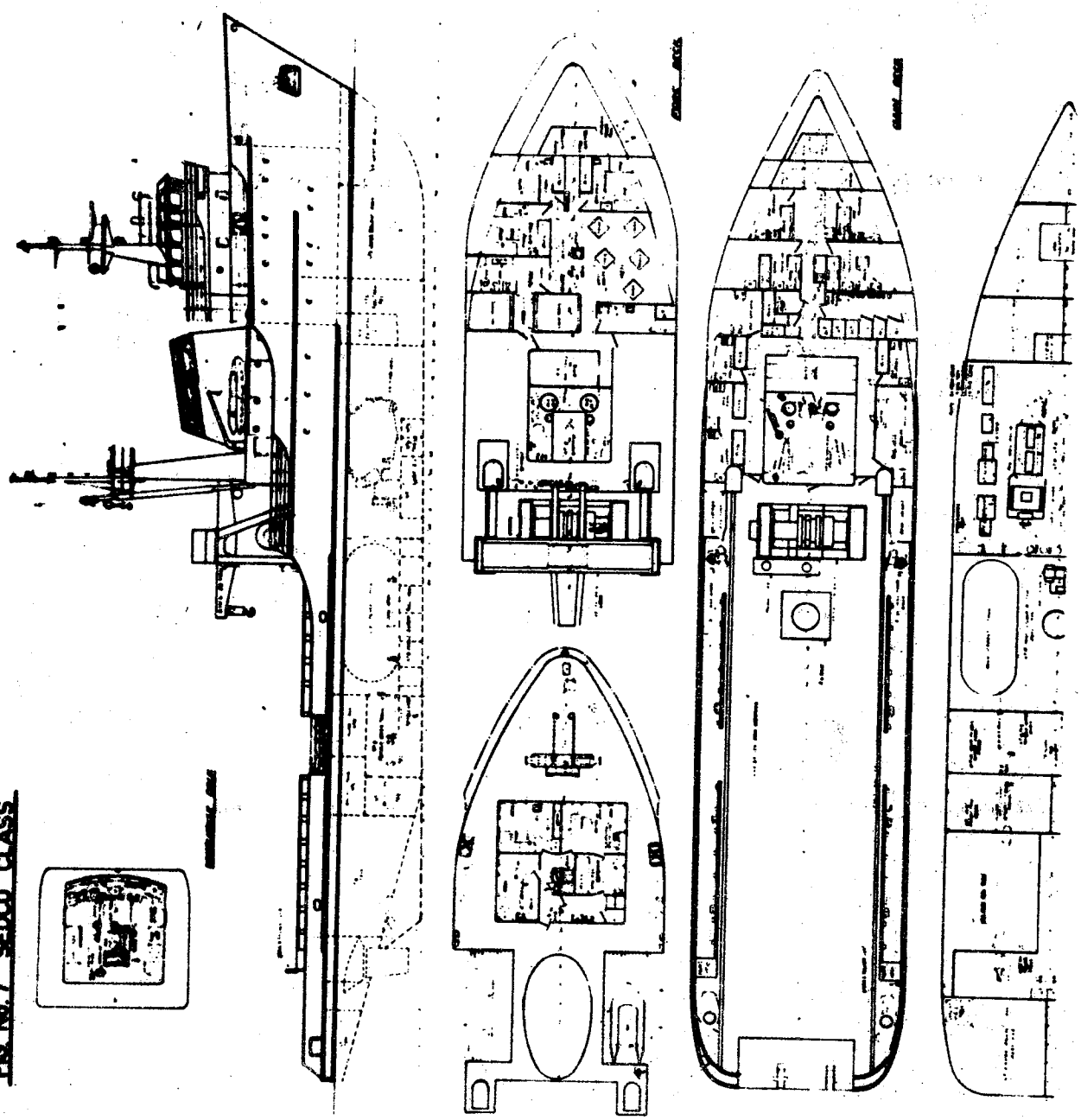


Fig. No.7 SEDCO CLASS

CONCLUSIONS

The Sarah Class has resulted in a rig supply, anchor handling, towing vessel of relatively large deadweight capacity, moderate speed capacity, but in the top half of the pull range for towing. Seaworthiness, manoeuvrability and comfort have been favourably commented on by operating personnel with reservations on the bow thruster for the first two vessels and the quick rolling. In new construction, a large enough bilge radius should be employed to allow a bilge keel of effective depth for roll damping within the side and bottom line of the hull and the bilge radius should be maintained to the stern to further reduce flat areas at the stern.

The vessels have shown no temperament in respect to trim and stability, with the maximum deck loads in the order of 550 tons and with maximum bulk materials made up of barytes.

The machinery concept of the two engines per shaft with fixed blade propellers has proved reliable and practical with the reservation that the existence of the critical close to the one engine per shaft running speed of 600 rpm inhibits the use of this mode of operation with fuller loads in other than fair weather.

The hull characteristics of the Super Sarah, Table 1, should also be studied as part of the Conclusion as they serve to illustrate some of the lessons learnt from the Sarah Class. The midship section with round bilge can be straight sided and fuller without fear of damage, to achieve a lower prismatic, down to .62 and this will favour the resistance and the two engine per shaft fixed propeller concept. The reduced resistance of the lower prismatic provides some balance to the maintaining of the high displacement length ratio necessary for reasonable deadweight/displacement and return on the additional power required by the duties of these vessels in anchor handling in still deeper waters.

The generous time in the design stage allowed the way of working, propounded in the Introduction, to work near its best in this project. Time had allowed sufficient design interpretations of the client's instructions to be viewed for mind changing, prior to the contract being let. The principal items of equipment were technically and financially assessed and chosen, allowing detail plans to be initiated prior to contract. All this information was available and communicated to the tenderer, who, following price acceptance, was able to move into the construction stage with minimum delay of drawings and proceed through construction of two vessels without any basic modification.

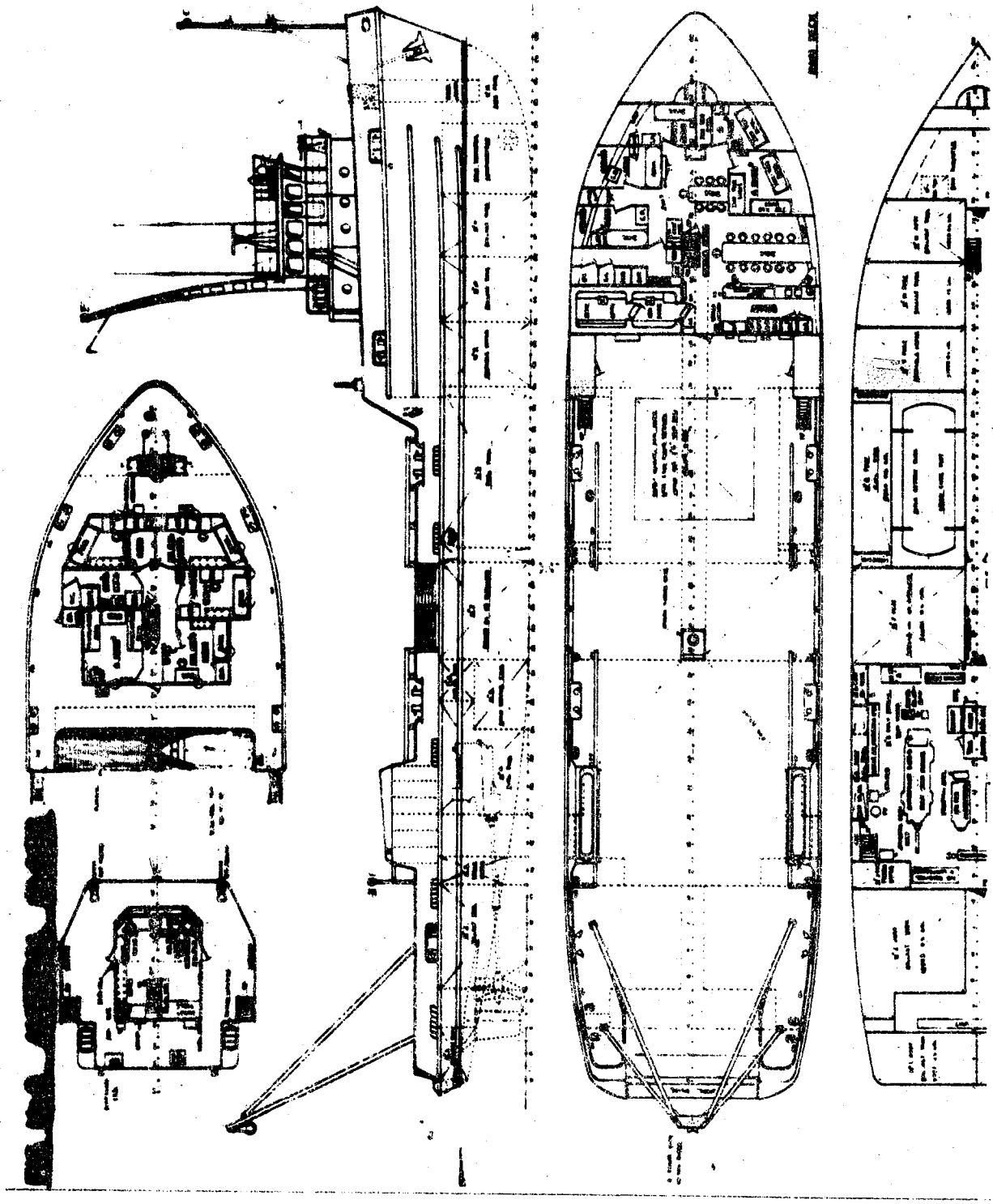
Despite the pre-planning, equipment cost surveying and sound co-operative working relationship that developed in this project between the owner, consultant and builder, Table 7 shows the cost of these vessels has increased beyond the rate of inflation, during a time when the builder was recognised by one government and assisted by another. The subsidy - now called bounty - is fighting a losing battle meeting the overheads of a 'registered' industry. Some further evidence that assistance in another form is desirable is the fact that in mid-1975 the only Australian

offer for the Super Sarah (particulars Table 1) after subsidy of 27.5%, fell short of overseas competition by 2.5%.

It appears time, in the interests of competitive pricing, that consultants seek efficient new 'unregistered' shipbuilders to recreate the pre-May 1972 era when the 'unrecognised' shipyards could underbid the 'recognised' at least by the amount of subsidy.

ACKNOWLEDGEMENTS

The Author wishes to acknowledge the assistance of present and past staff of Eken & Doherty and associates at AOS.



PERFORMANCE AND MANOEUVRABILITY OF MODERN TOWING VESSELS

by

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SUMMARY

A comparison between the performance and manoeuvrability of tugs fitted alternatively with fixed nozzles in association with a single rudder, fixed nozzle in association with a three shutter rudder system and a conventional steering nozzle reveals that the fixed nozzle shutter rudder system has advantages over the other two in respect of bollard pull at positive helm angle and in steering capability or directional thrust. It is further shown that the upgrading of obsolete tugs by means of fitting a fixed nozzle shutter rudder system is an economically viable proposition.

INTRODUCTION

It is easy to forget how comparitively recent is the introduction of the modern diesel tug. Almost twenty-five years ago our company designed its first diesel tug, and at that time such designs were something of a novelty. Now we have not only the conventional tug, single or twin screw, but a whole range of other tugs with fixed nozzles, shutter rudder systems, steering nozzles, steerable right-angle drive units and with cycloidal propeller drives. During this period developments in the design of tug propulsion systems and the requirements of tug owners have been very considerable. Twenty-five years ago the normal bollard pull for a dock tug was 10-15 tons, and standards of manoeuvrability were very low. With salvage tugs anything over 30 or 40 tons bollard pull was undreamt of and the use of fully vectorable tugs, either of the Tractor Tug type with S.R.A.D. units or the Water Tractor type with Voith Schneider propulsion units, was in its infancy.

A large number of owners, not fully appreciating the significance of the changing requirements, were caught by this rapid development. To them tugs of modest manoeuvrability and 20 tons bollard pull were formidable units and, in many parts of the world, a large number of effectively "obsolete" new tugs have been built during this period.

Many owners are now saddled with these vessels and are faced with the question of determining what real performance is required of tugs for a given service, and whether to build new tonnage and whether to scrap existing vessels or upgrade them to meet the changing service requirements. In any case, it is necessary to determine what are the optimum levels of bollard pull, tow rope pull and manoeuvrability on a line, manoeuvrability at close quarters and controllability during the picking up of wires and handling of large vessels.

Some owners, when confronted by the choices now available to them, have difficulty in assessing the relative merits of the various

alternatives, whether it be for the design of a new vessel or for a project to upgrade the performance of an existing vessel.

In the case of tugs and tug/supply vessels, it is today more or less mandatory to fit ducted propellers in order to achieve reasonable levels of performance per horsepower installed. Both these classes of vessels require very good manoeuvring and vectorable thrust capabilities, and careful thought must be given to the rudder systems used in conjunction with the propulsion ducts. For ahead steering these may be summarised as follows:

a) One central single rudder fitted at the trailing edge of a fixed nozzle.

b) A Burness Corlett TOWMASTER Shutter Rudder System, which involves three rudders fitted at the trailing edge of a fixed nozzle.

c) A steering nozzle.

d) A fully rotatable steerable right-angled drive ducted propeller, such as a Schottel or Duck-peller unit etc.

The intention of this paper is to consider the relative steering performance and manoeuvrability imparted to the vessel by systems (a) and (b), and to compare the directional thrust characteristics of systems (b) and (c). Additionally, comments are made regarding the performance improvement that can be achieved in up-dating an obsolete tug by the fitting of one of the above systems.

Fig. 1 shows outline aft end arrangements corresponding to systems (a), (b) and (c) above.

BASIS FOR COMPARISON

A particular ship has been taken as an example. This vessel has an arrangement similar to that shown in Fig. 1(b), with three shutter rudders of 2.85 ft. cord and 10 ft. span. These rudders are fitted across the exit of a nozzle of 10 ft. throat diameter, and the propeller is optimised for the bollard condition, being designed to absorb 2,000 horsepower. The vessel has a longitudinal ahead bollard pull of 33 tons.

For the comparison between directional thrust characteristics of systems (b) and (c) a single screw nozzle rudder tug has been selected. This vessel has a similar installed power, and equal draught aft to that of the fixed nozzle tug. Due to the smaller propeller diameter available within a given draught on a steering nozzle tug, the maximum ahead bollard pull is reduced to approximately 29 tons. Alternatives are considered where the bollard pull is made equivalent to that of the fixed nozzle tug by means of:

(i) Increasing the installed power.

(ii) Increasing the draught aft to accommodate a larger propeller.

COMPARISONS OF SYSTEMS (a) AND (b)

In order to compare the steering effects of the alternative rudder configurations lift coefficients for the differing aspect ratios of rudder have been calculated and, in Fig. 2, are shown plotted against:

(i) Rudder angle.

(ii) Angle of attack of water, including a 15° drift angle.

The rudders have been assumed to have an aerodynamic section similar to NACA 0015, namely with a 15% thickness of section. The three shutter rudders in system (b) have the same total area as the single rudder in system (a), and this determines the aspect ratios which have been used, namely 1.175 for the single rudder and 3.52 for each of the three shutter rudders.

In the case of the single rudder in system (a), it can be seen from Fig. 2 that at 5° helm angle for example it develops a lift coefficient of 0.13 and at 10° helm angle a lift coefficient of approximately 0.31. Its maximum lift coefficient is approximately 1.25, occuring at a rudder angle of approximately 37°. After this point massive flow separation occurs, the rudder stalls, and the lift coefficient drops sharply to a figure of approximately 1.0.

In the case of the individual shutter rudders for system (b) a greater steering effect is achieved at small helm angles. It will be seen from Fig. 2 that the lift coefficient of 0.31 is achieved at a helm angle of only 5°, and at 10° this rises to 0.63. The peak lift coefficient of 1.2 is reached at a lesser helm angle than that for the single rudder, occuring at approximately 22°. Thereafter the rudder stalls and the lift coefficient drops to 0.90.

When the three shutter rudders of system (b) are considered as working together however, a very different picture emerges. The presence of adjacent rudders suppresses stall on two of the three rudders. Each rudder has a suction face and a pressure face, and when a high helm angle is applied two of the suction faces are blanketted by pressure faces from the other rudders. In this case flow breakdown cannot occur, and only one of the three rudders can be in a stalled condition. This fact has been checked extensively with model flow tests and found to be so, up to very large rudder angles, approaching 50°.

A comparison can thus be drawn between the single rudder and the three shutter rudders of equal area for varying angles of helm, or more correctly, angle of inflow. Where all three shutter rudders are installed, it can be seen from Fig. 2 that this system effectively maintains the high steering force per degree of helm angle (i.e. lift - curve slope) of a high aspect ratio rudder to a helm angle which is considerably in excess of that available even on a low aspect ratio rudder. It further increases the lift available by a factor of up to 250%.

On the bollard, i.e. at Vs = 0, the rudder angle and inflow angle are the same, but when running free, the ship acquires an angle into the turn, or drift angle, of approximately 15° in the case of a tug.

Initially however, the drift angle is 0°, and this builds up after the rudder is applied.

Above the stall point of a single shutter rudder, the average lift coefficient for three rudders is obtained by averaging between two rudders operating on the section of the curve where the stalling is suppressed, and one on the stalled section. A simple arithmetical calculation enables the overall lifting effect of the three shutters at any angle to be obtained against the single equivalent rudder. Fig. 3 shows the ratio of the lift or steering effect available from three shutter rudders of a given total area when compared with one rudder of the same area. It will be seen that this ratio of lift is plotted against helm angles of between 0° and 45° in a bollard condition, and inflow angles of between 15° and 60° when running free.

In the case of the bollard condition scale on Fig. 3 this represents a true comparison between the systems (a) and (b) for a tug working on a wire, and is therefore a measure of the comparative steering capability when pulling hard at low speed. It can be seen that at very small angles of helm, the shutters produce nearly 2½ times as much lift as the single rudder of the same area. This ratio drops away at about 25-30° of helm to approximately 1½ times as great as the single rudder. Thereafter, because the single rudder is beginning to stall, the shutter system increases its relative efficiency, reaching twice as much effect as the single rudder at a helm angle of approximately 45°. This is a normal angle for the shutter rudders, although they are worked effectively up to 50-55°. In exceptional circumstances, where maximum turning effect is required for working in confined spaces, and where thrust while turning is not of prime importance, the rudder stops are set at a helm angle of 60°.

When a tug is running free, the rudders when put over initially, lift the stern of the vessel sideways without drift angle. This being so, the three shutter rudder system will give nearly 2½ times the steering effect of the single rudder. In other words a turn is initiated very quickly by comparison. However when an appreciable drift angle has been built up (e.g. 15°), the inflow angle to the rudder is reduced. At an angle of say, 25° for a single shutter, the effect of the movement of the ship will be to reduce this angle to only 10°. This rudder is therefore unstalled, and the ratio of lift of the three shutter system to the single rudder again becomes 2.5. In fact, examination of Fig. 3 shows that, assuming the 15° drift angle, the shutter system remains more than twice as effective as a single rudder up to angles of more than 30°. Thus it can be said that the steering effect is over twice as great as that of the single rudder over virtually the whole of the rudder operating range.

Effect of Aspect Ratio

Fig. 4 is of interest in that it shows the effect of aspect ratio on the lift curve slope. If a given rudder has a 10 ft. span and a 2 ft. cord, it has an aspect ratio of 5, and its lift slope curve is then just under 0.07. In other words its lift coefficient at 10° will be 0.7. If however the rudder has a span of 5 ft. and a cord of 4 ft., i.e. it is the same area but has an aspect ratio of 1.25, then it will only develop ten times 0.03 or 0.30 lift coefficient at 10° helm angle. Thus it will be seen that the first rudder produces over twice the lift of the second, although they are both the same area.

Fig. 5 is interesting as an exemplification of this. It should however be noted that the curves are theoretical and not strictly accurate, for instance the maximum coefficients are all shown as being the same, whereas in fact they will vary to some extent with aspect ratio.

COMPARISON OF DIRECTIONAL THRUST CHARACTERISTICS OF SYSTEMS (b) AND (c)

When a nozzle (or duct) is fitted around a propeller it increases thrust in two ways. Firstly it prevents cross-flow around the tips of the propeller blades, thus effectively increasing their aspect ratio. This fact does increase the propeller thrust to some extent. Secondly, the propeller induces a strong flow through the nozzle, leading to a circulation around it so that the nozzle itself develops lift and thus thrust, rather as does an aircraft wing. In a tug on the bollard the nozzle will develop as much as 40% of the total thrust.

With a fixed nozzle this system remains unchanged when helm angle is applied, the rudders changing the direction of the exit flow. With a steering nozzle however, a different situation exists. The nozzle rotates about the line of the propeller tips, and on the horizontal diameter the tip clearance increases rapidly with helm angle. The result of withdrawing the blades from the nozzle boundary layer is to reduce thrust, both because a cross flow then results and a weaker circulation around the nozzle is being induced. Thus the longitudinal thrust of a nozzle rudder drops markedly when helm is applied. The nozzle deflects the flow, but not to the same extent as the angle of the nozzle, and because the total thrust is dropping, so the transverse thrust, and hence steering capability is affected.

Fig. 6 shows a so-called vector diagram comparing directional thrust for systems (b) and (c), where, as defined above:

(b) Represents a three shutter rudder system as used on TOWMASTER Tugs.

(c) Represents a nozzle rudder system of equivalent design, assuming equal power and draught aft.

This diagram shows the pull available in any direction. For example, taking the ahead pull, by measuring from the origin to the extreme of the curve in an ahead direction, the pull available is 33 tons for the shutter rudder fixed nozzle, and 29 tons for the nozzle rudder. Astern there are proportionate differences, with system (b) giving a maximum astern thrust of 20.5 tons and system (c) a maximum of 17.5 tons.

Fig. 6 shows a thrust vector drawn from the origin to the points of maximum port thrust in the case of system (b) and the maximum starboard thrust in the case of system (c).

At this point, system (b) is producing a longitudinal thrust of 26.5 tons and a transverse thrust component of approximately 14 tons. At the equivalent point on the curve for system (c) the nozzle rudder tug is producing an ahead thrust component of 18.5 tons and an athwartships component of 10.5 tons.

Although it is not possible to show the relative helm angles on this diagram, it should be noted that these points of maximum athwartships component of thrust occur at approximately 40° of helm in the case of system (b) and 30° in the case of system (c).

As explained above, these comparisons are made on the basis of equal power and equal draught aft. In the event that a greater installed power was provided in the nozzle rudder tug, so as to give the same bollard pull as for system (a), then, at the point of maximum athwartships thrust, the longitudinal pull would become approximately 21 tons and the transverse component would become 12.5 tons. Thus it will be seen that in this case, the ahead thrust component of system (c) is approximately 80% that of system (b), and the maximum transverse thrust component of system (c) is approximately 90% of system (b).

In the case of equal power and equal propeller diameter, i.e. with a deeper draught aft in the case of system (c), there will be an equal bollard pull at 0° helm angle. It can be shown however that both longitudinal and athwartships components of thrust fall off with application of helm, in the same proportion as that given above for the case of increased power and equal draught.

It can be seen from the above that on all counts, but especially in the case of equal power and equal draught, the nozzle rudder is inferior in respect of both longitudinal and transverse thrust components at positive helm angles to the TOWMASTER shutter rudder system.

UPGRADING OF OBSELESCENT TUGS

There are a considerable number of very good tugs in service today, which are capable of many years of useful life, but, with the increasing size of ships, are now outmoded, particularly in terms of towing capability and of manoeuvrability and control.

Many of these vessels were built with open propellers, rather crude steering arrangements, and in some cases even with direct drive engines onto limited diameter propellers.

Many owners will consider the possibility of upgrading the performance of such vessels as a viable economic alternative to scrapping them and building new tonnage. A comparatively simple and inexpensive method of upgrading is to fit a fixed nozzle and three shutter rudder system. This can often be done without major structural modifications to the basic hull, and certainly without touching the propulsion machinery or shafting. Due to the low steering torque requirement of the shutter rudders, it is also usually not necessary to renew the steering gear, despite the higher thrust.

It is instructive to consider two hypothetical tugs of, say, 2,000 horsepower, 100 ft. overall length, and with different types of propulsion. These tugs will be designated X and Y as follows:

X - This tug is fitted with an open propeller and has a direct drive diesel, turning the propeller at 330 RPM.

Y - This tug has an open propeller driven by a geared diesel drive, with a propeller sized in accordance with normal practice, i.e. to optimise the bollard pull.

Two alternative methods of upgrading the performance of each of these tugs is considered, as follows:

X_1 - This represents tug X, rebuilt with a reduction gearbox fitted, and a fixed nozzle and shutter rudder installation in conjunction with an optimised diameter propeller.

X_2 - As an alternative, tug X rebuilt in the same manner as X_1 above, but with a nozzle rudder in place of the fixed nozzle.

Y_1 - This represents tug Y modified by the fitting of a fixed nozzle and shutter rudder installation, in conjunction with a new and optimised diameter propeller, but without change to the engine, gearbox or shafting.

Y_2 - This represents tug Y with a nozzle rudder fitted in the existing stern aperture.

Considerable improvements in both performance and manoeuvring capabilities may be expected by means of such conversion, and in terms of available working capability, immediately elevates such a tug to a level which can cope with a great deal of the most demanding modern work.

The improvements that could be expected from the conversions outlined above are summarised, in relative terms, in Table 1.

Such conversions are not academic. They are becoming increasingly popular with owners who have built fine ships, overtaken shortly after construction by the tide of events. In this context, the recent conversion from open propeller to a fixed nozzle shutter rudder system of the tug ABEILLE 15, owned by Les Abeilles of Le Havre, is of particular interest. This vessel was built by Messrs. Cook, Welton and Gemmell, being subsequently re-engined with a Nohab Polar 9 cyclinder diesel engine, rated at 2475 metric B.H.P. at 335 RPM.

This installation was direct drive with a 2510 mm (8.25 ft.) diameter propeller and a fixed rudder post with flat plate rudder. The steering gear was of 9.15 ton/metres torque capacity.

ABEILLE 15 had been a very successful tug, but was clearly underpowered for the work she was called upon to carry out. Additionally, her speed needed improving and her manoeuvrability was not outstanding. Her principal dimensions are:

Length O.A.	42.00 m (137.79 ft.)
Length W.L.	38.12 m (125.07 ft.)
Breadth	9.76 m (32.02 ft.)
Depth	4.42 m (14.50 ft.)
Draught Aft	4.71 m (15.45 ft.)

The conversion was made without altering the stern tube boss position, using the same steering gear and main engine, and with no alterations to the hull itself.

The conversion basically involved the addition of a fixed nozzle and three shutter rudder assembly, a new propeller and a reduction gearbox.

The main engine now drives through a Vulcan type EZ Series 158 Solid Coupling to a plain reduction gearbox having a ratio of 2.455:1. A four-bladed propeller of 3350 mm (11.00 ft.) diameter, of Kaplan Blade Profile type was designed for use in the nozzles. The three shutter rudders were linked together and operated by the original steering gear.

Before conversion the vessel had a free running speed of approximately 12 knots, a bollard pull of 22 tons and typical, but not very good steering capability.

Trials carried out after the conversion showed that the free running speed had increased to approximately 12.5 knots. Manoeuvring trials showed that with a full helm (35° of rudder), either to port or starboard, and at speeds ranging from full speed to dead slow, the turning circles were two ship lengths in diameter.

At the design shaft horsepower of 2350 metric, the bollard pull uncorrected for the trial conditions was 40.6 metric tonnes. Using the standard method of correcting for depth of water and length of tow line, this can be calculated to rise in ideal conditions to 42.4 tonnes.

By using a higher gear ratio and a larger propeller-nozzle assembly, but necessarily involving a completely altered shaft line, still higher performance results could have been achieved. However, for a minimal alteration to the basic structure of the ship, a notable increase in performance was achieved.

This simple conversion, at a cost (in 1971) equivalent to $100,000, almost doubled the bollard pull and greatly improved the manoeuvring qualities of the vessel. Although this tug is now used for handling larger vessels than previously, the operators report a 15-20% drop in fuel consumption, compared with pre-conversion figures, and some stern vibration that was previously evident completely disappeared.

CONCLUSIONS

From the experimental and practical work providing the data on which this paper is based, the following conclusions can be drawn:

1. For ducted propellers on tugs and supply vessels it can be seen that fixed nozzles give more bollard pull per unit power than do steering nozzles. This applied more particularly where a draught limitation exists, requiring the propeller diameter in the steering nozzle to be somewhat less than optimum.

2. Fixed nozzles, with one single rudder per nozzle, do not give as good steering qualities or docility on a line as do steering nozzles.

3. Steering nozzles do not provide as good handling qualities, docility on a line or bollard pull as do fixed nozzles, when fitted with a three shutter rudder system.

4. The fixed nozzle, fitted with the shutter rudder system, gives between 2 and 2½ times the steering effect of a single rudder behind a fixed nozzle, and appreciably more than a nozzle rudder. More importantly, it gives the tug excellent qualities under a line on load, the ship being docile and resisting any tendency to "skate". It can also, because of the large steering power available, turn under a line to avoid being girted. In this respect the shutter rudder fixed nozzle system is superior to that of a steering nozzle, and incomparably better than the basic single rudder fixed nozzle system. It is surpassed only by the full Tractor Tug layout.

5. Differences in the size of steering gear needed for the three types are significant. The ratios of the torque capacity required for steering gear are approximately as follows:

Fixed nozzle with three shutter rudders	1
Fixed nozzle with single rudder	3
Steering nozzle	8-10

ACKNOWLEDGEMENTS

Acknowledgements for the experimental and theoretical work providing the data which forms the basis of this paper are due to Dr. E.C.B. Corlett, M.A., Ph.D, F.R.I.N.A., F.I.MAR.E. and also to R. Clark, C.Eng., F.R.I.N.A.

TABLE 1

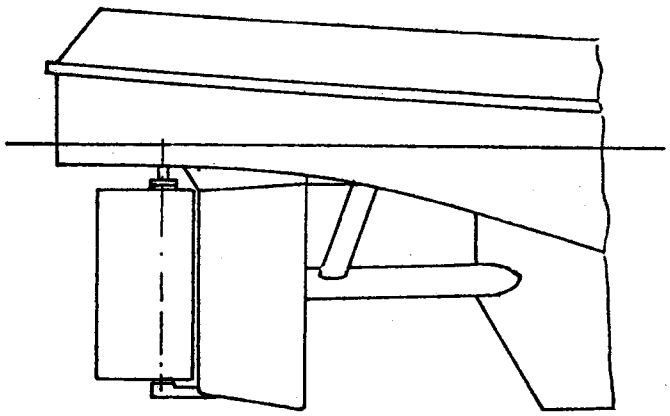
Tug/Conversion	Bollard Pull at 2000 H.P.	Free Running Speed with Fixed Pitch Propeller	Free Running Speed with Controllable Pitch Propeller	Basic Turning Circle	Steering Power on a line		Steering Gear Torque Required
					Ahead	Astern	
X	100	100	-	100	100	100	100
Y	129	96	-	100	100	100	100
X_1	182	99	103	50	200	130	60
X_2	159	103	103	75	150	130	200
Y_1	174	95	103	50	200	100	60
Y_2	153	103	103	75	150	120	180

TABLE 1a

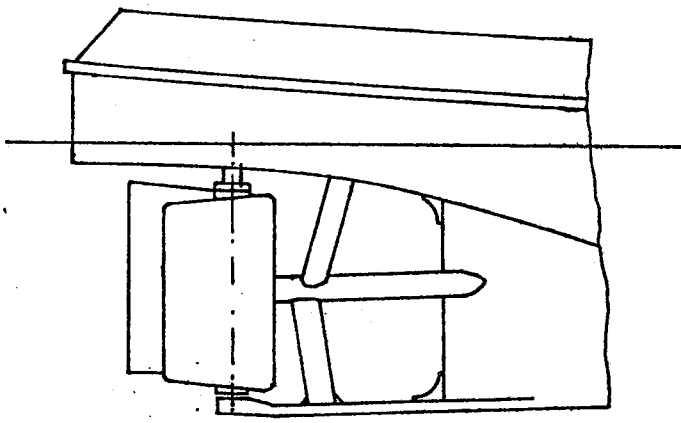
NAME	CASTLE COVE	WONGARA	TARRAGAL	WARRAWEE	WANGAREE
LOA	98'-9"	125'-0"	105'-0"	135'-0"	96'-3"
Beam Mld	26'-6"	33'-3"	29'-0"	34'-0"	28'-0"
Depth Mld	15'-0"	18'-9"	16'-3"	19'-9"	14'-6"
Draft Aft	13'-6"	17'-0"	14'-9"	19'-3"	13'-5"
Displacement (Tons)	398	790	500	1084	430
Single or Twin Screw	S.S.	S.S.(C.P.)	T.S.	T.S.(C.P.)	T.S.
Total BHP	1169	2717	1700	3920	2500
Free Run Speed (Knots)	12.3	13.72	10.66	14.06	12.5*
Bollard Pull (Tons)	23.2	45.5	28.64	66.9	39.5*

* Predicted performance

Principal particulars of some Australian tugs fitted with TOWMASTER fixed nozzle shutter rudder systems.



(a)



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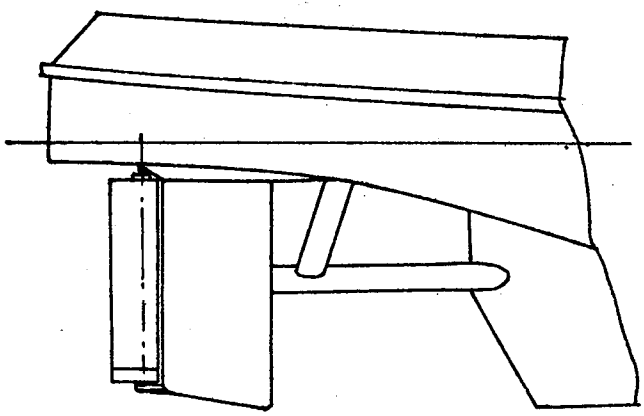
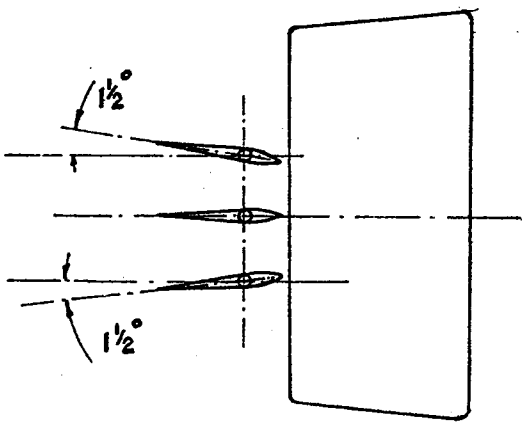




(b)

Fig.1 Aft end arrangements.

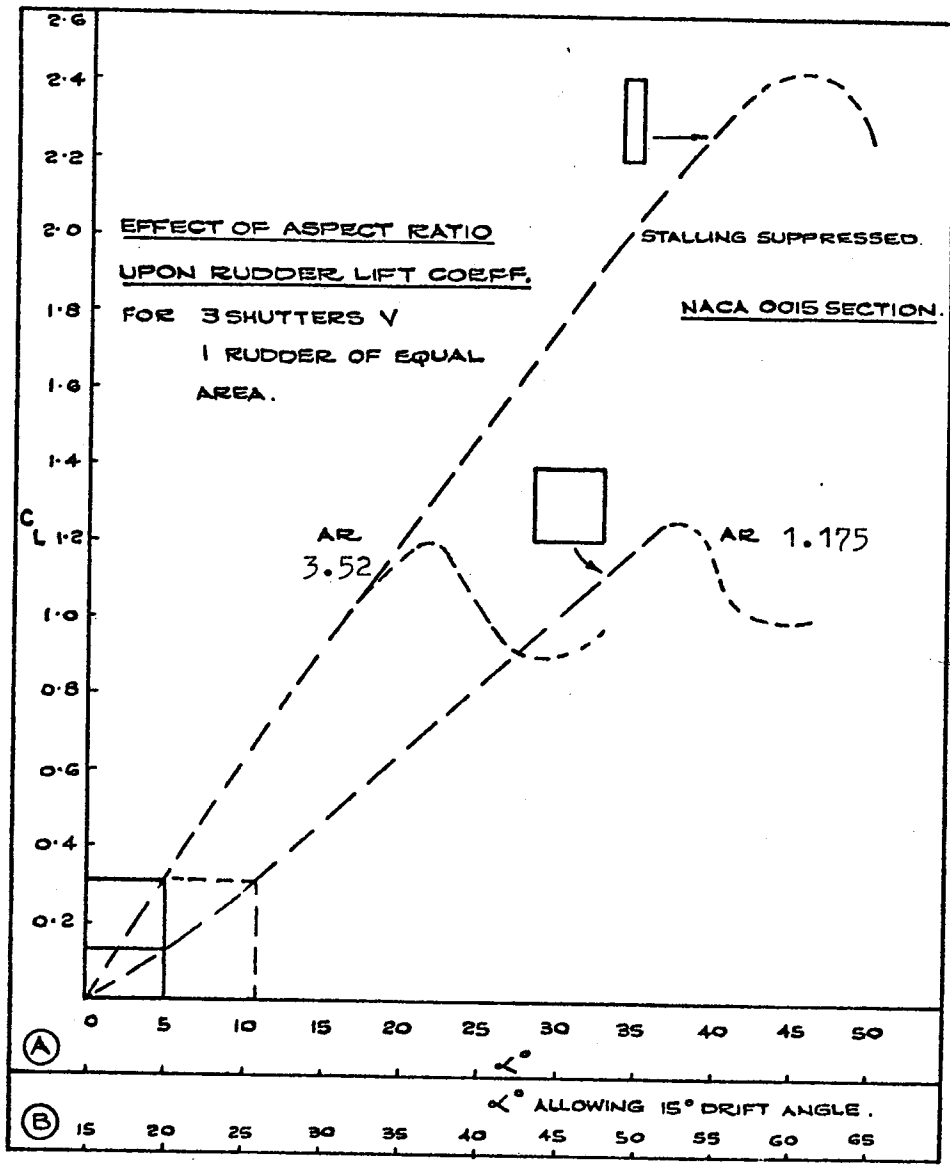


Fig. 2 Effect of aspect ratio upon rudder lift coefficient.

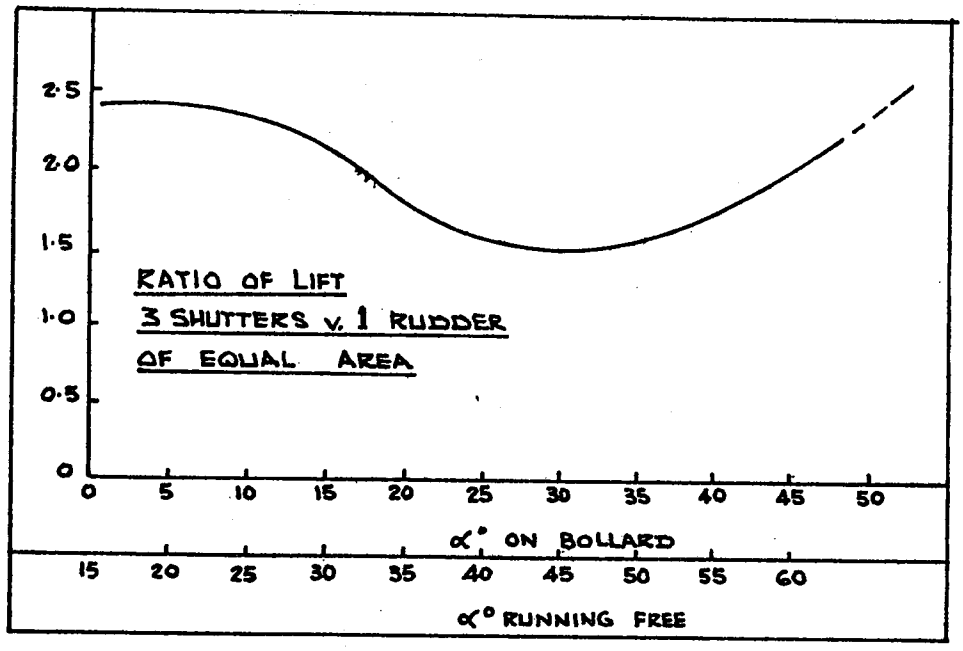


Fig. 3 Comparison of ratio of lift vs. helm angles.

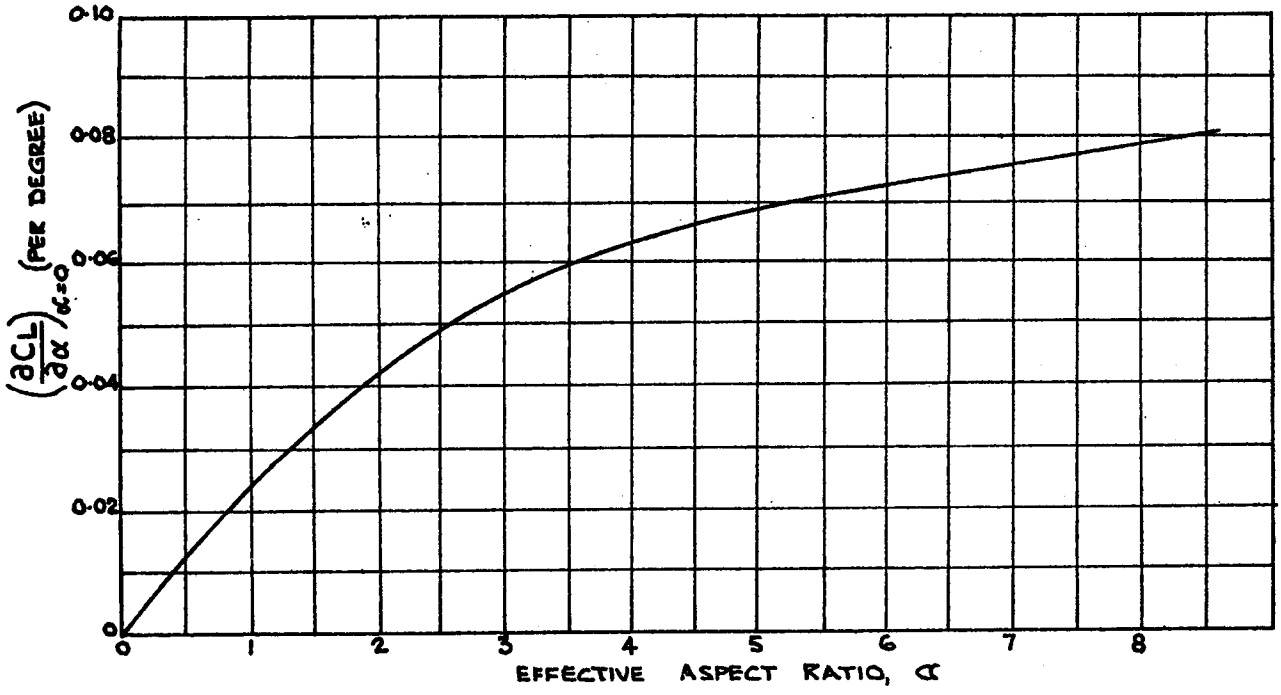


Fig. 4 Effect of aspect ratio on lift-curve slope.

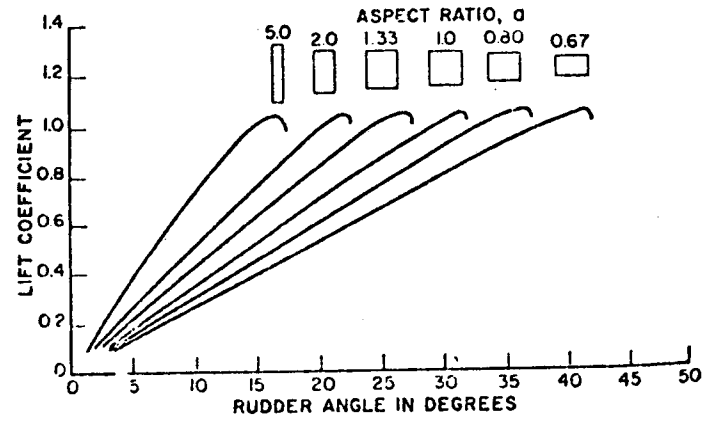
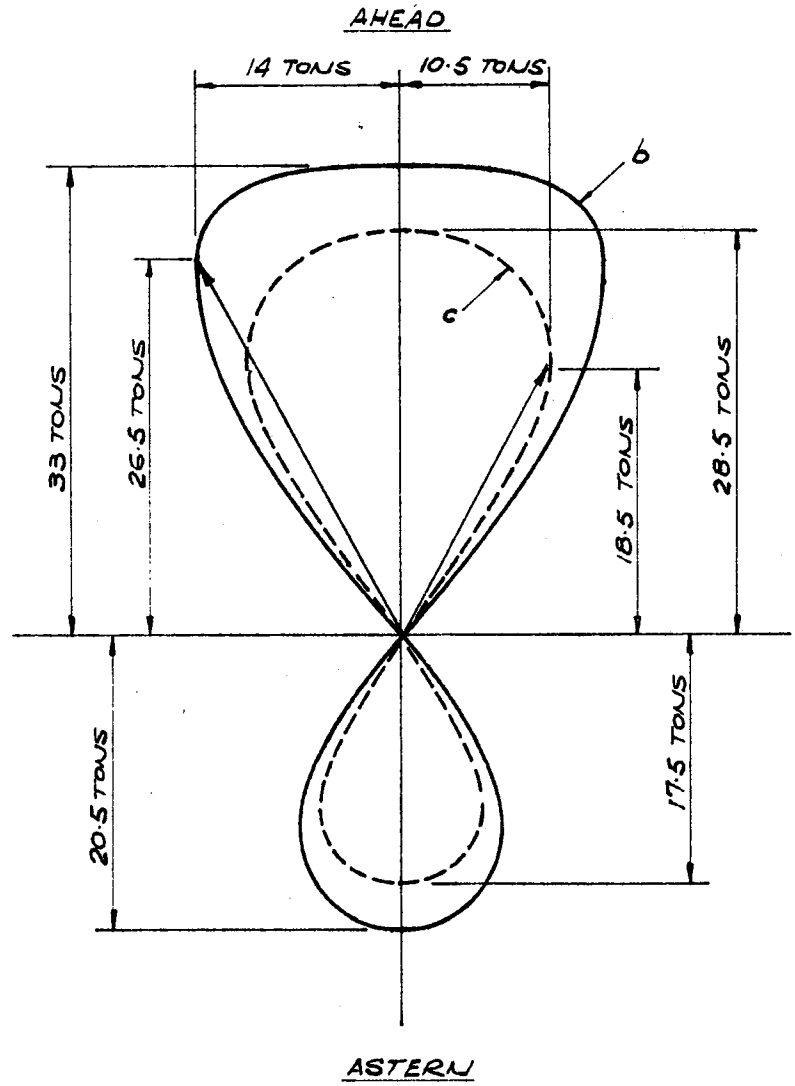


Fig. 5 Effect of rudder aspect ratio on lift coefficient



(b) Fixed nozzle with 3 shutter rudders.

(c) Nozzle rudder, assuming equal power and draught aft.

Fig. 6 Comparison of directional thrust for systems (b) and (c).

SOME OBSERVATIONS ON THE STABILITY CHARACTERISTICS OF SMALL SHIPS

by

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SUMMARY

In general, small ships present the designer with more varied and, frequently, more difficult stability problems than do large ships. In part, this is a result of the relatively more severe sea conditions in which they operate and, in part, due to the varied tasks which they are required to perform.

Several different situations are described which illustrate the need for improved methods of stability calculations and increased understanding of certain dynamic phenomena if improvement is to be made in the designer's ability to insure adequate stability in such craft.

I. INTRODUCTION

The fundamental natural laws governing ship stability are the same, of course, whether applied to small ships or large. These include Archimedes' principle, static equilibrium of forces and moments, and the considerations of the stability of that equilibrium in terms of small and large displacements from the equilibrium position. The designer of small ships, however, is frequently confronted with more difficult problems in attempting to assure adequate stability for his designs than is the designer of large ships. Some of the reasons for this are solely a result of vessel size, some are related to her function, and some are of a non-technical nature. These reasons include the following:

The environmental conditions are relatively more severe for small ships than large ones. This is purely a function

of absolute size; both operate in the same wind and sea conditions.

The loading, draft and trim may undergo relatively more extreme changes during normal operation.

The normal operation may involve large disturbing moments and loads, e.g. heavy nets over the side in the case of a fishing vessel; towline pull in the case of towing vessel; large heeling moments due to rudder action in the case of a fast patrol craft. Many of these are dynamic in nature.

There is frequently a greater disparity in geometry especially freeboard, fore and aft, than in the case of large vessels.

The vessel is frequently not built or maintained under survey of a classification society or other regulatory authority.

The operating personnel are usually not as highly trained nor as experiencedin seamanship.

Today, the small ship naval architect is frequently called upon to assess the stability of floating craft having geometric characteristics for which there is neither precedent nor a history of experience upon which to base a judgment of adequate stability. Furthermore, the geometry of such craft sometimes is such that the conventional stability calculations based upon assumptions of small trim and fixed orientation of the axis of heel are completely incorrect. Such vessels are encountered, e.g., in offshore oil and gas drilling, marine construction, and oceanographic research.

It should be obvious that the small ship designer must, if anything, be even more alert and knowledgeable in dealing with stability problems than his counterpart who designs large sea-going vessels. The latter usually has a much greater store of past experience with similar vessels together with relatively well defined rules and criteria for testing his computations. His methods work well because the size and form of such ships have evolved slowly. The small ship designer frequently deals with vessels whose size and form differ drastically from one design to the next, and which do not behave according to the established rules. It behoves him therefore to understand thoroughly both the art and the science of stability, to know the ways of operation of the vessel and to be acquainted with her personnel.

We shall outline some examples in the following pages in an attempt to emphasize some of the idiosyncrasies of small ships with regards to their stability and, hopefully, to pass on the design profession some of the experience from past mistakes.

II. SOME EXAMPLES OF STABILITY PROBLEMS PECULIAR TO SMALL SHIPS

As noted in the previous section, many of the problems which we shall consider apply to large ships as well as small, but differ

in degree between the two cases. Small ships, however, are sometimes found to have certain characteristics of geometry or function which make it difficult or even incorrect to apply conventional calculation methods, safety margins, and criteria which have been developed for larger vessels operating under quite different conditions. We shall look at a few specific cases in this section.

The Effect of Vessel Geometry on Calm Water Static Stability.

Many classes of small ships are characterized by great dissimilarity in the geometry of the fore and after bodies. In most such cases, the forward sections have high freeboard, narrow lower waterlines, small local B/T and considerable flare. The after body has low freeboard, wide beam and, perhaps, shallow local draft. Vessel types in which we find examples of these characteristics are:

Seagoing tugs

Numerous types of large and small fishing boats

Oil rig supply boats

The oil rig supply boat provides a good example to illustrate the effects of vessel geometry on calm water stability. These vessels have been built in great numbers during recent years in response to the increased offshore drilling activities in many different areas of the world's oceans. A description of their design and operational characteristics, with special reference to stability considerations, is given in Reference (1).

For a typical supply boat, having a beam in the range of thirty-five to forty feet, the freeboard in the after three-quarter length may be only two to three feet. With this low freeboard to beam ratio, the deck edge will be immersed at a relatively small angle of heel, and the righting arm curve will have both a low maximum value and short range of stability. This effect is especially apparent if we compare a typical supply boat and large cargo ship on the basis of equal GM as shown in Figure 1, curves A and D. In order to obtain adequate stability supply boats must operate at much higher absolute values of GM than larger ships of conventional proportions. Curves B indicates that an increase of fifty percent in GM is necessary in order to obtain the same range of stability as the cargo ship, and even then, the supply boat has a maximum righting arm only one-half as large as that of the latter.

Clearly, GM alone gives a misleading indication of the stability of low freeboard vessels. A stability criterion derived from the Rahola criterion, which takes into consideration the area under the righting arm curve, the angle of the maximum righting arm, and its value has proven satisfactory and is described in reference (1).

In considering vessels having geometric characteristics which differ greatly in the fore and after bodies, it is essential that the righting arm calculations be made in such

a way that the vessel is permitted to trim as heel is increased. We recall that the conventional manual method of computing cross curves of stability, using a mechanical integrator, assumes heel to take place about an axis which remains parallel to the water surface. The righting arms are then read from the cross curves at a constant value of the displacement, thus the condition of static equilibrium of vertical forces is satisfied. Any change in the longitudinal position of the center of buoyancy as the ship heels is not, however, considered and, therefore, static equilibrium of trimming moments is not necessarily satisfied. For a ship having near symmetry fore and aft, the center of buoyancy shifts but little, there is insignificant trim, and the cross curves give results which are approximately correct.

For a ship having a raised forecastle with pronounced flare, combined with low freeboard aft, it may easily be shown that such a procedure tends to overestimate the righting arms, i.e., the actual righting arms for the ship which trims as she heels will be less than those predicted by this traditional untrimmed cross curve method. The effect is illustrated in Figure 2, which shows forward and after sections of a vessel having the above characteristics. Waterline WL_o corresponds to no trim while WL_1 is the trimmed waterline corresponding to no net trimming moment. If the ship heels about a fixed axis in WL_o, the newly immersed area in the forward section will exceed that which emerges, while in the stern the reverse is true. This results in a shift forward in the center of buoyancy with increasing heel, and the creation of a trimming moment by the stern. If the trim restraint is now released so that the vessel is allowed to trim in response to this moment, the shaded areas between WL_o and WL_1 will emerge forward and be immersed aft. The transverse position of the centroid of the shaded area is such that the local sectional center of buoyancy tends to move to the left from B to B' at the sections both forward and aft. The net effect when integrated over the vessel length is a reduction in the righting arm, GZ, at this angle of heel as compared to the untrimmed case.

Most static stability computations today are performed by digital computers, and it is a relatively easy matter to incorporate equilibrium in trim as well as equilibrium in displacement into the computer program. The naval architect should therefore satisfy himself that such is indeed the case when developing a new static stability computer program or when using an existing computing service, if he is to achieve the greatest possible accuracy in describing the performance of his design.

As can easily be seen in Figure 2, the effect is most pronounced in vessels having great differences in the freeboard and flare of the fore and after bodies. We have noted previously, that oil rig supply boats are characterized by such features. Figure 3 illustrates the righting arm curves for our example supply boat computed with and without trim, and the difference is seen to be appreciable. In this case, the use of the conventional cross curve method would result in an overestimate of the maximum righting arm by about twenty percent.

Geometric Effect of Waves.

We have previously observed that, since the sea is the same for both, small ships are more likely than large ships to encounter sea conditions that are severe in relation to vessel size. The stability characteristics which the ship's designer customarily computes and uses as a basis for judging the adequacy of her stability are almost always based on an assumption of calm water. It is readily apparent, however, to anyone who has observed a vessel at sea, that wave and ship dynamics play a most important role in determining her ability to remain upright.

The behavior of a small ship operating at high speed in a heavy following sea is especially interesting and potentially hazardous. Much has been written about the problems of steering and directional instabilities which may lead to complete loss of control and broaching. There is, however, a purely static effect on her transverse stability which can be described in its essential features without resorting to ship hydrodynamic theory.

Let us consider the case of a small ship running before a heavy following sea. At times she will find herself on the crest of a wave and, at other times, in the trough. These two positions as well as sections of the ship forward, amidships and aft are shown in Figure 4. When the ship is in the wave trough, the flared bow and stern sections are deeply submerged and the vertically sided amidships section is less so, whereas with a crest amidships this situation is reversed. It is clear from the figure that the total righting moment will be greater in the former case than the latter because of the greater contribution from the deeply immersed flared sections. This effect will be most pronounced in the case of a vessel having low freeboard amidships and raised superstructure with considerable flare at the ends. Typical righting arm curves in still water and in waves are illustrated in Figure 5 for a raised forecastle tuna seiner of the older type. The wave stability curve is computed by assuming the ship poised in a position of static equilibrium on the wave in a manner analogous to the traditional bending moment calculation, and the traditional L/20 wave is assumed for this example.

The wave-induced reduction in stability in the crest is quite apparent, as is the increase in stability in the trough. Stability variations computed by purely static considerations as described here have been found to agree quite well with values measured by use of a towing tank model which is towed at an angle of heel in regular following seas. Some comparisons of theory and experiment as well as a discussion of the effect of changes in hull proportions are given in reference (2).

Dynamic Effects in Following Seas.

It is obvious that if the wave crest induced stability reduction described in the previous section is sufficiently severe, the ship may be in danger of capsizing. In order for this to occur, however, she must experience this reduced stability for a sufficient period of time, of the order of one-half her roll period or longer. This may occur if the ship speed is approximately equal to the wave speed so that she

travels with the wave, remaining nearly stationary relative to the crest. This requires a quite high speed, e.g., in waves of length equal to ship length a Froude Number of about 0.4 is required for exact speed matching. The period of time in the wave crest may, however, still be sufficient for capsizing at lower more realistic speeds if the waves are sufficiently steep and the stability is initially low.

If the ship is running before the sea and the waves are fairly regular, the righting moment curve will oscillate between the upper and lower values shown in Figure 5 as successive seas overtake her. Figure 6 illustrates, schematically, this time-variation of the righting arm curve for a constant angle of heel. If the frequency of oscillation of the righting moment remains fairly regular for several cycles, and if this frequency bears the correct relationship to the ship's natural frequency of roll, a large rolling motion may sometimes develop. This phenomenon may be described qualitatively as follows. Assume that a disturbance such as a beam wind gust strikes the ship as she is in the crest of a sea therefore in the position of diminished stability. She heels to some angle under the influence of this disturbance after which the disturbing moment dies out. Now, while she is heeled, the wave crest moves on and a trough nears the midship position, thus resulting in an increased righting moment. As a result, the ship is accelerated in roll back towards the upright. If now a wave crest moves into the midship position just as the ship rolls past upright, thus reducing the righting moments once again, her momentum will cause her to roll far to the other side. Again the wave crest moves on and a trough, with an increased righting moment, moves amidships as she reaches the extreme roll angle. She is then accelerated back the other way, and it is not difficult to imagine this sequence repeating itself several times so long as the group of waves remain sufficiently steep and are encountered at a nearly constant frequency.

This phenomenon is known as "autoparametric excitation"-an oscillatory motion which develops without an exciting moment other than the small initial disturbance, but is a result of time variations in the restoring moment coefficient in roll. A detailed discussion in which the motion is associated with unstable solutions of the differential equation of motion may be found in reference (3).

Some experiments using radio-controlled ship models in natural seas on San Francisco Bay to study ship capsizing in heavy seas, are described in reference (4) and have revealed the occurrence of this phenomenon under realistic conditions. From the verbal description given above and also from the mathematical analyses, of reference (3), it is found that the rolling motion takes place at a frequency equal to one-half the wave encounter frequency. Figure 7 contains records of the pitch and roll motions of the model which were recorded during an experiment run in following seas. The pitch motion takes place at the frequency of wave encounter and, therefore, is a good indication of that frequency. In Figure 7, the roll is clearly seen to take place at one-half the pitch frequency. This experiment culminated in a capsize of the model and illustrates how the motion may grow rapidly to catastrophic proportions, given the proper conditions.

Rolling and Capsizing in Beam Seas.

The open water experiments referred to above included numerous runs in beam seas in addition to quartering and following seas. While frequent capsizes of the model were experienced in following and quartering seas, no beam sea capsizes were obtained. This result may, however, be explained in terms of physical differences between the experimental model and the actual arrangement of a ship, large or small.

The experiments were conducted using models of a cargo liner and a containership. Both models had hull form characteristics typical of large seagoing merchant ships. Neither model was equipped with bulwarks, and the upper works, (deckhouses, masts, above deck containers) were intentionally omitted for reasons of scaling and in order to focus attention on the fundamental hydrodynamics of hull and waves. Two effects, expecially important in the case of small ships, were therefore, not present: water entrapment on deck, and wind heeling moments. In beam seas, these effects, are of course, of vital importance in determining the tendency towards capsizing. Some relevant experiments on trawler models in beam waves have been conducted in Poland and reported in reference (5). In these experiments, the models were equipped with bulwarks, but wind effects were not present since the work was done in a towing tank. Two important observations were recorded concerning the nature of capsizes in regular beam seas:

(1) Capsizing was always connected with intensive flooding of the deck.

(2) Capsizing always occurred into the waves.

The entrapment of water by bulwarks leading up to capsize is sometimes observed to take place in a cumulative fashion. That is, the rate of outflow through the freeing ports in each wave cycle is less than the inflow over the bulwarks as the vessel rolls into the sea. There is, therefore, a net accumulation of water on deck, which, after several successive waves, becomes sufficient to cause a capsize. Similar observations concerning the capsizing of a model of a cargo ship with partial internal flooding are given reference (6).

At least one loss of a California tuna seiner in recent years is believe to have occurred in this fashion. The vessel was proceeding in moderately severe head seas and experienced a loss of lubricating oil pressure which made it necessary to shut down the main engine. She thereupon fell off into beam seas, rolled heavily three or four times and capsized into the waves.

A complete theoretical solution for the motion of a ship with water trapped deck is not yet available. The situation is somewhat similar to that of a ship fitted with a free surface type of roll stabilizing tank. Two additional effects seem to play important roles in the capsizing phenomenon, however. They are the accumulation of water on deck in successive waves, and the impulsive heeling moment which is applied as each wave spills over the bulwark.

Flooding of internal spaces.

Attention to the integrity of watertight spaces is a problem containing design, operational and regulatory components. We still hear of vessels being lost as a result of flooding through exposed watertight doors which are left open "for ventilation" despite explicit instructions that they be kept closed at all times while the vessel is at sea. Reference (1) contains a brief description of a recent loss of an oil rig supply boat which foundered while engaged in picking up the rig's anchors and chains. Flooding of the engine space took place through an open weather deck door which could not be closed because it was blocked by one of the anchors just taken aboard. Reference (7) describes the losses of two seagoing tugs both of which involved flooding of the engine rooms through open weather deck doors.

A very rough impression of the nature of the flooding may be gained by considering the rate at which water may be admitted through such an opening. The door sill may be approximated as a sharp edged weir, for which the flow rate is given, from reference (8), by

$$Q = C_w \, 2/3 \sqrt{2g} \, H^{3/2} \, W$$

Here H = depth of water over the crest of the weir

W = width of the weir

C_w = loss coefficinet, approximately = 0.6

For a door opening two feet wide having the sill submerged by two feet, this formula gives a flow rate of 9.07 cubic feet or 0.36 ton per second. At this rate, ten tons of water will enter the craft in something like forty seconds. The implications for a small fishing vessel, e.g., are obvious but do not always seem to be fully appreciated by the personnel who operate such craft.

III. CONCLUSIONS

The objective of this brief paper has been to discuss some special topics in the analysis and judgment of the stability of small ships. These are intended to illustrate a few situations in which the designer of small ships may be confronted with a more severe test of his ingenuity, understanding and imagination than is the case with his counterpart who designs large vessels. Some of these problems, such as the righting arm computations, merely require a more thorough and accurate approach to the analysis without the simplifications which have been permissible with ships of conventional form. These problems may usually be dealt with easily and accurately, for large ships as well as small, by modern computing devices, and require only an awareness of the existence and proper use of the appropriate programs. Other problems, such as the dynamic effect of the seaway, are still incompletely understood, and, in the absence of complete understanding, must still be dealt with by the application of engineering judgment.

Finally, the designer must know something of the temperament, background, and methods of the operating personnel, in addition

to his thorough knowledge of the functioning of the ship herself. Only through such understanding will he be able to anticipate all of the potentially hazardous situations into which his ship may be placed, and then design into her the inherent abilities, or provide to her crew the operational information necessary to her survival.

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	Length	Beam	Depth
Cargo Ship:	520 ft	75' ft	42.5' ft
Supply Boat:	164 ft	36' ft	15' ft

Curve	Ship	Freeboard	GM
A	Cargo	15.0	5.0
B	Supply	3.0	7.5
C	Supply	2.5	7.5
D	Supply	3.0	5.0

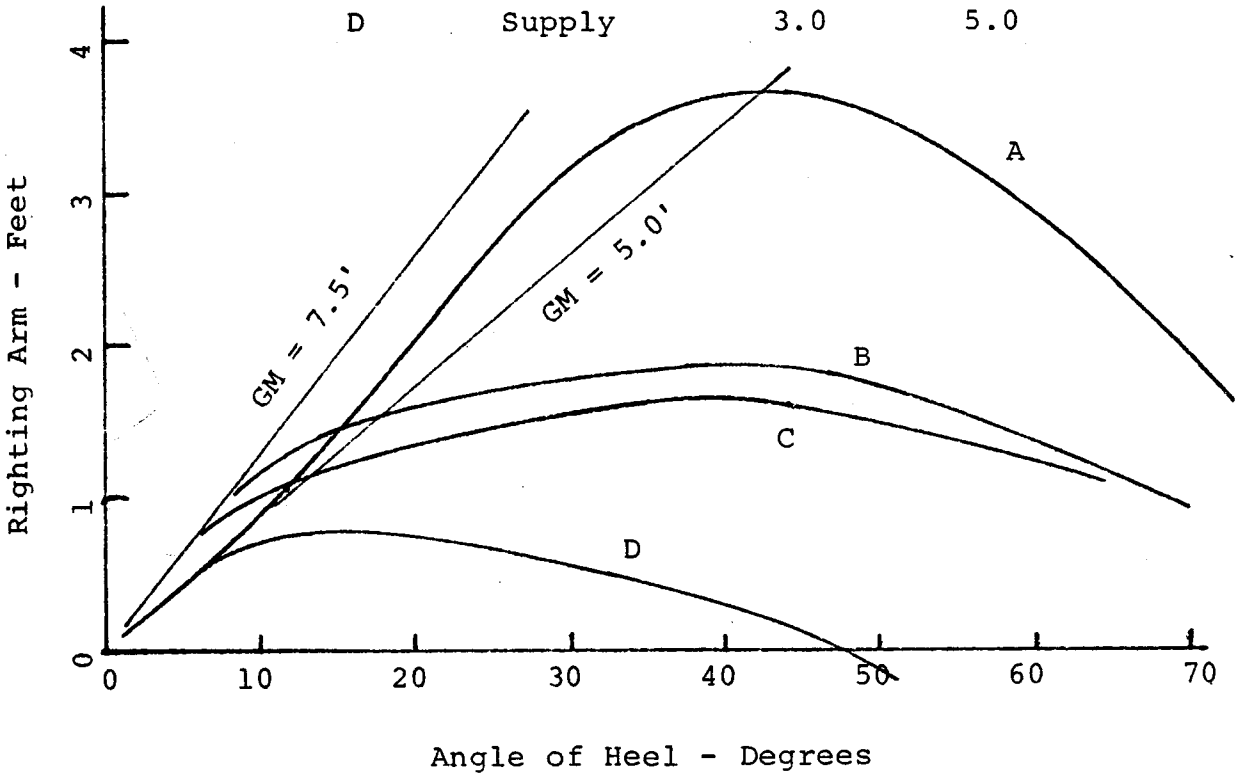

Figure 1. Righting Arm Curves for Conventional Cargo Ship and Oil Rig Supply Boat

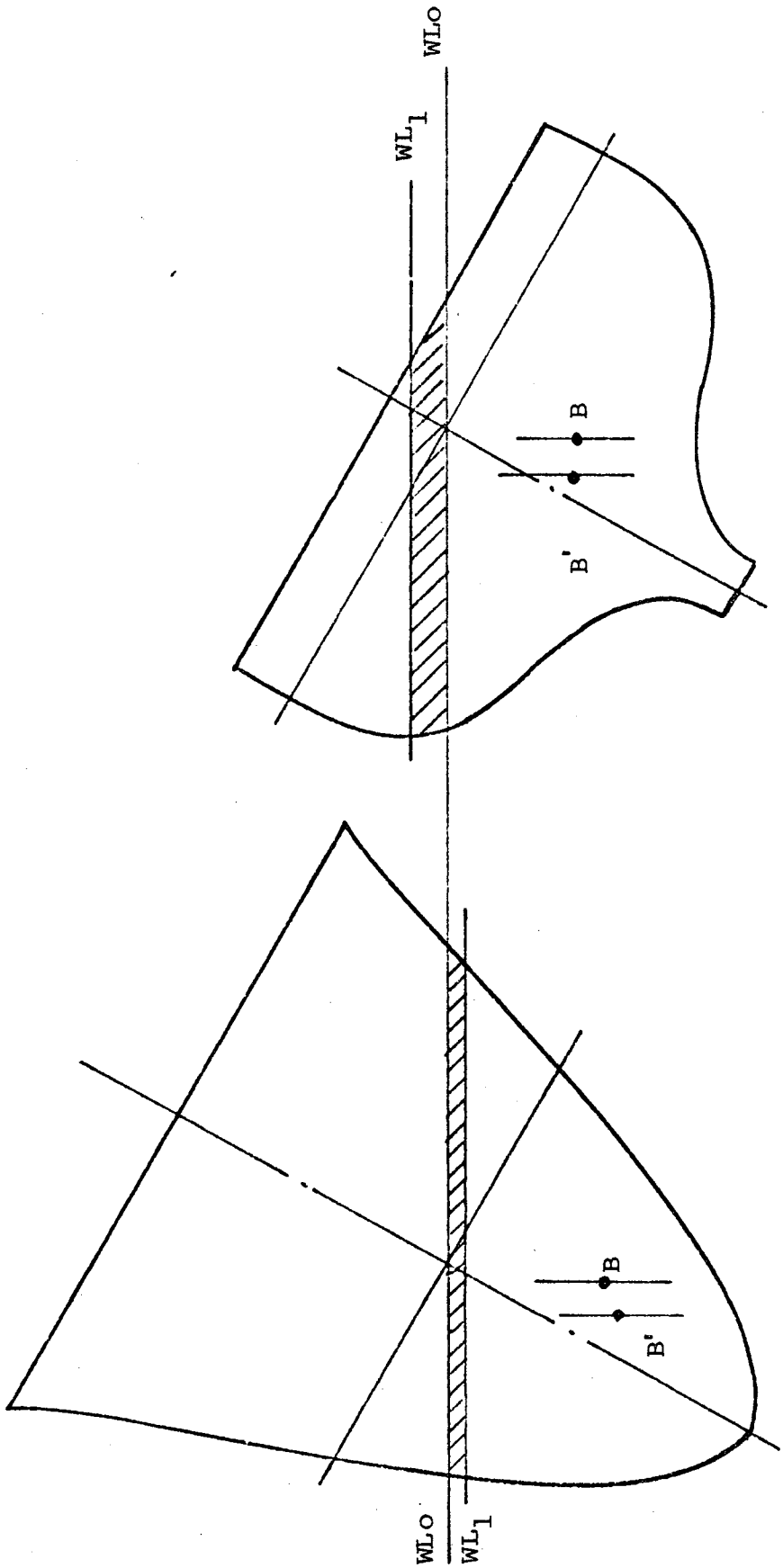

Figure 2. Heeled Sections Showing Effect of Trim on Local Center of Buoyancy

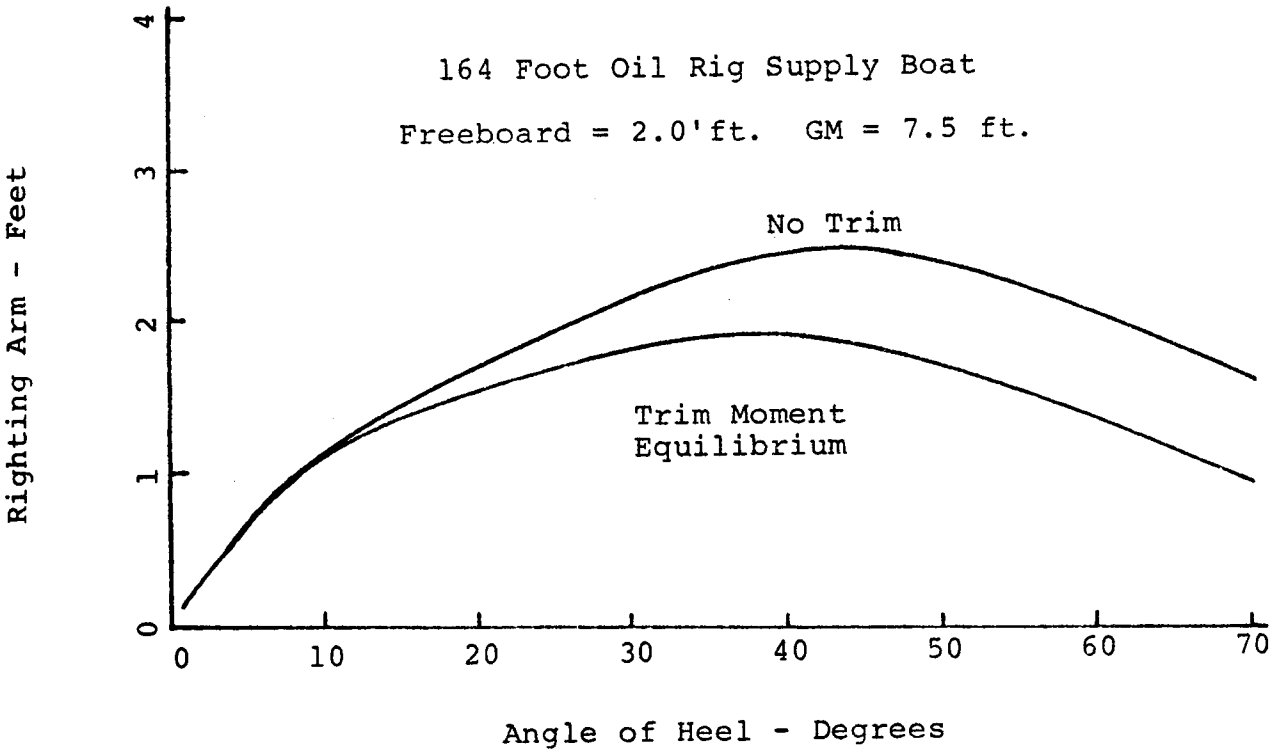

Figure 3. Comparison of Righting Arm Curves Computed With and Without Trim Moment Equilibrium

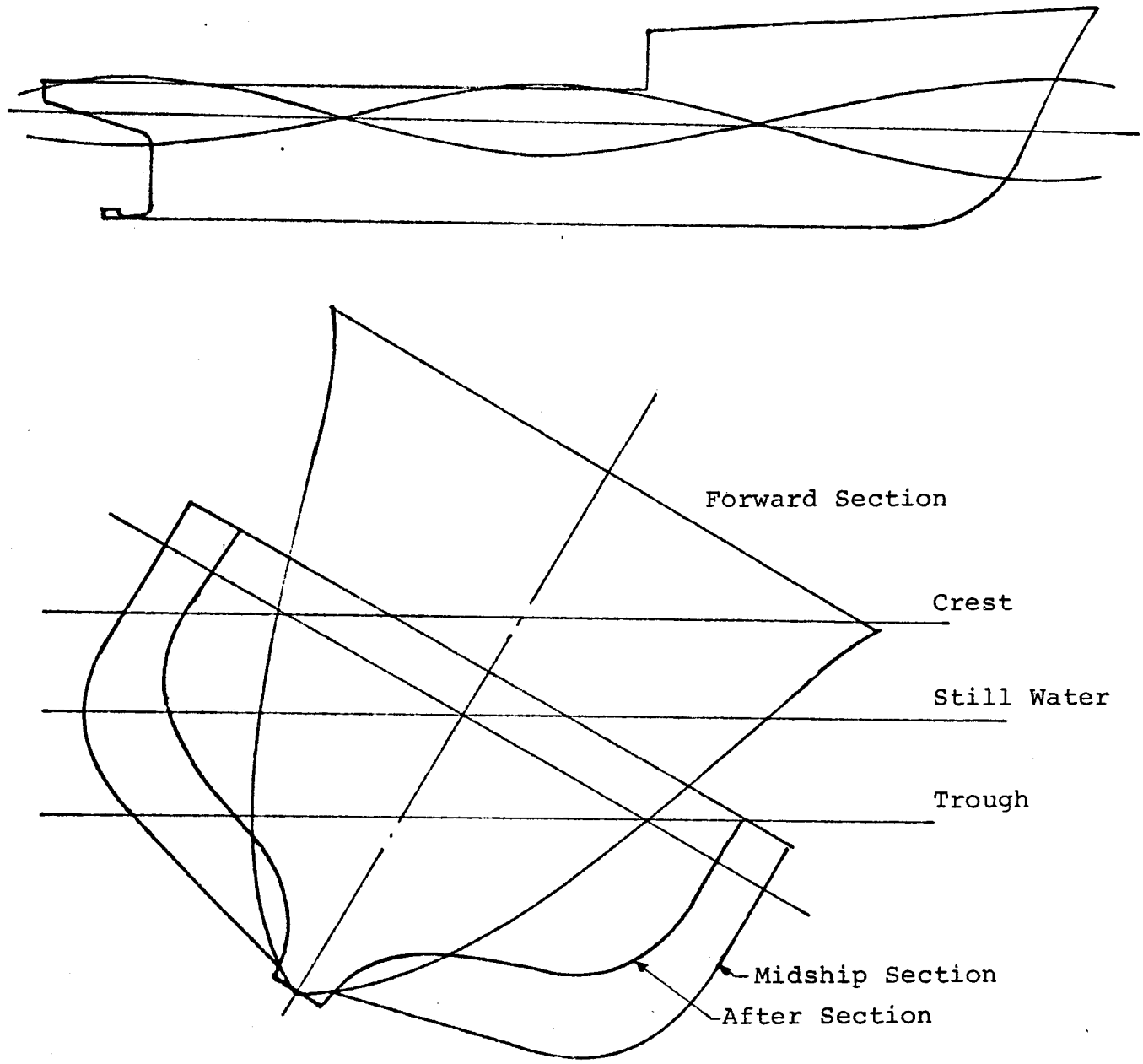

Figure 4. Heeled Sections of Ship in Following Seas.

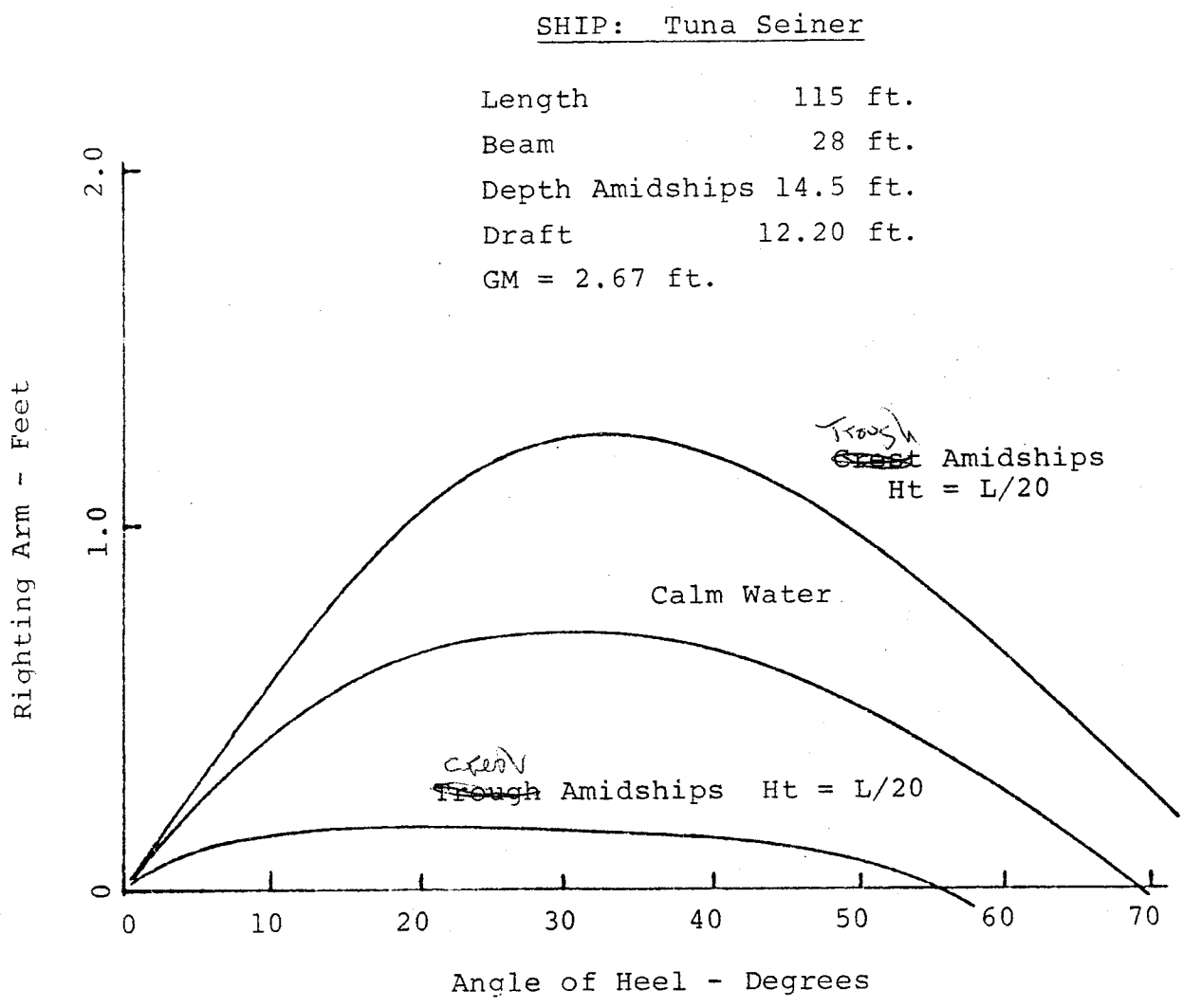

Figure 5. Stability in Calm Water and L/20 Waves For Tuna Seiner

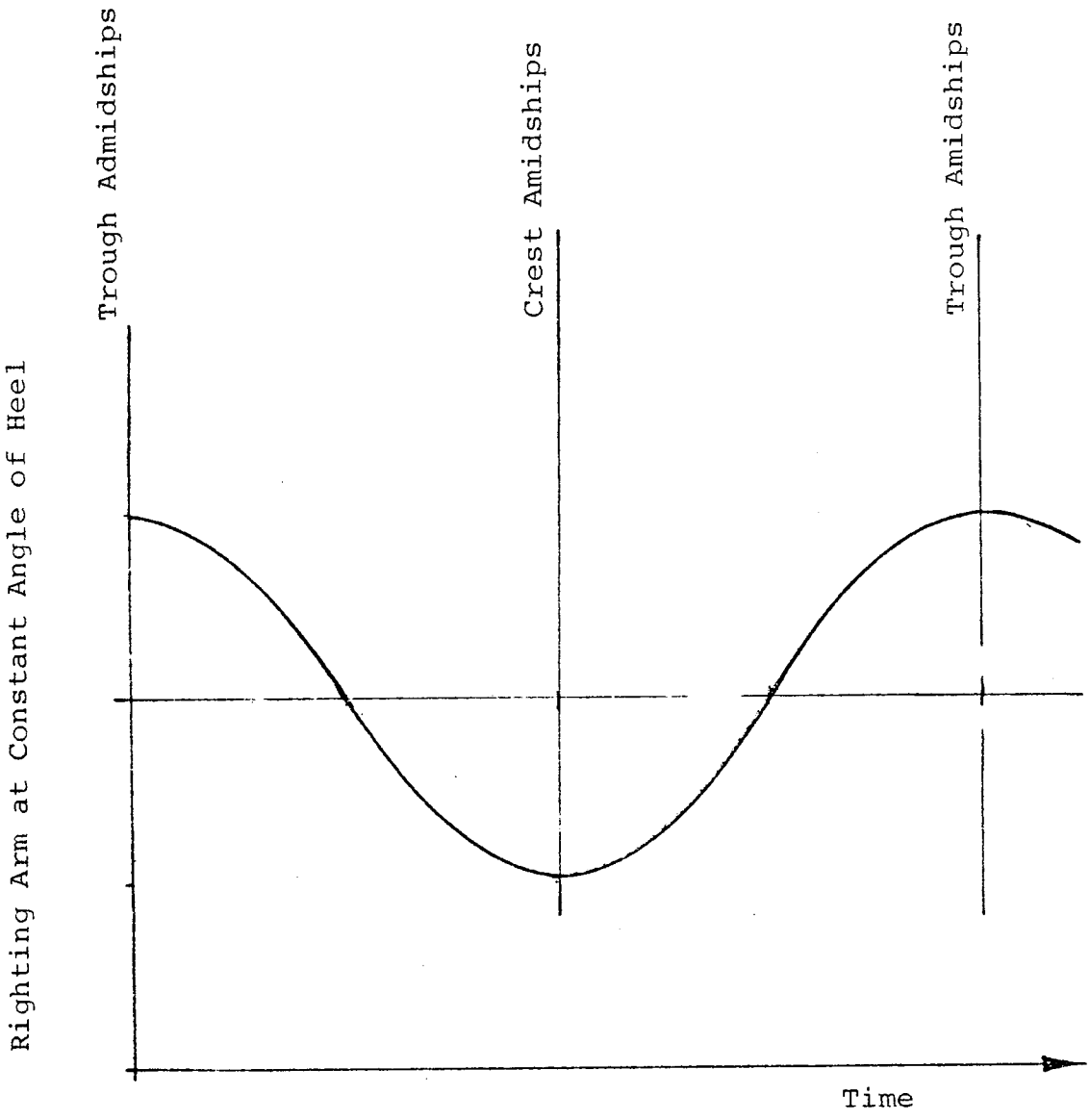

Figure 6. Variation of Righting Arm with Time in Following Sea

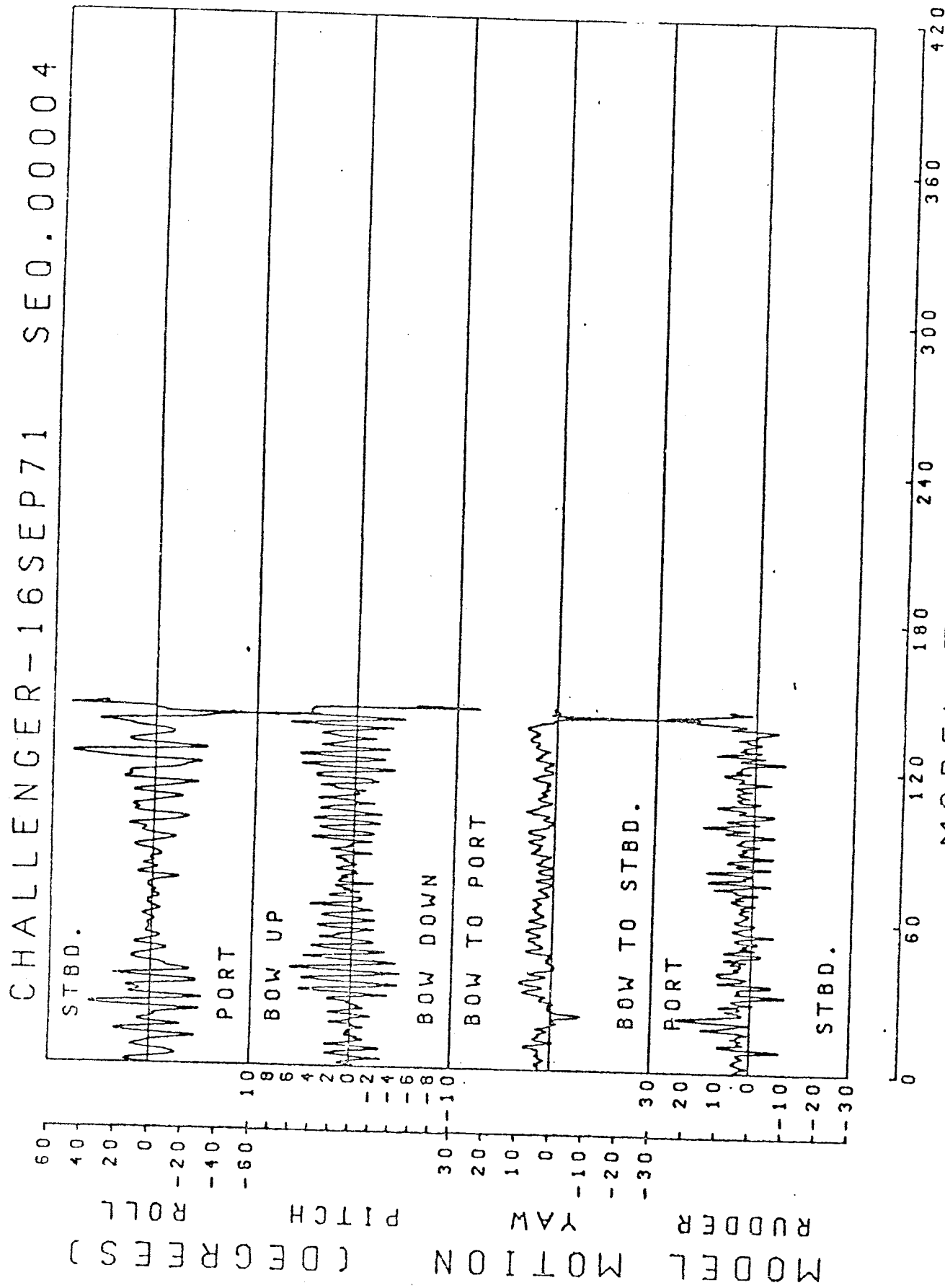

Figure 7. Motion Record from Open Water Model Test-Following Seas.

FERROCEMENT CONSTRUCTION : SOME POINTS TO WATCH

by

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SUMMARY

There are some aspects of ferrocement construction that are important to a successful vessel. The contractor will be in control of most of these factors and it is he who will largely decide whether a vessel is heavy, corrosion susceptible, and subject to coating failures. These topics as potential and avoidable problems are considered.

INTRODUCTION

Ferrocement had its beginnings as a popular boat building material in Australasia only about fifteen years ago. At that time enthusiasts and believing engineers began to seriously consider ferrocement for pleasure and commercial use. In 1961 construction of a small displacement vessel began in New Zealand and innovative builders tried their hand in increasing numbers. Some of these early builders began businesses many of which still exist today in North America, the Pacific Islands, Australia, and New Zealand.

For a time, ferrocement enjoyed a tremendous boom: books appeared, many hundreds of plans were sold, business and amateur associations were formed, companies were started and a wide variety of popular articles were published. Although it was not so much the situation in New Zealand, overseas there was extensive publicity advocating ferrocement as a quick, easy and cheap medium from which to build a boat. A number of articles appeared that halted this trend. The two best known were written by Friedman (1972) and Cartwright (1972) but there were also a proportion written by some well-known designers including Brewer (1971), Hartog (1972), Colvin (1972), Bingham (1973), and Garden (1973). These articles were largely critical of ferrocement as a boatbuilding material.

The quick rise of ferrocement into a popular medium of construction had disastrous consequences for many people both amateur and professional. Designers experienced in other materials were compelled to provide designs in ferrocement with little, if any, previous experience. Weight estimates could not be met, coatings would not adhere and there was too much flexibility and vibration. Amateur builders fared far worse and scores of unsightly boats were produced and a good number were abandoned. Vessels have been known to fall apart during lauching or transporting and people new to sailing and ferrocement construction lost their vessels on maiden voyages, shortly thereafter, or were the subject of air and sea searches.

At this point in time there is a reasonable and steady progress with ferrocement and it is expected that this trend will continue. Of particular importance are commercial craft in tropical climates. The low maintenance and long life of these vessels plus the fact that they can be built indigenously has created much interest and activity.

The preceding discussion is germane to the theme of this paper for several reasons:

(a) to a large extent the attitudes now encountered with regard to ferrocement are unfavourable. Reputable designers and commercial firms have had to overcome not only the problems usually associated with development but also a considerable amount of hostile feeling. The authors consider it important, therefore, that the comments to follow are interpreted in a constructive manner only.

(b) In the amateur and commercial construction of ferrocement vessels worldwide, every conceivable mistake has been made. There is, thus, a rich and valuable amount of service experience to draw upon.

Only three topics of concern to builders are considered here: weight, corrosion, and sealing and painting. These are the most salient points because small ferrocement vessels are often too heavy; it is a common belief that ferrocement corrodes although it has exceptional resistance in this regard and seldom does; and, satisfactory sealing and painting has been a chronic problem with ferrocement. Furthermore, it will be largely in the hands of the contractor, not the designer, as to whether or not these items are problems. For the builder, therefore, these are some points to watch.

WEIGHT

On currently accepted scantlings for vessels built by conventional means, ferrocement will be heavier than steel. Furthermore, weights are more apt to runaway with ferrocement than with any other material. The subject of weight is considered in some detail by Baugh, Bowen, and Kenyon (1975): tables of weights are calculated and case studies considered. There are a variety of reasons why ferrocement vessels generally have a weight problem and there are various means to cope with each factor.

First, ferrocement varies somewhat in specific weight. From about one hundred test cylinders taken during plastering in various parts of New Zealand, the specific plaster weight has varied from a low of 20 kN/m^3 (127 lb/ft^3) to a high of 22.8 kN/m^3 (145 lb/ft^3). The variation arises from different sands and gradings, different degrees of compaction, various water to cement ratios, etc. There can be errors in design weight calculations approaching ten per cent from this source alone. Furthermore, the steel content can also vary between about 5 and 8 per cent by volume on the same vessel from position to position. Designer and builder need to be cognizant of these points so that a reconciliation with theoretical calculations can be made by weighing.

The greatest single factor that causes excess weight is the cover of plaster over the mesh, as shown in figure 1. Some builders feel that substantial cover is essential to corrosion control. Unless the vessel was designed to accomodate excess weight this philosophy can lead to difficulty. Excess cover can also occur quite unintentionally if the armature is not fair and thoroughly compacted. Plasterers naturally add extra plaster in an effort to fair out these flat spots. On a fair compact armature excess cover can still occur by the accidental use of too thick a skim coat. Once the mesh is covered there is no way to know the extent of the cover without scraping back.

Fig. 1: Slab of plaster cover from a damaged ferrocement vessel. Thickness varies to a maximum of approximately 14 mm. Professional plastering of amateur construction.

There are several ways to keep the cover to an absolute minimum. One way is to plaster onto a male or female mould and the other is to intentionally leave the mesh exposed by scraping back the plaster left after the armature is filled. Protection against corrosion is then provided by sealing. Inside tying can also be beneficial in reducing cover thickness since the tie end is usually the proudest portion of the armature and thus the determining factor in the minimum thickness of the skim coat.

Another factor influencing the build-up of weight is local thickening. Some designers favour extensive interior framing with lighter skins. This may or may not weigh less depending not only on the initial design but also on the care with which the plastering and armature construction is done. Fillets at intersections quickly add up. It is not only the framing system but engine beds, water tanks, hull-transom and hull-deck intersections, horn and stem, etc. To reduce fillet thickness and, consequently, weight, there are several possibilities. First, mesh in the fillets must be kept slack so that it can be compacted and bulky structural shapes should not be incorporated into the stem and horn.

BUILDING TO AVOID CORROSION

There are a number of factors that influence the ability of a ferrocement vessel to withstand corrosion. First, the steel must be kept encased in plaster where the high alkalinity and low level of moisture content prevents normal oxidation and the plaster itself should be inert to any chemical reaction with seawater. The building process should also eliminate any possible galvanic cell circuits that might form in either a passive situation or by the potential of the ship's electrical system. Most of these factors are influenced by the contractor and if translated into construction practice would include attention to these details:

(a) Adequate structural design to prevent the possibility of stress cracking under the normal operating conditions expected of the vessel. Adequate provision must also be made for resistance to abrasion. This requires that the builder provide wooden rubbing strakes or cappings on areas exposed or worked hard. Plaster unreinforced by mesh should also be avoided since it

cracks easily and contributes little strength. Cracking or abrasion will result in unsightly rusting of exposed mesh.

(b) On vessels formed in a conventional manner there is some advantage to tying from the inside. If rust spotting and streaking do occur on a vessel it will be at tie ends which are generally the greatest protrusion from the armature. Inside tying places the end inside the vessel where corrosion is unlikely.

(c) Exposed and submerged metalwork that is electrically continuous with the armature can enter into a possible galvanic cell circuit either on a macro-scale or in a local manner as shown in figure 2.

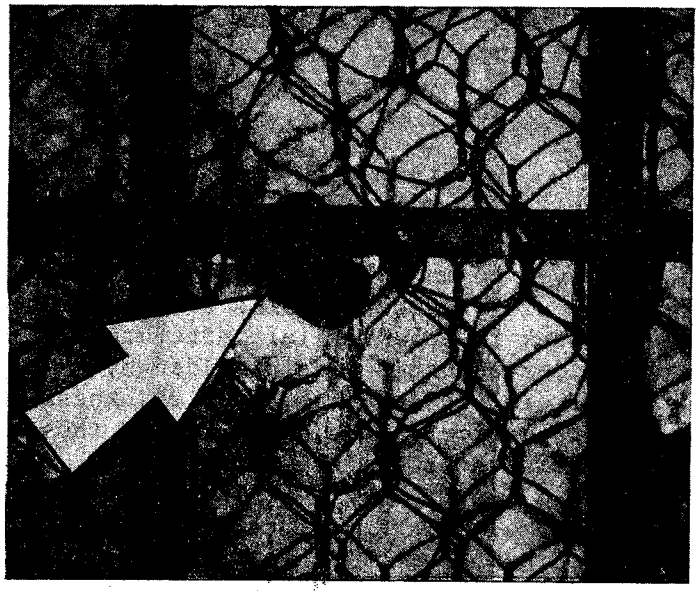

Fig. 2: Local galvanic cell action inside ferrocement as shown by x-ray. The copper alloy bolt (arrow) has completely corroded the 6mm steel rod and surrounding mesh.

Furthermore, the process can be driven by the ships electrical system leading to an accelerated form of corrosion as shown in figure 3.

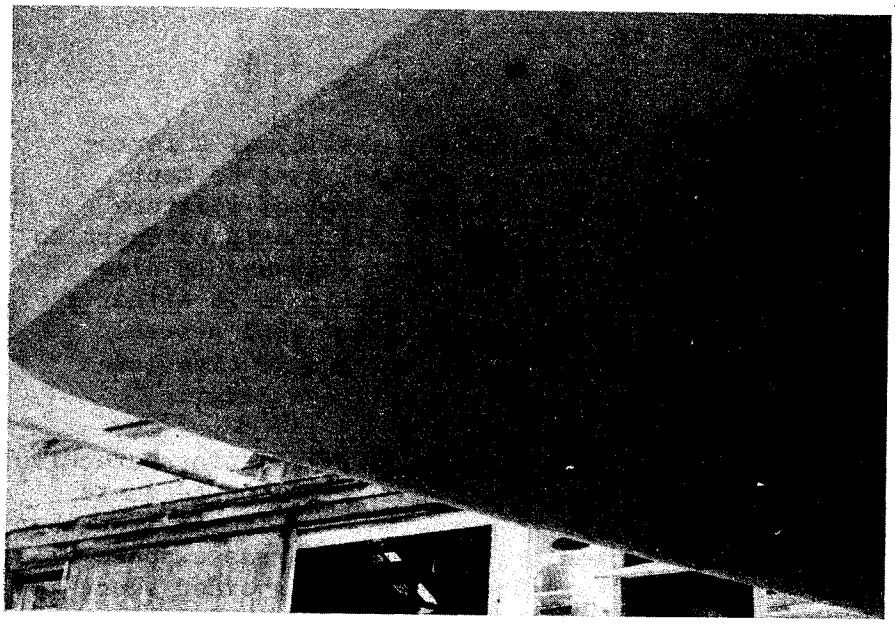

Fig. 3: Galvanic cell action on the bow of an Auckland vessel. This action is believed to have been driven by the vessel's electrical system. (Photograph courtesy of G. Kenyon)

All significant visible corrosion as yet detected in existing ferrocement vessels has been the result of submerged and exposed metalwork connected to the ships electrical system. Although the actual chemical processes have not been investigated by qualified physical chemists the solution of corrosion problems by rewiring is evident. For a builder then, all exposed and submerged metalwork should be isolated from the armature. Through hull fittings can be set in oversize holes backfilled with expoxy concrete. Stern tube and rudder post detail may be selected to break electrical contact with the armature. Some of this detail is reported in corrosion articles published by the New Zealand Ferro Cement Marine Association (1974). A two wire electrical system should also be used.

(d) Ferrocement vessels should be sealed. All plaster is permeable to some extent and a build-up of chloride ion may lead to a self-sustaining corrosion. This has been found in reinforced concrete bridge decks treated with de-icing salts.

(e) Tri-butyl tin based anti-foulings are preferable to those using copper. Although copper anti-foulings may not enter directly into any corrosion process, it is a failsafe approach to use an anti-fouling safe even for aluminium craft.

(f) The plaster should be designed for maximum strength and watertightness. The factor having the greatest influence on the permeability of the plaster is the permeability of the cement paste. The maximum permeability can be obtained by using the lowest amount of water possible for placement. Age also has an important influence. Pozzolan is used religiously by many builders for watertightness and has been used as a replacement for cement at levels up to 25 per cent. The lime released during hydration appears as $Ca(OH)_2$ and is susceptible to leaching. A silicon rich pozzolan combines chemically with this compound to give a more watertight paste. Pozzolan is also known to improve resistance to sulphate attack. Every individual case will have to be decided separately because of the variability of cements, pozzolans, and aggregates. The 28-day compression test is also meaningless because pozzolan addition results in a lower rate of strength gain.

The cement paste should be resistant to reaction in seawater. Neville (1972) states that a practical division between cements of good and poor performance is about 7 per cent of C_3A by weight. New Zealand cements chemically analysed by Kennerley and Clelland (1959) showed C_3A contents of about 10 per cent placing all of them in the poor performance category.

Aggregate used in the plaster should be sharp, clean, strong, and well-graded. Some guidelines on ferrocement plaster have been given by McDonald (1974), Mahaffey (1970), and the Portland Cement Association (1969).

(g) The plaster should be of such a consistency that it can be placed without forming voids. Too dry a mix will not knit together after passing a wire or rod whereas too wet a mix will not meet the desired water to cement ratios for high strength and impermeability. The inability of a stiff plaster to knit after passing a rod results in what is termed a shadow void. Advocates of two stage plastering claim that shadow voids are eliminated by plastering in two passes. The armature is filled from the outside initially and after a week or two the inside is grouted and then plastered. With liberal grouting and vibration, two stage plastering should be entirely satisfactory.

Single stage plastering is probably most successful when the armature is filled from the outside and smoothed off on the inside. Small air pockets and voids near the surface are then inside where they will not present leakage or corrosion problems. Figure 4 shows a void on a single stage plastered vessel.

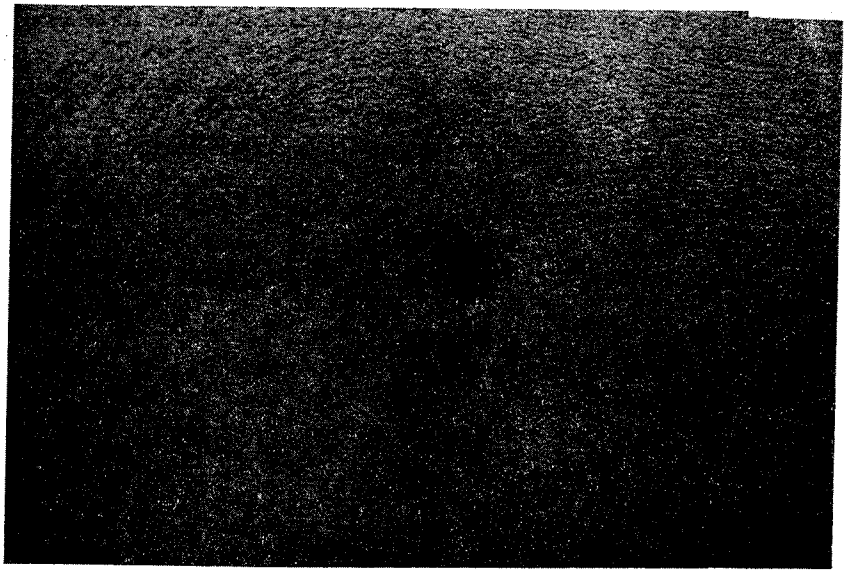

Fig. 4: Void found just beneath the surface after single stage plastering. The diameter of the opening is about 40mm. (Photograph courtesy of W. Bray)

The builder can do much to prevent the formation of voids by avoiding impenetrable build-ups of mesh and reinforcing steel. If voids exist, and one should suppose that they will, they should be located and filled. To locate voids there is no better procedure than a water test as described in detail by Samson (1973) and illustrated in figure 5.

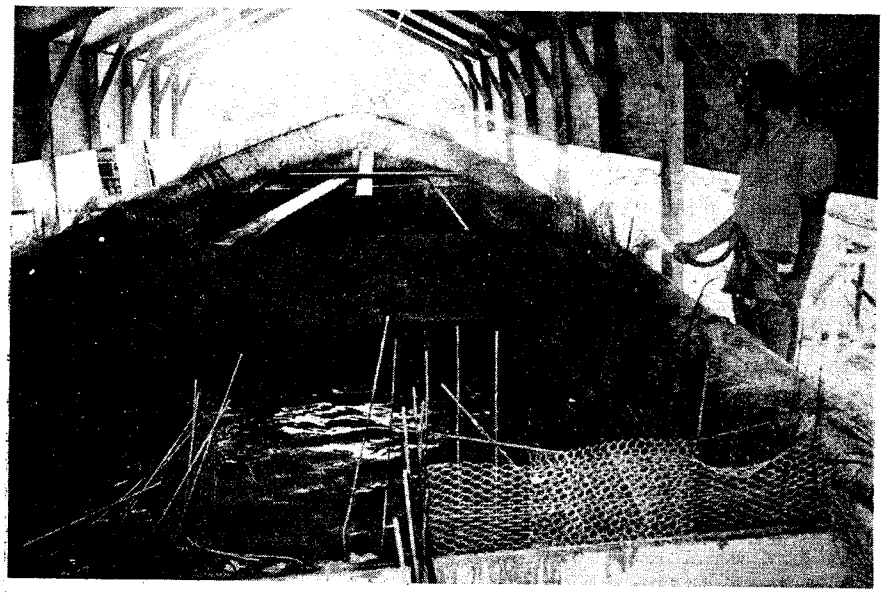

Fig. 5: Hull compartment filling in preparation for water testing. (Photograph courtesy of Samson Marine (Bahamas) Ltd.)

The test consists of filling the inside of the vessel with water up to the level of interest. Due regard being given to the support of the structure. When the vessel is drained the voids appear as lingering wet spots which can be chalk marked for later drilling and repair.

Voids can also be found by rubbing a piece of steel over the hull and listening for variations in tone. This is not always satisfactory although large voids can usually be found.

The grouting of voids has often been done with small hand operated piston pumps. The wear on close fitting moving parts and the problem of cleaning has led the wider use of diaphragm pumps. Although the pressures are lower, they are cheaper, easier to maintain, and can still create enough pressure to spall plaster.

(h) No discussion of corrosion could be complete without mentioning the addition of chromium trioxide as investigated by Christensen and Williamson (1971). It is not so much a question of corrosion when chemical activity takes place in fresh plaster as it is one of flaws in the plaster. Chromium trioxide is now widely used to suppress bubble formation.

SEALING AND PAINTING

Many people still question the need to seal a ferrocement vessel. Although a large number have not been sealed and have not suffered any apparent deterioration, a conservative and recommended approach is to seal. Furthermore, sealing can yield some additional benefits such as increased resistance to abrasion and increases in mechanical strength as found by Disenbacher and Brauer (1973). In any case, it makes little sense not to seal since the expense and trouble is small compared to the total investment.

The performance of any selected sealer will be decided by the surface preparation, the method of application, environment at the time of application, and the number of coatings or the overall film thickness.

Generally surface preparation is done in several stages. The first is a rub down of the surface with an abrasive stone during the curing process. It should be done at this time, otherwise it is a difficult job. The rub down removes loose and projecting sand particles. Of course, this step would not be required in a female moulding process. Just prior to painting, the surface should be mechanically abraded again to remove dust and hydration products. In lieu of abrasion one may acid etch. This has sometimes led to difficulty from incorrect concentrations and the problem of cleansing the surface afterwards. Hunt (1974) has recommended phosphoric acid for etching because of the problems associated with hydrochloric acid.

Another method for surface preparation before painting is the use of a sodium silicate. This combines chemically with the released lime to make the surface hard and impermeable. It thus doubles as a surface preparation for painting and as a sealer. A description of the use of sodium silicates for marine ferrocement has been given by Oberon Enterprises (1973).

There is a good possibility of sealer failure if the surface is not properly prepared. In some cases strips of epoxy or fibreglass have been removed with a film of white powder on the back. According to Bingham (1974) the only way to be certain that this will not occur is by treatment with a proprietary product that he recommends. The product is almost certainly a sodium silicate with, perhaps, some modifiers to reduce surface tension. Bingham attributes the formation of the powder to moisture leaching through the plaster. Whether this is the case or not, it appears from a few local applications of sodium silicate that it is the solution to coating problems.

Excess moisture in plaster can be a problem. In areas of local thickening such as around ballast, moisture often remains for many months after placement. These areas often cause coatings to blister if they are painted too soon. They should be regarded as potentially wet and requiring some additional time for complete hydration and drying.

Sealers are probably best applied with a brush. A vigorous scrubbing action will cover the humps and hollows on the surface whereas spraying or rolling may not. The manufacturer's instructions must be followed carefully. Some failures of sealers have been the result of inadequate thinning of the first coat. The viscous liquid has not made physical contact with the small indentations and the adhering area has been too small. Other failures have been traced to too long between additional coats. Since epoxies form a waxy substance on their surface while curing, it is imperative to apply further coats before the curing process is complete.

Direct sunlight has also caused difficulties. It cures the coal tar epoxies too rapidly making the usual recommended time between coats too long. Chlorinated rubber in sunlight is subject to pinholes from the mechanical drag of the brush on the fast drying coating.

Although one undiluted coat of a coal tar epoxy over one thinned coat is probably adequate an additional coat is preferred. Some coatings do not build in thickness well because of low viscosity or because they dissolve previous coats.

Coatings have failed from the action of internal corrosion, improper formulations, internal voids filled with seawater, oil based paints reacting and many for unknown reasons.

The only experimental investigation of coatings specifically for marine ferrocement known to the authors is the investigation done by the British Columbia Research Council (1972). The systems tested, however, did not include the total range of possible coatings and permeability was not measured.

CONCLUSIONS

Builders have an obligation to be careful with weights because the material is heavy and can build-up rapidly. This can be accomplished primarily by reducing cover over the mesh to an absolute minimum and avoiding local thickening at structural intersections.

Corrosion can be prevented by: avoiding exposed reinforcing steel by inside tying and the fitting of rubbing strakes and cappings; exposed and submerged metalwork in electrical contact with the armature should be avoided and the electrical system should be isolated from the armature; the plaster should be sealed and corrosive anti-foulings avoided; a cement resistant to sulphate attack should be used and placed at a low water to cement ratio; the possibility of voids should be reduced by avoiding steel build-ups and too stiff a plaster; voids should be located by the water test, preferably, and filled.

Coatings should adhere if attention is given to surface preparation, adequate thinning, avoidance of direct sunlight, and if the manufacturer's recommendations are followed.

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THE ECONOMIC NECESSITY FOR THE CONSTRUCTION OF "PRODUCTION LINE" SHIPS IN AUSTRALIA.

'by'

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SUMMARY

In this paper I shall try to point out the possible causes of the low profit and the high rate of failure in the small shipbuilding Industry in Australia, and possible steps that can be taken to improve the situation.

The reasons for this unhappy position that the Australian Shipbuilding Industry finds itself in are many, and in fact do vary somewhat from yard to yard, a point that I shall try to clarify at a later stage, but in general the following 5 basic points are the main reasons.

1. Lack of continuity of orders.
2. Failure of yards to build production line type of vessels (Partly caused by point one).
3. Insufficient incentive for yards to modernise and increase capital expenditure.
4. Overheads that are too high because of inefficient use of facilities and high cost of tendering and production planning.
5. Loss of production through strikes and demarcation.

It is obvious that to get the Shipbuilding Industry out of it's present difficulties something should be done about the 5 points mentioned above and the rest of this paper is devoted to submit certain suggestions how this could be achieved, or at the very least improve the situation from what it is at present.

STRATEGIC ISSUES, POLICIES AND PLANS (3).

In determining an economic and competitive strategy for a company, within a certain Industry it is necessary to first analyse (a) the present state and future of the industry and (b) the distinctive competence of the firm and the requirements for successful competition within that industry.

It is fairly reasonable to say that in Australia the demand for small vessels in the 15-60 metre range has not been sufficient to ensure a steady flow of work for the Australian Shipyards engaged in this type of vessel on a regular basis. However, occasional heavy demands are experienced and if therefore ways and means could be found to even out these peaks then a much more suitable work flow would result. Furthermore the strategy and long term planning of each yard or group of yards should be aimed at specialising in the type of vessel that it can do well either because of experience, locality of

the yard, or capacity of their facilities. In other words yards should not build vessels that they are capable of building but they should build vessels that they can build especially well.

Of course what I'm stating is nothing new and it should be assumed that everyone is familiar with this type of thinking. The reason therefore that these fundamental rules are not applied anywhere near as much as they should, must be sought not in a lack of desire from the part of the shipyards but perhaps more in the conditions as they apply at present in Australia.

SHIPYARD LAYOUT AND OPERATION.

Several good articles have been written about this subject and I think that very little can be added. The ideal situation is of course, when we consider a new yard, in which case the layout can conform to modern construction methods and the type of vessel that the yard considers that it will be mainly involved in.

Basically the main principals are the same for any type of steel vessel. Steel and all other raw materials should enter the yard and should go through various processes in an unbroken line, to be formed into sections suitable for the lifting capacity of the yard to be assembled at the position in the vicinity of the launching area.

The planning of the construction of a vessel to follow the pattern as such, is not a great problem and in fact is relatively simple (see Fig. 1 & 2 of bar chart concerning 85' prawn trawler). However the true difficulty is not to prepare a construction programme but to adhere to it. Delays in delivery of materials, shortage of labour, alteration and additions all tend to delay the construction of a vessel. If this would apply uniformly to all vessels under construction in the yard then this in itself would not create any great difficulties other than late deliveries, tying up of shipbuilding capacity and consequently reduced profits.

However, if this happens in a yard which applies the modern production flow methods as described above and one vessel is being held up because of any one reason, then of course it follows that the vessels behind it are equally effected unless they are taken out of the system and by pass the "bogged down" vessel, thereby transferring the yard from one that was applying a production flow into a yard where vessels are built side by side independent from each other. In other words the yard will take a step back and thereby ignoring all modern production methods.

Needless to say that such a step results in far reaching consequences and will have an enormous effect on the profitability of the yard. Some of the extra costs are obvious and can perhaps even be recovered from the client, but experience has taught me that most of this cost is hidden and cannot be recovered and therefore serious losses are usually the result.

Unfortunately in Australia delays in ship construction brought about by shortage of materials, strikes, demarcation disputes and in some cases government red tape are more the rule than the exception. Therefore to improve the situation and arrive at a more orderly production flow these problems must be eliminated or at least greatly reduced. Time and space does not allow me to go into every aspect here mentioned and I dare say that such an undertaking should be carried out by the Australian Shipbuilding Association or a similar organisation.

In the meantime each yard must cope with these problems individually and try to reduce them to manageable sizes. Although there are various ways to tackle these problems with variable degrees of success I do feel that by far the most successful measure would be an Australian wide campaign to direct the shipyards into the area of production line vessels.

Yards that are engaged in "production line" type of construction are far less subject to the dangers as described earlier on for a number of reasons that I shall try to clarify and are therefore more profitable, and in my opinion, an economic necessity. This of course is nothing new because shipyards in Europe have long since proven this and in fact countries that at one stage were unable to build vessels for export because of their high wage structure in their particular country found that by man producing one or more types of vessel they could in fact compete more than favourably with countries that had much lower wage structures, the reason of course was fairly obvious. Large savings in production which meant lower prices and also much better and more reliable delivery times, resulting in much larger turn over, better use of facilities, less overhead etc.

Therefore because of the importance of the construction of standard type vessels, I would like to explain in this paper our personal experience, that we had with the construction of production line type vessels and the large number of direct and indirect benefits that it had on the output of our yard and profitability as such.

PRODUCTION LINE TYPE OF VESSEL.

The first and most important requirement to improve the Shipbuilding Industry in Australia is, in my opinion, to reach a stage where most if not all yards are standardising in some form or other on one or more particular type of vessel. Some attempts in this direction have already been made ourselves and some other yards with variable degrees of success.

It is interesting to note that where ever this failed it was invariably due to a lack of orders, clearly indicating that the limited market in Australia is one of the main reasons that "production line" vessels are hard to establish in Australia, unless ways and means are found to increase the market for vessels, either by export incentives or perhaps by some financial encouragement to the prospective buyers of vessels.

The exception to this has been the Fishing Industry, where over the last few years a healthy market did exist although all indications are that this also has come to an end, at least temporarily.

It seems to me that an extension of the subsidy as it stands at present to vessels built for export would have the desired result, that is to say to enlarge the market sufficient for ship yards to start construction of production line type of vessels and maintain the necessary steady flow of work required. Once the flow of work has been established, production cost will come down progressively and consequently subsidy could be reduced on a sliding scale and in fact could probably become unnecessary.

The real benefit would of course be a much cheaper and better product for the local market.

To illustrate this let us consider all the savings that are possible if a yard could produce a production line vessel without interruption and without being forced into the construction of other types of vessels. As an example I shall take a trawler at a value of say $500,000 and based on our experience show you the actual savings that can be made. In addition there are some intangible benefits that I will explain further.

1. TENDERING COST.

Naturally on a production line vessel this cost will be almost eliminated because it is a cost that once it has been established can be divided over say 10 vessels and from there on all that is required is a periodically up dating of this cost, which can almost be automatic and requires very little cost indeed. Another big advantage often overlooked is that it eliminates the necessity of tying up essential and often over worked management staff. It may be argued that this should not be necessary because the estimator should know his job, and should therefore be able to handle it alone. However it is my experience that in a small shipbuilding yard invariably, managers, production managers, draftsmen and even works foremen are actually taking part in the preparation of a tender.

Obviously this results in a deterioration of their actual jobs and this hidden cost of tendering is in my opinion often far more serious than the actual known cost as reflected in the costing sheets of tendering.

Because of this any small shipyard would be well advised to consider this and to double it's known cost to arrive on the actual cost of tendering.

2. CONSTRUCTION DELAYS.

It is well known that construction delays do invariably occur on custom built vessels. The reasons for this are many but the following are the main ones to be considered.

a. Changes during construction.

b. Delays of delivery of materials and equipment or indecision by the owner or naval architect on what type of equipment

to use.

c. Delay with working drawings.

d. Learning time for shipyard employees and possible mistakes by same.

e. Failure during trials because of faulty workmanship caused by unfamiliarity of shipyard workers to the particular design.

f. Failure during trials because of faulty design.

The cost to the owner caused by delays in the construction of a vessel has often been emphasized and has been the cause of many bitter arguments between ship owner and shipbuilder. Less known however is the enormous cost to the shipyard mainly because the cost is a hidden cost and it is often very hard to determine the actual extent of the losses to the shipyard caused by the delays.

In the past this cost was far less serious because not only did loss of labour hours (production) have less impact on the total cost of the vessel but also vessels were built site by site as it were with each group of employees building a vessel from the beginning to the end and consequently, if the construction of a vessel was held up for any particular reason, it did not effect the completion of other vessels.

Nowadays the position is vastly different. Employees are now specialised and virtually each employee is engaged in each vessel during some part of the construction. Because of this it follows that a delay in one particular vessel will seriously disrupt the construction of all vessels in the yard because the employees that should be available at a certain time for the next vessel are being held up on the first vessel and the result is a serious upheaval of the production programme on all vessels under construction and consequently a considerable loss of profit for the shipyard, which very seldom it can recover.

With a production line vessel delays are much less likely to occur for reasons already mentioned and therefore this serious profit/loss can usually be avoided.

3. LESS LEARNING TIME OF EMPLOYEES.

No matter how good a tradesman is and how detailed the working drawings the fact is that if a vessel is new to a workman he needs a lot more time to do his job than on a vessel that he knows well. To all of us who have done work of a technical nature whether it is in a shipyard or on a motor car it is a well known fact that when you do the same job for the second, third or fourth time it is a lot easier and we can do the same thing in almost half the time. The only exceptions to this are perhaps the welders and painters although they also will improve with additional vessels by directing boilermakers how to re-arrange certain jobs so that their times also do improve.

Of course this is nothing new, and in fact most of the arguments used in favour of production line vessels or any

product for that matter is to reduce labour hours.

We can no longer afford the luxury of having a staff of shipyard workers going through the process of virtually learning to build a certain type of vessel and then afterwards do away with this new learned knowledge by giving them a totally new type of design to build. It may be desirable from a workers point of view but it is against all logic and it certainly is making inefficient use of skilled labour which as we all know is a very scarce commodity these days. So therefore it should be obvious to all of us that a waste of skilled labour in this fashion is in direct contradiction to all we know of modern production methods and time and motion studies and simply should not happen. The cost of learning on the job which does happen on a one of a type vessel is a cost we can no longer afford.

4. WARRANTY WORK AND CORRECTION TRIALS.

This is rather intangible saving but nevertheless a very real one. With production line vessels produced in our yard it was found that corrections of faults after trials and/or warranty work was greatly reduced in comparison with one of a kind vessels. Naturally this is logical because all faults found in the proto-type vessel whether they were a design fault, wrong type of equipment, or simply faulty workmanship, all of those were corrected on any future vessels.

This is far more important point than it may appear to be on the surface. The fact is that if a certain vessel requires a fair amount of fault corrections after trials then shipyard labour must be made available and must invariably be of a highly skilled nature. Of course this is not always available so that labour has to be taken out of the production of other vessels under construction and thereby causing disruption in these areas, a fact that I'm sure most work managers in shipyards are very well aware of.

5. DEPENDING LESS ON HIGHLY SKILLED LABOUR.

In the production of production line vessels it stands to reason that a lot of work that is normally of a highly specialised nature can be turned into a routine job. After the proto-type vessel is completed detailed work drawings of sketches can be made of all types of fittings that were installed by a tradesman that had to work most of it out "on the job". It follows that on any future identical vessels these fittings can be installed by a tradesman of much less ability because the actual "on the job" design work has already been done for him. It might be argued by some Naval Architects and draftsmen that this should not be necessary if there are sufficient drawings, but those who are more in touch with the actual construction of a vessel know that drawings are never complete and a lot is left to the skill and ingenuity of the skilled tradesman.

If therefore we can reduce the necessity for this highly skilled labour and use labour of lesser ability the advantage is of great significance. The availability of lesser skilled labour is obviously much greater and therefore delays through lack of skilled labour can be avoided, thereby making considerable savings.

Also shipyards operating in Australia, with a very limited pool of highly skilled metal tradesmen are very much subject to pressures from outside, especially when large construction programmes are undertaken in the vicinity of their shipyard.

In such cases they stand to loose a big percentage of their skilled labour which are lured away by the very high wages that usually apply at these short term projects. The lesser skilled tradesmen are less likely to leave their secure employment in exchange for a short term gain and therefore it is of considerable benefit if a shipyard can make more use of lesser skilled labour, in other words, is less dependent on highly skilled labour which as I stated is such a scarce commodity.

Obviously the only way to achieve this is by the construction of production line vessels and thereby avoiding the delays, costly mistakes etc. because of shortage of labour, and the financial benefit that grows out of this is perhaps the most important single argument in favour of production line vessels.

6. DESIGNING TO SUIT YARD.

This also is a very important part of the cost saving of a production line vessel. The fact is that although we all know that the basic concepts of Shipbuilding are the same, and we are familiar with the perfect layout of a modern shipyard, reality demands that we take note of the actual facilities available to the shipyard and the talent and availability of labour employed, plus various other local reasons such as supply of materials, agencies, sub-contractors and many other considerations that vary from yard to yard.

With a custom built type vessel the naval architect will aim to design a good vessel but he can hardly be expected to design it to specifically fit in with the facilities and conditions of a certain yard, unless he was instructed to do so. The result is that for those shipyards where the design does not fit in with these facilities etc. the vessel will be more expensive to construct than it really should be.

On the other hand if a vessel is designed as a production line vessel specifically for one particular yard with their facilities, lifting capacity and all other abilities and limitations considered, in other words tailor made for that yard then obviously that yard will be working without handicaps and to it's maximum capacity. This does not mean that the vessel should not in any way be inferior to a custom built vessel. Far from it. The very reason that the vessel is designed to make maximum use of the shipyards facilities and ability should ensure a better vessel than what possibly could have been achieved otherwise.

7. DESIGN COST.

Obviously this cost will also be greatly reduced and in fact almost eliminated with a production line vessel, because the vessel will be designed only once, and afterwards all that may be required is an occasional updating of drawings if

improvements or corrections are made. The cost of the design therefore can be written off over the expected number of vessels that the yard expects to construct of this particular type. In our case this usually ranges around 10 vessels so that we usually spread the design cost over 10 vessels.

No doubt a yard could build a larger number of a standard design if they were to concentrate on one type only, but of course the limitations of the market do require more than one standard design.

8. USE OF SUB-CONTRACTORS.

In the Shipbuilding Industry a great deal of use should be made of sub-contractors somewhat similar to the building Industry. This not only eliminates capital outlay for the necessary facilities but also makes the shipyards lot so much easier during slack periods. Sub-contractors that do work for a ship yard will find alternative work outside during periods when work in the yard is insufficient to keep them fully occupied.

However on custom built vessels it is always a problem to programme these sub-contractors into the job exactly at the right time. Naturally on production line vessels this is far more predictable, and once more a cost saving is made because with the sub-contractors entering the job on the exact moment required, no unnecessary delays will be the result.

REPAIR WORK

Most yards in order to survive especially the smaller yards do undertake repair work in addition to new construction. Although this is very beneficial in times when new construction is at low eb, it is a great disadvantage when repair work does coincide with peak volume of new work.

When this happens a very heavy strain is put on the yard and the employees, and often creates chaos. An additional difficulty is that repairs usually require a high degree of skill from the tradesmen because more often than not they work without drawings and it is only their skill that can make the job successful. The result is that the works foreman will only put the very best tradesmen on the job and if he cannot find a sufficient number, he will take them away from new construction.

This is bad enough if the yard is engaged in production line vessels but usually the gap can be filled with tradesmen of somewhat less ability. However on a custom built vessel this is far more serious and the construction programme of this vessel will then be seriously disrupted.

Another area to be considered is spare parts. If the repair vessel is a production line vessel which was built at that particular yard then the yard will most probably have all the spare parts available and the repairs can be carried out in a much quicker and more efficient way without disrupting any new vessels under construction.

COST SAVING SUMMARY.

Approximate savings then can be made on a production line trawler as against one of type trawler based on actual experience. (Value $500,000)

	One of type Trawler	Production line Trawler
Design Cost	$30,000	$5,000
Tendering Cost	3,000	500
Learning time - employees	35,000	-
One of design instead of design prepared especially for yard.	5,000	-
Increased cost of sub-contractors One of type vessel	7,000	-
More delays one of type vessel	5,000	-
Warranty work	5,000	2,500
	$90,000	$8,000

Saving $82,000 = 14.4%

INTANGIBLE BENEFITS.

Happier clients because of better delivery times and generally better performance because of proven vessels. Less dependency on skilled labour. Larger turnover and better use of facilities.

When we consider the fact that a conservative cost saving of 14% can be achieved by purchasing a production line vessel as against a custom built vessel, it does seem strange, to say the least, that to a very great extent boat owners still insist on custom built vessels. Of course sometimes this is unavoidable. For instance, if the vessel is limited to a certain beam because of the width of a canal or bridge, or perhaps the draft is limited to the depth of a river or harbour. But in most cases these limits do not apply for Australian vessels.

So the only reason left why a shipowner may want a custom built vessel is the personal satisfaction that the vessel will be in exact accordance with what he wants. I have no quarrel with this way of thinking but I cannot help but feel that the shipowner does not want the best and fastest boat that he can afford but rather the cheapest and slowest that will do the job.

The fact is that we must accept conditions are changing fast and very soon the time will come that the one of design boats will become a thing of the past just as much as sailing boats did, and we might as well get used to it. The task of naval architects is to look for better and cheaper ways of construction based on the concept of mass construction and surely here in Australia we have got a great deal of talent among our Naval Architects that can do this quite successfully.

CONCLUSION.

From the facts and figures stated I think it is fair to assume that using economics as the criteria their is no doubt

that the Shipbuilding Industry in Australia should and in fact must move towards the objective of standard type vessels.

There are, as I have pointed out various ways to achieve this and none of them are easy. The government also should take an active part and should find ways and means of providing incentives for shipyards to change to "production line vessels" construction. This could perhaps be done by assisting with export subsidy and possible tax incentives etc.

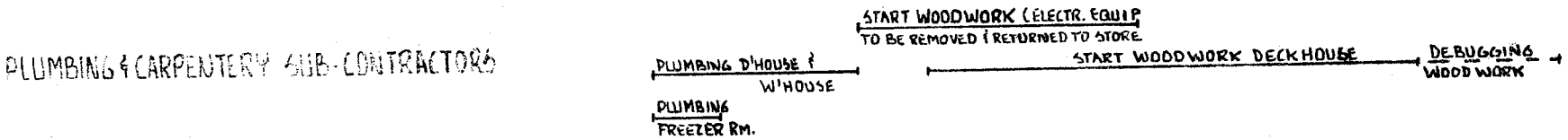
Of course it is not only the government that should encourage this change in the traditional way of shipbuilding. The shipyards, shipowners, naval architects and unions also must be very much aware that every possible way should be found to achieve this.

I think that it can be safely concluded that the change over by shipyards into the area of a production line product is an economic necessity and unavoidable and we simply do not have a choice. At present the shipyards in Australia are working uneconomically and as a result the industry has a high rate of failure. The track record of the Shipbuilding Industry over the last few years has certainly not been a good one and I think it is fair to say that in one way or another we must have all been responsible for this.

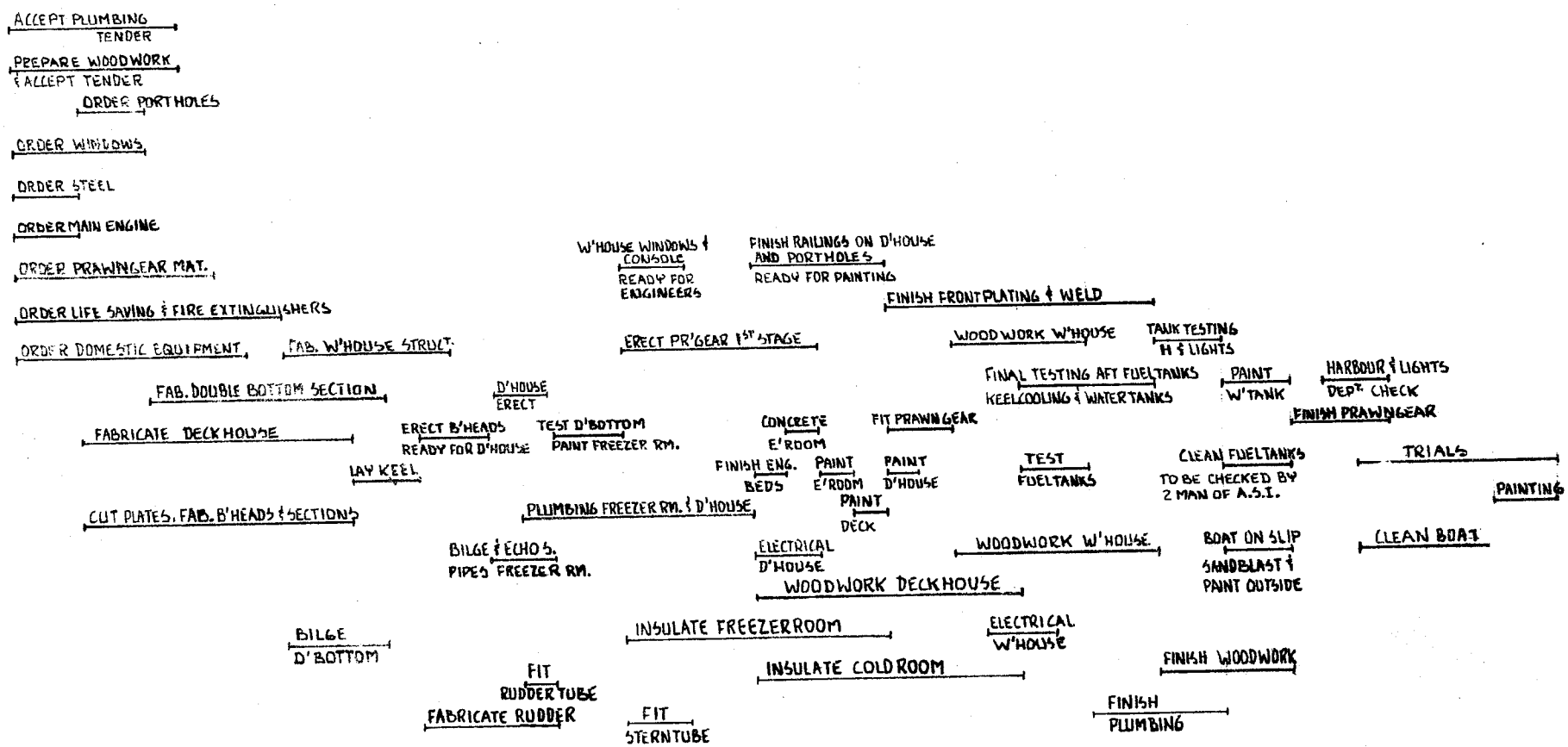
The yards, because of their lack of co-ordination and insufficient forward thinking. The naval architects, for neglecting economy of construction in their designs, the government for insufficient encouragement to yards to modernise and re-equip their facilities and for subsidies and last but not least the unions, for their obsession with demarcation lines.

Fig. 1.

AUSTRALIAN SHIPBUILDING INDUSTRIES BAR CHART FOR 85FT. PRAWNTRAWLER



AUSTRALIAN SHIPBUILDING INDUSTRIES



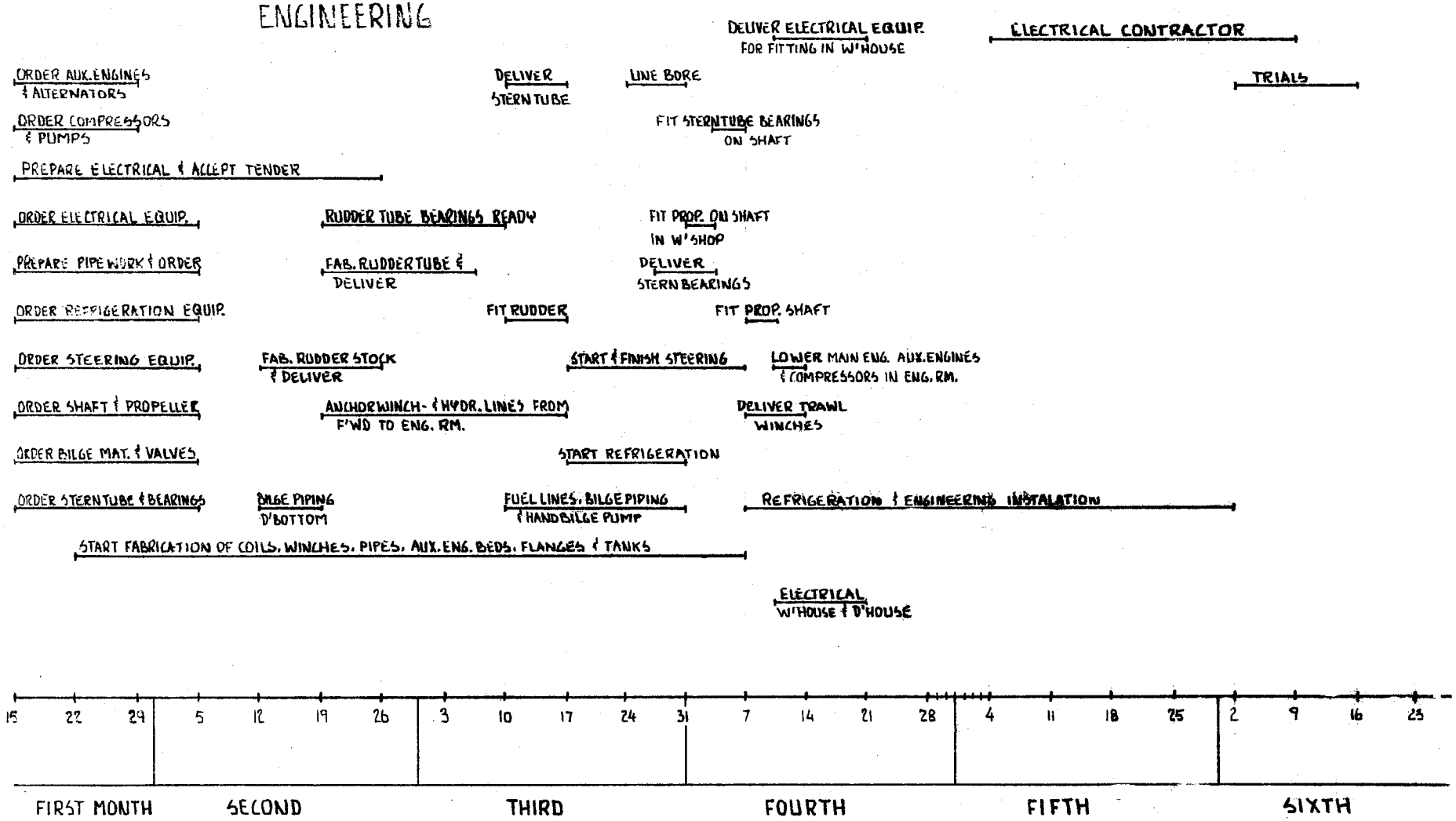

ENGINEERING
DELIVER ELECTRICAL EQUIP. FOR FITTING IN W'HOUSE
ELECTRICAL CONTRACTOR
ORDER AUX. ENGINES & ALTERNATORS
DELIVER STERN TUBE
LINE BORE
TRIALS
ORDER COMPRESSORS & PUMPS
FIT STERNTUBE BEARINGS ON SHAFT
PREPARE ELECTRICAL & ACCEPT TENDER
ORDER ELECTRICAL EQUIP.
RUDDER TUBE BEARINGS READY
FIT PROP. ON SHAFT IN W'SHOP
PREPARE PIPE WORK & ORDER
FAB. RUDDERTUBE & DELIVER
DELIVER STERN BEARINGS
ORDER REFRIGERATION EQUIP.
FIT RUDDER
FIT PROP. SHAFT
ORDER STEERING EQUIP.
FAB. RUDDER STOCK & DELIVER
START & FINISH STEERING
LOWER MAIN ENG. AUX. ENGINES & COMPRESSORS IN ENG. RM.
ORDER SHAFT & PROPELLER
ANCHOR WINCH- & HYDR. LINES FROM F'WD TO ENG. RM.
DELIVER TRAWL WINCHES
ORDER BILGE MAT. & VALVES
START REFRIGERATION
ORDER STERNTUBE & BEARINGS
BILGE PIPING D'BOTTOM
FUEL LINES, BILGE PIPING & HANDBILGE PUMP
REFRIGERATION & ENGINEERING INSTALATION
START FABRICATION OF COILS, WINCHES, PIPES, AUX. ENG. BEDS, FLANGES & TANKS
ELECTRICAL W'HOUSE & D'HOUSE
15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23
FIRST MONTH
SECOND
THIRD
FOURTH
FIFTH
SIXTH

Fig. 2.

DEVELOPMENT OF A MODERN SHIPYARD FOR SMALL VESSELS.

by

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Summary.

The purpose of this paper is to outline the history of Carrington Slipways, their transition from an obscure timber boat builder and repairer to a major Australian shipbuilder of small and medium sized steel vessels.

Outlined in the document is the ship research, design rationalisation, marketing policy, organisation structure, control systems and construction methods necessary to gain maximum benefit from the recently constructed flow line shipbuilding facilities at Tomago, N.S.W.

Company History.

Carrington Slipways, a privately owned family company, began operations with a small hand operated slipway in 1958. A 160 ton capacity power slipway was installed as the company extended repair operations to commercial vessels, which included barges, fishing boats and workboats. During this period the company negotiated its first new construction contract, a cable driven, twelve car, wooden vehicular ferry. This contract necessitated construction of a building berth, or more correctly, a building wharf as there was no available land on the restricted site where the slipways was located.

Improvisation was a necessary ingredient for survival in those early days for the estimated cost for a conventionally constructed wharf was more than twice the contract value of the ferry and certainly a lot more than our finances could withstand.

The alternative was to place short pile stumps on the harbour bed at close intervals to support the wharf bearers. Decking was completed with second-hand wharf material and despite the unconventional methods and some criticism, the wharf withstood some 50 launchings and is still standing today.

Much to the dismay of the owners' representative, the ferry was constructed upside down, allowing much easier and faster work in planking, caulking and sheathing of the bottom section. When the hull was complete, it was launched upside down and tarbuckled over in the water. The decking and outfitting were then completed afloat.

The principle of inverted construction is still used by the company today, however, since that initial launching, all vessels have been turned over prior to launching.

Carrington Slipways first venture into steel construction came with a contract for two large vehicular ferries. Initially the steelwork was subcontracted and then by direct employment of metal working labour.

In 1962 a contract was won to build two ocean-going steel hopper barges and it was then that the first of the yellow overhead gantry cranes became a landmark for the company beside the Cowper Street bridge in the Newcastle suburb of Carrington.

In addition to the construction of ferries and barges from 1964 much of the work was for vessels used in shallow water around Northern Australian and neighbouring islands.

It was in 1965 that the firm built its first tugboat and began exporting vessels to New Caledonia and other Pacific areas.

It was found that there were several limiting factors in applying the principles of the big yards to our needs.

The most glaring factor was the enormous capital outlay to develop a yard for the purpose of an assembly line method necessary for the "series production" concept adopted for the international market in the medium and large ship field.

The bigger yards can expect a long term run when applying this concept whereas ours is a market that demands limited numbers of diverse types.

With the foregoing in mind, it was decided that the new yard would be designed around a "flow-line" principle. That is, we would incorporate the technology and controls of the big yards and at the same time have the flexibility in production to meet the needs of our customers.

The singular most important factor to consider was the attitude of the workforce to relocation of the shipyard.

Before any moves were made all employees were informed of the planned changes and the reasons why and were kept informed throughout the construction. Not one employee left due to the shipyard relocation.

When all the studies proved to be favourable, 40 acres of land were purchased on the Hunter River at Tomago, 11 miles upstream from the existing shipyard at Carrington.

The basic design for the new flow-line shipyard at Tomago (Figs. 3 & 4) contrasted sharply with the old yard at Carrington.

Twelve of the yards 40 acres were to be used for the flow-line extending 1,000 ft. between the steel fabricating shops and the southern end of the building berth situated on the river bank.

At Carrington, the shipyard area totalled less than 4 acres in three separate yards with the fabricating shop a quarter of a mile from the building berth.

The building berth area was so crammed that a second berth had to be constructed behind the main berth on the shores of Throsby Basin. As a ship was launched, sections of the next ship were transferred from the second berth to the main berth.

A total cranage concept as opposed to conveyors played an important role in feasibility studies as it was realised that cranes would give the flow-line the capacity to slow down, speed up or disperse production on processed steel. Conveyor systems tend to choke up when variations are required to the workload not in keeping with the conveyor design.

The Tomago flow-line would start with an 80' wide main steel fabricating shop. This was eventually to be 300' long, including a 100' section of sliding roof.

The sliding roof section of the fabricating shop would enable large ships sections to be kept under cover until ready to be lifted and taken further along the flow-line in 40 ton units by the gantry cranes.

On either side of the main fabricating shop were to be two smaller shops. One for special fabrications such as sterntubes and steering nozzles.

New construction continued to expand with orders for various types of smaller vessels and barges.

Ship repair also expanded but with erratic and heavy demands on labour were causing disruption to the shipbuilding programme.

Although ship repair was profitable, it was decided that the long term goals and ambitions of the company lay with new construction work.

Ship repair work ceased and the company concentrated on expanding its shipbuilding facilities.

This marked a real turning point in the firms development and it has been from 1967 that the growth of the work-force has shown a marked increase.

As the firm gained in experience, so its reputation increased and by 1968 contracts were won for more complex ships.

A 200' oil rig supply ship became Carrington Slipways largest order and necessitated the construction of a new building berth on land adjacent to the original site and a second overhead gantry crane added (Fig.1). The second crane, larger than the first, had a lifting capacity of 20 tons. Prompt delivery of the 200' supply vessel was the main factor in winning contracts soon after to build four more oil rig supply vessels (Fig.2).

The company adopted a research and marketing approach of persistent and personal contact with current and potential owners. A major break-through came in 1968 with the winning of a contract to build a 26 M twin screw ship handling tug. The owners had accepted our proposal that a small twin screw vessel would be more manoeuvrable, more economical and more powerful than the much larger single screw tugs currently employed. Certainly the purchase price was much lower.

This model tug has proven so successful that some 16 vessels have now been built, three being sold to Middle East owners.

Despite extension to the Carrington yards, it was obvious by the end of the 1960s that the assembly line methods needed for maximum efficiency could not be developed properly on the two sites at Carrington. As a result, a decision was made to relocate the shipyard.

CONCEPT AND PLANNING OF A FLOW-LINE SHIPYARD.

The idea of a flow-line method of ship assembly was conceived and developed during overseas study tours by company management.

Many small Japanese and European shipyards visited were in the main unimpressive and outdated when compared to their larger and more modern counterparts.

Modern shipyards designed to cater for the construction of very large bulk carriers had almost unlimited resources used in their planning and development and offered the greatest potential for study purposes.

Materials handling, panel lines, unit and block assembly, production planning and scheduling, information and control systems, standardisation of parts and units - couldn't these principals be scaled down to suit small ship construction? It was along these lines the basic layouts and feasibility studies were carried out.

The other workshop would house the machine shop of the newly formed engineering division established to handle the machining and engineering equipment manufacture which was then being subcontracted.

The 20 tonne cranes would travel virtually the whole length of the assembly line. Beyond the fabricating shop would be an assembly area where ships hulls would be assembled. Inside the workshops there were to be overhead travelling cranes ranging from 5 tonne to 10 tonne capacity. Designs have since been prepared for a 200 tonne gantry.

When as much of the hull as possible was assembled, in an inverted shape, it would then be turned right way up in sections and moved onto the 400' building berth (twice the size of that at Carrington) for final assembly, fitting of superstructure, installation of main engines and machinery and general outfitting prior to launching.

The building berth would be parallel to a specially dredged 400' long x 160' wide channel, which would open off the Hunter River at right angles. The channel was to have a low water depth of 15' and a high water depth of 22' on peak high tide conditions. (Carrington could only offer a 10' high water maximum).

The greater depth of water would enable more fitting out of ships to be done on the building berth before launching. This would be closer to the workshop, better serviced by cranes and more efficient than outfitting after launching. All major steelwork would be processed in one continuous flow-line starting in panel and fabrication shop through to the construction berth, allowing more efficient handling of units and components by any of the 15 overhead cranes servicing the area.

Adjacent to the building berth would be a series of stores and workshops, all within a few metres of the construction area.

Each contracting group would have their own lock-up workshop and store (painters and dockers, electricians, plumbers and joiners) enabling them to store their materials and equipment at the shipyard.

Construction of the Tomago Shipyard.

Following approvals of plans by statutory authorities and shipyard management, work on the new yard commenced in January, 1971 and was completed according to plan by May, 1972 to coincide with the launching of the Ship No. 71, the 29 M tug "Roebourne", the first vessel built at the new yard.

During the shipyard construction period, it was necessary to transport, separately, the 3 twenty ton overhead gantries from the old yard. This was achieved by rolling them onto barges on railway lines and shipping them upstream.

Plans were made for each department to transfer to the new site as they completed their work on the last vessel at the old yard. With few exceptions the transfer was remarkably smooth, mainly due to the excellent co-operation of the employees

DEVELOPMENT AND CONTROL OF SHIPBUILDING PRODUCTION.

During this expansion period, it became necessary to review the management organisation, planning and control systems.

The company was growing from a small family business into a medium size industry and required quite major changes from the present system. Some of the necessary changes were not realised immediately and caused a few growing pains.

Organisation Structure and Staff Training.

The administration was arranged into three main divisions, Contracts, Commercial and Shipyard with managers appointed to head each division.

The Contracts division is responsible for estimating, purchasing and contract administration.

The Commercial division is responsible for legal, financial, cost recording and all general commercial functions.

The Shipyard division controls all production including planning and scheduling of labour and materials.

The total staff upturn between 1969 (120employees) and 1973 (peak 300 employees) was 180, an increase of 150%. Most of the original 120 employees have remained with the company and now hold key positions.

The company adopted a promotion from within policy and only specialised staff were appointed from outside.

Training and personnel development were given high priority with "in house" training sessions as well as specialised outside courses for technical and management people. Strong emphasis is placed on human relations and communications training, such as the Dale Carnegie Courses, for we realise the good relations established over the years by personal contact has been a major factor in the companies success and must be maintained by all supervisory staff.

All employees are encouraged to attend Technical Colleges and fees were reimbursed on successful completion of the chosen subjects.

Strong emphasis has been placed on apprentice training. First year apprentices are given an introductory training course in the theoretical and practical aspects of all shipbuilding trades and techniques.

Following the initial training, they are put to work,and at regular intervals are transferred to various sections of the plant, including the drawing and planning office.

This policy of apprenticeship training, introduced several years ago, has resulted in a high class of trainee.

One recently trained apprentice is now assistant production planner and another, still in training, was selected as the district shipwright apprentice of the year.

Purchasing.

A large proportion of the equipment cost in a twin screw tug involves imported items, principally main engines, auxiliary engines, steering gear, rubber fenders, electronic equipment, fire monitors and navigation equipment generally from European manufacturers.

The delivery period on the completed vessel is dependent upon receipt of the imported items and an Australian shipyard has a two to three month disadvantage ex. yard delivery against European yards.

To combat the delivery lag of imported items, Carrington Slipways developed a system of forward ordering of main and auxiliary machinery. The forward ordering involves substantial funds and in some cases may limit the choice of manufacturer to the customer, however, the resultant shortening of the delivery time has won the company many local and overseas contracts.

By keeping a close liaison with material and equipment suppliers, our purchasing staff are able to obtain knowledge of overseas and Australian developments and processes. Information is then fed through to relevant levels and departments in the organisation.

As a result of extensive overseas travel by Carrington Slipways management, overseas "tie-ups" have resulted in an ability to rapidly acquire equipment and advice on new developments in products and research.

Marketing.

In the export area of competition, the Australian shipbuilder loses the benefit of close liaison with overseas operations. A two day promotion campaign by a European builder compared to a full flight four week promotion tour by an Australian executive. A mid-day personal telephone call as compared to the telex or late night/early morning international call.

These disadvantages are covered by the appointment of overseas sales managers in Europe, the Middle East and the U.S.A., who are constantly on call for the personal touch necessary in overseas negotiations.

Having previously exported overseas is of great benefit to the company. A working tug seen by a prospective operator is worth many thousands of drawings, brochures and words. Because of isolation we have endeavoured to bring interested owners to see our yard, or alternatively, our overseas products in operation, either wholly or partly at our cost. Having tugs in operation overseas has brought many more enquiries than paper publicity could ever have done, although intensive overseas advertising and publicity have been carried out.

Production Planning and Control Systems.

By careful planning, the line production, unit production, transport, painting and fitting out operations are controlled so that work flow is continued with maximum quality.

Methods improvement is the main area in which productivity can be increased and this is being vigorously attacked at all levels of Carrington Slipways staff and a department formed for this purpose.

Shipbuilding labour costs are high, however, ship design standardisation and rationalisation, together with strict control and follow-up, the work task is much more tolerable and inducive to efficiency.

Production planning is mainly achieved by the use of critical path network planning. At this point in time the network plan is developed manually, however, with the gradual introduction of computerised information, a more rapid revision will be possible when required.

The company is currently using a computerised wages and costing system and has plans to develop other systems for computerisation.

A numerically controlled lathe was recently placed in operation and with the realisation of the cost saving advantages of numerical control, an N.C. flame cutting machine was ordered. The N.C. flame cutter has yet to be installed, however, staff have been selected from within the organisation and are currently undergoing training in N.C. lofting and usage techniques.

Construction Methods.

Possibly one of our greatest advantages was the lack of traditional large ship construction experience.

The experience previously gained came from wooden boats and the method of inverted construction used in plywood construction was applied to the use of steel. Full plates were offered up for the shell, scribed and cut on the job. This method could be considered crude but in the main was much quicker and offered substantial labour saving, therefore, proving to be more economical than conventional methods.

Early equipment installation and outfitting was done as required on the job "or by ear". Steelwork was cut from the basic drawings using steel plates orded to size.

Today, with 12-15 vessels a year, many changes and improvements have been made.

Steel plate in standard 9 m x 3 m plates is purchased direct from B.H.P. and up to 1,000 tons are kept in stock to allow an immediate start on construction.

All vessels are secionalised, programmed and templated for total plate destruction.

A blast cleaning unit for steel pre-treatment was installed adjacent to the cutting shop.

Outfit and service installation details are now formulated by the drawing office and has proven a great benefit.

The systematic development of the drawing or "planning" function made it possible to optimise the early outfit principles as adopted in large ship construction.

Critical path analysis, labour and resources allocation scheduling are combined to produce production schedules both for long range purchasing, labour requirement and weekly production requirements.

This detailed planning helps maintain a balanced production programme, highlights problems which may affect completion dates, shortening building times maintaining delivery dates is of great importance. Six months delay or extra building time on a vessel worth $1M could cost the owner up to $50,000 in extra interest alone, without considering loss of earnings.

Close liaison with owners reduces the need for many expensive extras.

Portable work banks are installed to supply all services such as welders, power, gas, air and water adjacent to work areas and on ship under

construction.

Standard parts have been developed over a period and kept in stock for items such as hatches, port holes, davits and sliding water tight doors.

The potential for continual cost reduction is unlimited and must be pursued at all levels, never simply accepting what was good today will do tomorrow. Probably more responsibility for this reduction lies with naval architects than is realised. Recent experiences in Scandinavia indicate builders are designing vessels with economy of construction as the first criteria. Hence the abandonment of bulbous bows in favour of conventional bows. Engine room and accommodation modules are widely used.

Constant research into welding processes resulted in several firsts for our yard.

Trade Unions.

To be involved in commercial shipbuilding in Australia today means full involvement with all waterfront and maritime unions. To believe otherwise is suicidal. Our early and sometimes bitter experiences bear the scars of proof. Undoubtably this involvement increases labour costs considerably in certain areas and cause almost unbelievable frustrations.

Our company has learnt to live within the "rules of the game" and full union membership is a condition of employment.

Through many hours of personal involvement we have been able to establish good working relations and understand and achieve optimum results within the "system".

The Future.

The challenge is to improve the present, install new systems and equipment and avoid over capitalisation. This will mean research and development of many larger systems to suit our needs.

Much of this challenge will come in the area of computerisation. Recent research into mini-computers has revealed they are now viable as a production aid.

Conclusion.

Carrington Slipways, in 17 years, has expanded from a small family boat building business into a shipbuilder of international standing.

It is our belief that this has resulted from the recognition of the need to expand, research and develop new ideas, study new trends and developments and adapt them to suit our organisation, market standardised and rationalised ship designs and encourage good trade relationships.

We feel that we understand the objectives of the trade unions and recognise the need to work within this framework and encourage employee responsibility and involvement with a view to good industrial relations.

We feel that our future lies in the small ship field, however, should the opportunity present itself to enter into the medium or large ship field, we will have the capabilites to meet the challenge.

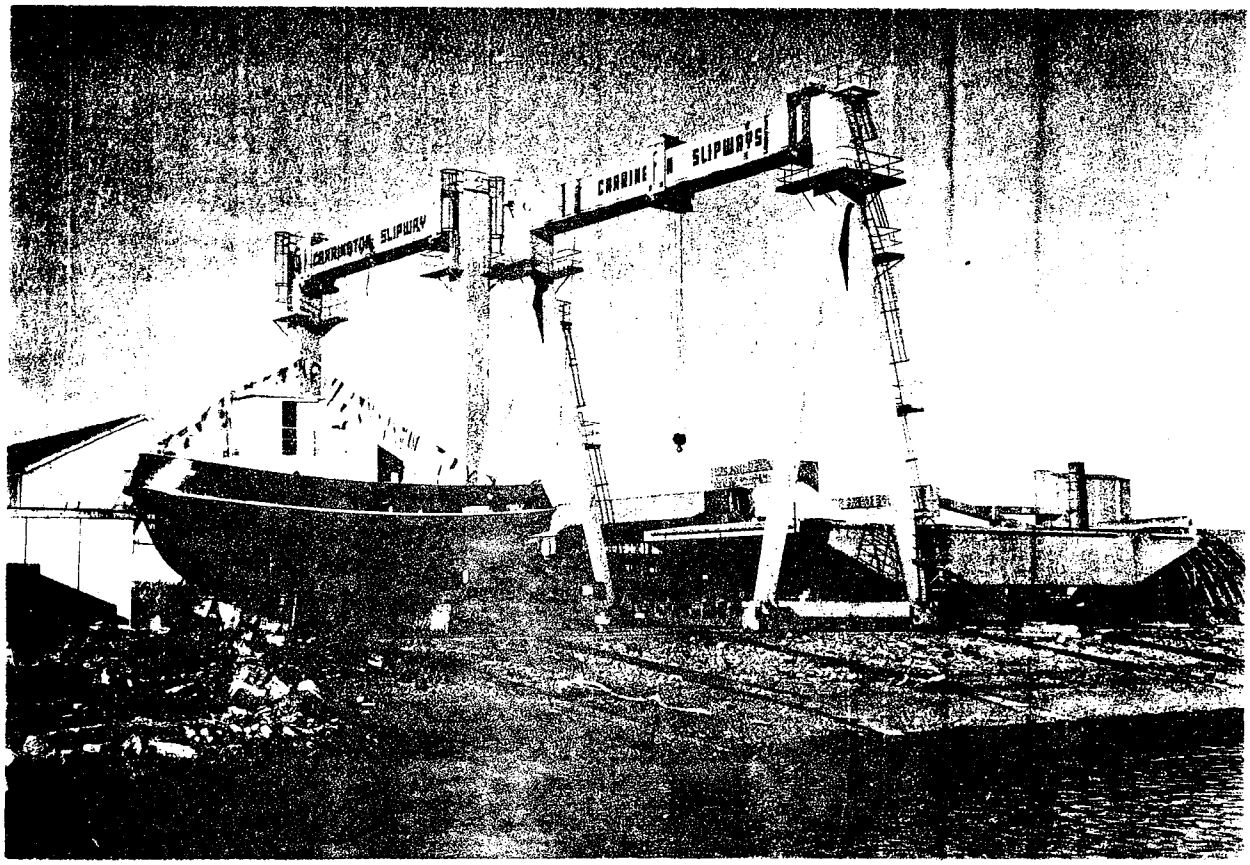

FIG.1 CARRINGTON SLIPWAYS PTY. LTD. OLD SHIPYARD, JULY, 1971.

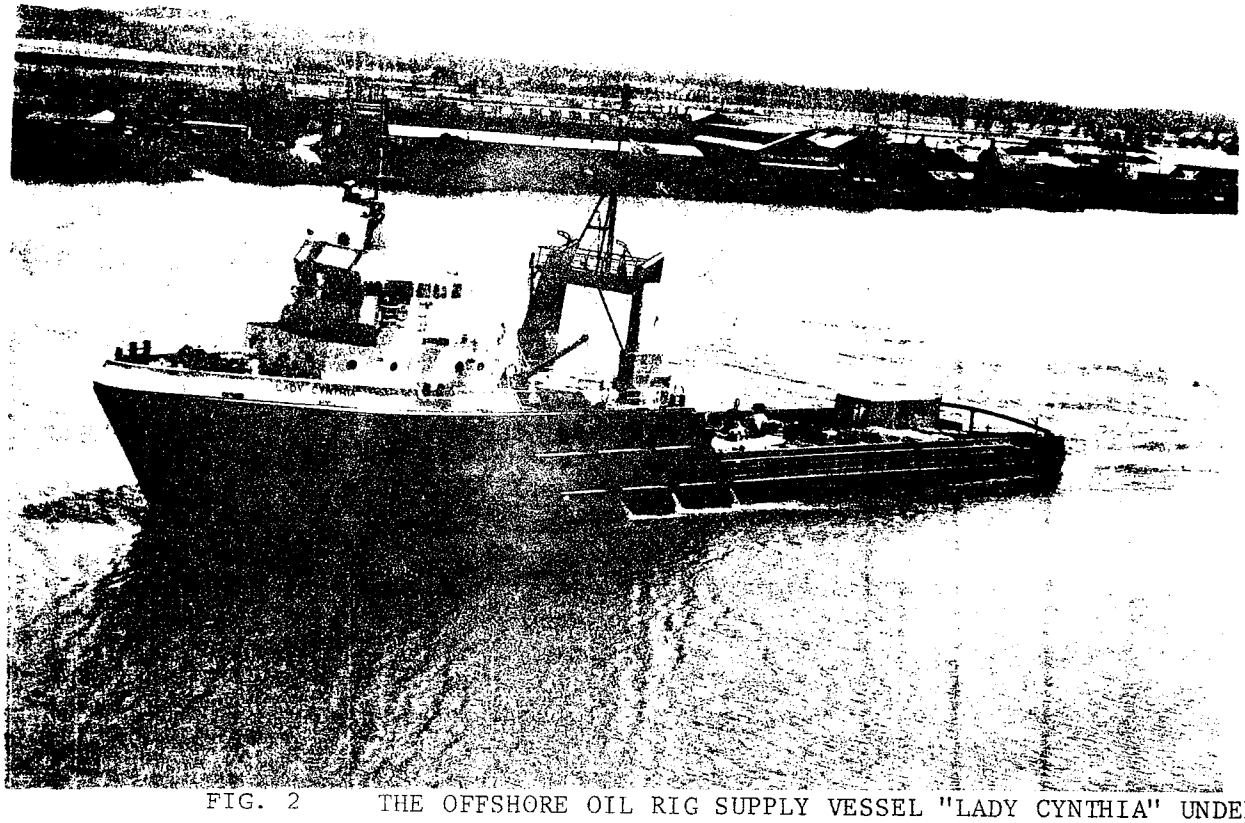

FIG. 2 THE OFFSHORE OIL RIG SUPPLY VESSEL "LADY CYNTHIA" UNDER TRIALS.

1. Administration office and Amenities
2. Electrical Sub-station
3. Bulk Oxy and L.P. gas
4. Fabrication Shop
5. Fabrication Shop Sliding Roof
6. Fabrication Shop Frames and Panels
7. Machine Shop
8. Fabrication Shop Amenities
9. Plate Storage
10. Production Office and Amenities
11. Store
12. Pipe Shop
13. Shipwrights (Fitting out & Loft)
14. Subcontractors
15. 3 x 20 ton Gantry Cranes
16. Building Berth
17. Launching and Fitting out Harbour
18. Car Park

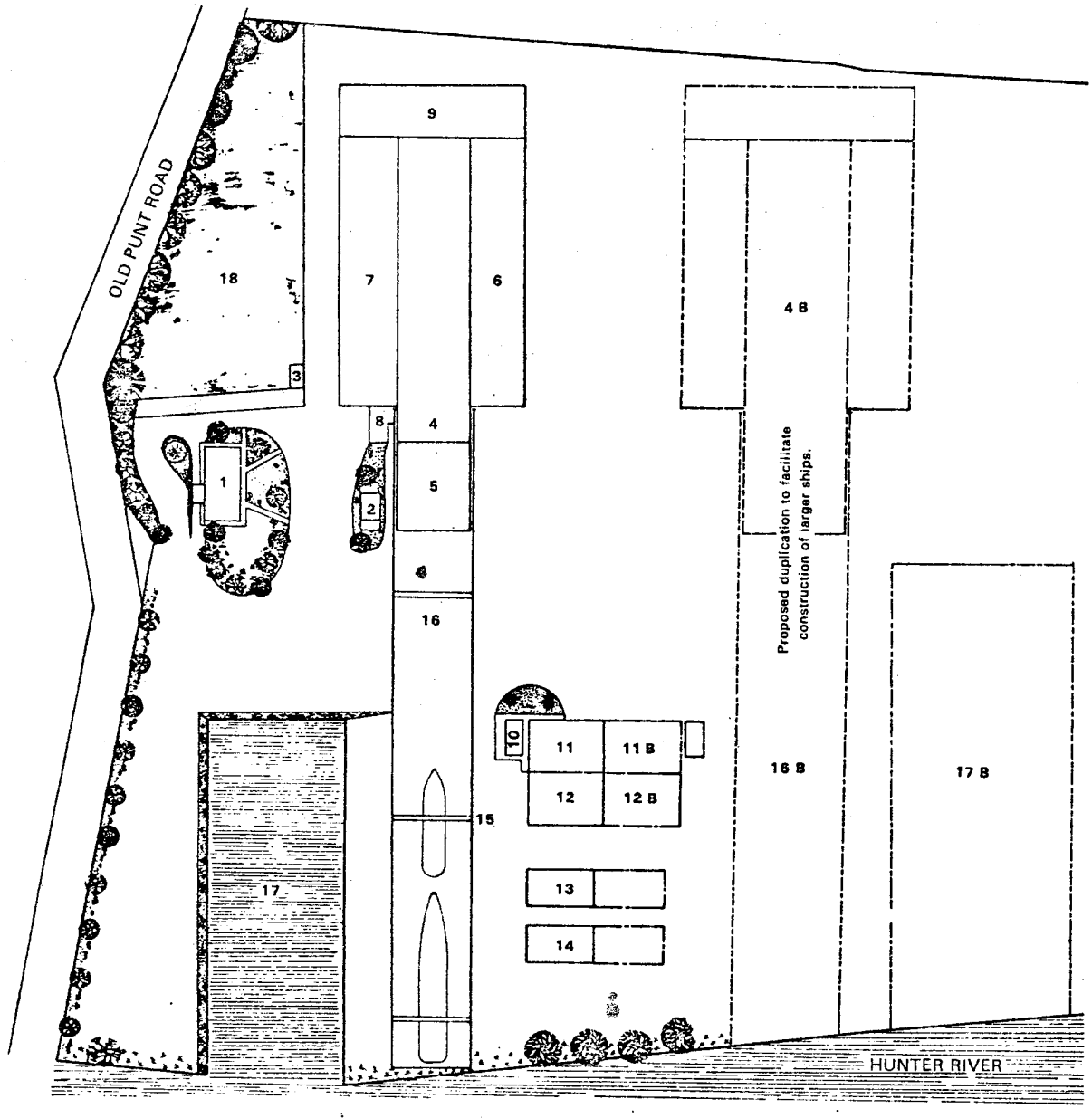

FIG. 3 CARRINGTON SLIPWAYS PTY. LTD. FLOW-LINE SHIPBUILDING

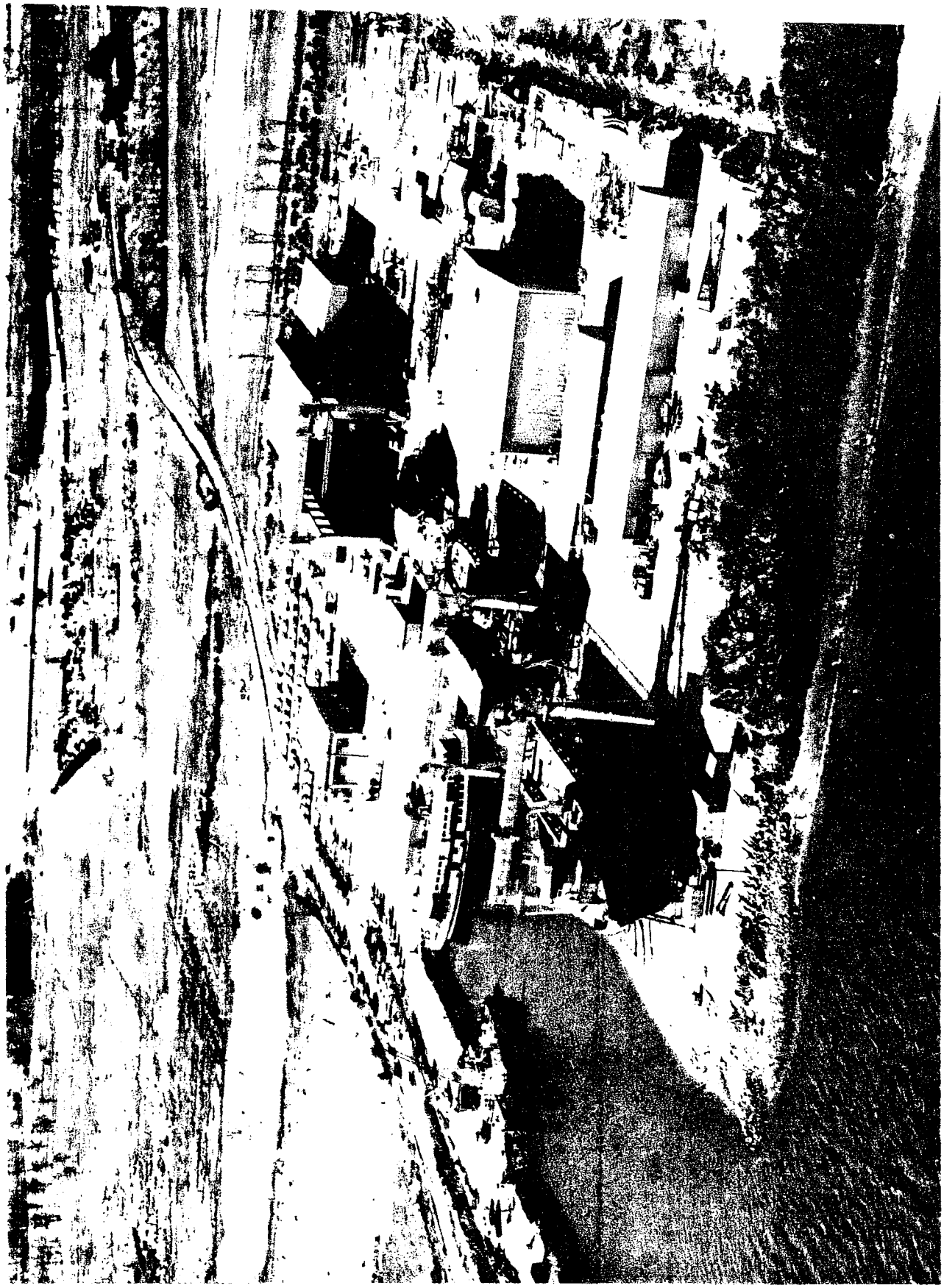

FIG.4 CARRINGTON SLIPWAYS TOMAGO FLOWLINE SHIPYARD, SEPTEMBER 1973.

G.R.P. HULLS - CONSTRUCTION AND TECHNICAL STANDARDS

by

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SUMMARY

A review is made of the development of glass reinforced composites in the marine application. Reference is made to construction techniques, including evaluation, material selection, and the special considerations of a low modulus structural material and fire protection. Material production problems are discussed with recommendations made for the maintenance of Quality and Quality Control.

INTRODUCTION

Since the inception of glass reinforced plastic around 1940, the applications for this material have developed over a very wide spectrum. The material has taken on the significance of an accepted, proven, and dare we say, tried structural material.

Acceptance in the marine field grew rapidly in the 1950's, particularly in the field of pleasure craft. Boat owners were attracted by the robustness and durability of this new material, and particularly by the dramatic reduction of annual maintenance costs. By the end of the 50's G.R.P. was the established boat building material rather than the exception. Conventional materials were no longer competitive, since production line techniques were reflecting favourably in the selling price of G.R.P. Hull units. In the 60's, 80% of all pleasure craft in the U.K. were produced from G.R.P., this pattern was repeating itself throughout Europe phased three or four years behind the U.K. market.

Commercial operators of small launches began to show a strong interest in G.R.P., in its capabilities, life span, low maintenance costs, etc. Probably the first established institution to recognise the potential of a G.R.P. hull was Trinity House of London. In 1963, Trinity House purchased two 40' launches for general pilotage duties in sheltered waters (Plate I). Both of these launches are still in operation and both have now exceeded 300,000 miles of operational duty with no structural rectifications. The conclusion of this investment was a progressive build-up of the Trinity House fleet to a level of some 26 launches. Numerous craft of different application have resulted from this and other similar developments.

The British Board of Trade was monitoring a similar revolution in the field of ships' lifeboats. Biennial surveys confirmed that despite the stringent operational requirements, levels of exposure and lack of maintenance, G.R.P. showed a clear lead over conventional materials, so much so that today, approximately 95% of the total of all ships' lifeboats produced throughout the world are manufactured in G.R.P.

The trawler market had long held an attraction to the G.R.P. moulder; however, the specialised nature of many of the craft, coupled with the restrictions imposed by Government Statutory bodies, has tended to prohibit a rapid growth in the U.K. In 1970, the White Fish Authority gave grant and loan approval for the construction of the first G.R.P. trawlers (Ref. 1). These craft were based upon a traditional design, the lines being drawn from proven boats in service. This single action has probably done more to allay resistance to this new material in a highly traditional industry (Plates 2. and 3).

More recently we have seen the completion of trials of the first self-righting fast afloat 54' lifeboat for the Royal National Lifeboat Institution. At a full load displacement of 30 tons, the craft obtained a speed of 19 knots on station (Plate 4).

To date in the U.K., boatyards have produced sailing yachts of up to 71' and power boats up to 85'. Developments underway will shortly push these sizes up. Outside the boat building industry, the most significant advance in the use of G.R.P. has been the construction for the Royal Navy of the "150" Mine Counter Measure Vessel H.M.S. Wilton. It has recently been released that a further design for a mine counter measure vessel at 200' is now underway.

Design Considerations

The marine moulding industry has developed as a contact moulding process in a female mould using polyester resin and E. glass reinforcement in a cold curing cycle.

Glass Reinforced Plastic is unique material insofar as the material forming the structure is made in situ as a homogenous matrix of glass fibre and polyester resin. Initially the glass reinforcement was in the form of chopped strand mat, subsequently other forms, such as woven roving and unidirectional mats have been introduced. Intelligent use of these reinforcements, and careful consideration

given to the direction of fibre orientation, result in optimum characteristics being obtained. A comparison of the properties of G.R.P. laminates and other marine construction materials is made in Fig. 1.

Hull construction falls into three categories.

1. Grillage Construction. A high design interface is required when adopting this type of construction, however, the resultant economy in the use of raw materials, and overall reduction in weight of hull unit, more than justify the additional overhead. The grillage concept follows traditional lines, with the exception that G.R.P. allows the incorporation of premoulded units e.g., tanks to be added into a structure and thus perform a dual role, such as a welded double bottom unit contributes to the strength of a steel ship (Fig. 2 and Plate 5).

2. Heavy Shell Laminate. This technique is associated with the use of a chopper spray gun, where high bulk of material is laid to produce a thick stiff skin, requiring minimum supporting structure. This system has been used in America for the production of large trawlers having a shell approximately 4 inches thick. The advantage of low labour intensity is offset by high material costs (Fig. 3).

3. Sandwich Core. The sandwich core principle has been applied to a number of hull mouldings. The design problem associated with this technique relates to the bond interface between the core and the skin, which is a potential source of sheer failure. Failure is very difficult to detect and once it has occurred, repair is almost impossible without major surgery.

One core material that has been used by the industry is end grain balsa. A high integrity bond can be achieved with a balsa core, and it has good sheer strength characteristics, particularly when impregnated with polyester resin; however, as a material it is not suitable for double curvature moulding, and coupled with problems of structural connections and attachment of fittings, its use in marine application has not really advanced. It is common practice, however, to produce flush deck units incorporating balsa core, these have shown good reliability on vessels up to 70' in length (Fig. 4).

EVALUATION OF STRUCTURE

Since there is still a shortage of historic knowledge, each design must be considered on its individual merits, and

designed from first principles. Vessels less than 65' are evaluated principally for panel loadings. Fig. 5 indicates a chart of hydrodynamic slamming pressures against speed and wave height (Ref. 2.). Shell thicknesses can be readily determined from fixed edge panel theory, provided deflection is limited to a maximum of t/2 (where t equals panel thickness). Frames are assumed to carry all the load input from the shell, the longitudinals in turn supporting the frames. Large hulls must be approached in a more stringent manner, as the Wave Bending Moments tend to produce buckling stresses in the bottom shell and deck laminates between the transverse members, and it is these that become the main criterion. Figs. 6, 7 and 8 indicate dynamic bending moment derived from a large hull using a system favoured by Halmatic.

Note that a speed function is introduced into the equation in the form of an empirical 'G' gradient added to the primary load curve thus producing a more realistic Bending Moment.

These figures can be fed into the structure and factors of safety determined.

Modulus of Elasticity

The usually low value of the modulus of elasticity results principally in low stiffness. The high torsional rigidity of top hat frames and girders goes a long way to minimise this deficiency, large shell deflections are the main cause of complaint usually resulting in the debonding of joinery and delamination in way of 'hard spots' such as bulkheads and floors etc.

It is important therefore to consider the effect of stiffness of different glass reinforcements available.

Deflection of a flat plate under uniform load is given by:

$$y = \frac{Kwb^4}{Et^3}$$

where b is the shortest side
w is the unit load
E is the modulus of elasticity
t is the thickness of plate
K is determined from the ratio of the sides.

It can be seen that for a plate of fixed length and width under a given load, the deflection is inversely proportional to the modulus and the thickness cubed (i.e. Et^3).

Consider now the comparison of a single layer of chopped strand mat and woven roving as detailed in the table below.

MATERIAL	WEIGHT	THICKNESS	$THICKNESS^3$	E	Et^3
2 oz. C.S.M.	2 oz./ft^2	0.054 ins.	1.58×10^{-4}	1.0×10^6	1.58×10^2
24 oz. W.R.	2½ oz./ft^2	0.035 ins.	0.43×10^{-4}	2.0×10^6	0.86×10^2

It can be seen that a 24 oz. woven roving is only 54% as effective as 2 oz. chopped strand mat in stiffness. A similar calculation can be carried out to show that under tension a 24 oz. W.R. is 15% stronger than 2 oz. C.S.M. along the warp or weft only. The laminate thickness is of course the influencing factor, but more important, thickness is proportional to the resin absorption ratios ot the matt and cloth. Fig. 9. shows the variation of tensile strength against glass content (Ref. 3). Assuming stiffness and weight are firm considerations, then a balanced matrix of the two materials produces the best result.

The effect of temperature on flextral modulus has been studied in some depth. At ultra low temperatures of -250°C, modulus is approximately 35% higher: and at 70°C. approximately 30% lower than relative properties at 20°C (Ref.4). Thermal stresses in decks exposed to tropical sunshine were considered to represent a problem, however, the use of light coloured gel coat pigmentation coupled with the high insulation properties of G.R.P. have resulted in good retention of the mechanical properties up to 70°C. No real development has yet been undertaken to exploit the very good qualities of G.R.P. at ultra low temperatures, such as in the carriage of liquified natural gas, where experience has shown many dangers resulting from thermal stress fractures in conventional materials.

Arun Lifeboat

The design requirement associated with the R.N.L.I. 54' Arun lifeboat shows a good example of the particularly severe problems which had to be overcome. The hull shell and framing were required to withstand maximum slamming pressure with a factor of 2 for the dynamic condition, and a further 1.5 on ultimate, giving a load of 3 tons per square foot. The open grillage deck was designed to carry a load of 1 ton per square foot. The superstructure, a

load of ¾ ton per square foot plus an allowance for a forward speed of 5 knots inverted. The hull incorporates seven transverse watertight bulkheads, two longitudinal watertight bulkheads and sufficient foam buoyancy to support the full load displacement of the craft. The weighted weight of the hull, deck, superstructure, bulkheads and buoyancy etc., was 11.35 tons (Ref.5 and Plate 6).

Abrasion

The protection of G.R.P. hulls from superficial damage is frequently raised as a cause of concern. This was particularly true of trawlers with regard to the likely damage resulting from chaffing and severe knocks whilst shooting and recovering trawl gear. The incorporation of expendable G.R.P. topside protection panels mounted on the rubbing strakes clear of the hull have proved so successful that today, the concept is being incorporated on to wooden trawlers.

Fire Retardency

The element of risk from fire is present in all small launches, regardless of the material from which they have been constructed. Generally, G.R.P. construction presents no greater fire hazard than conventional materials, despite the fact that polyester resin is combustible carbon compound. Completely fire-resistant resins do not exist but it is possible to improve the fire retardancy and make a polyester resin self-extinguishing. Fire retardancy of a laminate can be further reduced where high glass content is employed, the penetration and spread of flame being dramatically reduced.

The British Ministry of Defence utilised this technique in the construction of"H.M.S. Wilton" (Ref. 6). The entire hull, decks and superstructure were produced from woven roving. Tests and trials showed that once the surface resin had been burnt, the glass cloth formed a durable fire barrier, and the levels of smoke and fumes generated were low.

Passenger vessels requiring class approval from the British Department of Trade are manufactured entirely from self-extinguishing resin. An antimony trioxide or chlorinated paraffin wax is added 20% by weight, to the normal laminating resin to produce the low surface spread of flame required. Whilst by this method the level of combustibility has been reduced, this must be offset against a reduction of mechanical properties, and poor weathering characteristics. Also, in the event of fire, and the laminate does burn a highly toxic

thick black smoke is produced which can render firefighting a very difficult and dangerous task.

In general, the system favoured by the industry and commercial organisations, such as the White Fish Authority (Ref. 7) is to protect areas of high fire risk. Normal construction is used, and all internal surfaces are coated with a fire barrier of woven glass cloth, bedded into an intumescent coat of resin. Intumescent resin was designed as a protective coating against direct flaming (Ref. 8). When a flame is applied to the surface, a carbonaceous foam is formed. Whilst this surface may glow red hot, almost total insulation and protection of the laminate below is achieved. Very low levels of gas and smoke are generated from intumescent resin, and re-application to damaged surfaces can easily and economically be carried out.

MANUFACTURING PRACTICES AND QUALITY CONTROLS

Arising from the fact of building the material in situ, there is a paramount need for a good working environment and strict controls to ensure consistency of laminating. This is particularly important to the design staff who have to take into account established factory standards in arriving at scantling.

To obtain total cure and consistency in the physical properties, it is necessary for workshops to be equipped with effective insulation, heating and ventilation (Ref. 9). Lloyds Register of Shipping recommend a temperature range of not less than 15°C (56°F) and not more than 42°C (90°F) with a maximum humidity not exceeding 80%. The upper temperature limit is rarely crossed in the U.K. however, care should be taken when laminating in direct sunlight.

The handling of raw materials in an uncured state can prove to be a fire hazard. A water sprinkler system is strongly recommended by Insurance Companies as a precaution.

Those materials particularly favoured for the U.K. marine moulding market are:-

Resin

Crystic 189 LV polyester resin manufactured by Scott Bader Limited. It is approved to B.S. 3532, 1962 type A, and by Lloyds Register of Shipping. Crystic 189 is particularly suited to contact moulding application, where outstanding toughness and water-resistance are required. A special feature of this resin is the relatively long "green stage" which allows complete chemical bonding to take place between successive layers in the laminate, a characteristic of great importance

in large mouldings.

Chopped Strand Mat

"Super E" chopped strand mat is manufactured by Fibreglass Limited. It is produced in accordance with specification B.S. 3396 part 1, 1966, and is approved by Lloyds Register of Shipping.

"E" glass is a low alkali construction having good long term strength and weathering properties. The mat construction consists of strand approximately 50 mm. long randomly distributed and bonded together with a silicone type binder.

Woven Rovings

Glass woven roving ECK24 is produced by T.B.A. Industrial Products Limited. "E" glass strands are spun into continuous toes, and these are loom woven into a plain weave material. Woven rovings offer a high reinforcement construction with good strand continuity.

Hand lay-up necessitates an established induction programme for trainee laminators. This should start with an initial period of laminating non-structural components, to ensure that a thorough understanding is gained of the basic procedures to be adopted; and then be followed by successive periods under strict supervision on a range of hull moulds.

Production control will only be as good as the standard of technical definition. The type and quantities to be added of catalyst, accelerator, colour pigment etc., must be clearly defined, and there is merit in adopting a central mixing bay under the strict supervision of one experienced operator.

Construction drawings must clearly define the number of layers in a matrix, the size of overlaps and the sequence of build. Without this definition schedules of pre-cut mat cannot be prepared and recorded prior to issue.

The responsibility for maintaining standards rests firstly with the supervisor in charge of the laminators and secondly with the quality controller, who should carry out checks throughout the production cycle. A test sample of the main laminate should be produced so that it can be used to check resin ratio, number of layers and mechanical properties. As a final check, the hull can be weighed and the result compared with the recorded input of materials.

CONCLUSION

It is clear that G.R.P. has become the principal material in the U.K. for boatbuilding both for leisure boats and work boats. It is likely the overall economies of cost of build and of maintenance during life of a hull will result in the steady progress of G.R.P. as a building material, not only for boats, but also for small ships.

The development of material systems will obviously continue, with the emphasis directed towards producing a stiffer matrix to allow a greater utilisation of the high specific strengths available. Equally important, is the further development of mechanical laminating equipment and production techniques to reduce the labour content of a hull moulding.

As in the past, it is important that as the utilisation of G.R.P. grows, the close relationship which exists between the moulder and the approving authorities, such as Lloyds Register of Shipping, should continue to ensure proper standards are maintained for the use of the material.

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NOMINAL MATERIAL PROPERTIES	G.R.P. LAMINATES		E-GLASS FIBRES	HIGH MODULUS CARBON FIBRES	RESIN	WOOD (12% MOISTURE)		MILD STEEL	ALUMINIUM (N8 ALLOY).
	CHOPPED-STRAND MAT	WOVEN ROVINGS.				OAK	LARCH		
RESIN WT. FRACTION	0·7	0·5	–	–	1·0	–	–	–	–
TENSILE lbs/in^2	16000	34800	507500	2900000	725	13000	13000	31800	20300
COMPRESSIVE "	18850	26000	–	–	20300	7250	6500	31800	20300
SHEAR "	12350	17400	–	–	–	1890	1740	20300	12350
INTERLAMINAR SHEAR "	2900	2780	–	–	–	–	–	20300	12300
YOUNGS MODULUS lbs/in^2 x10^3	1450	2040	1300	580000	510	1380	1300	20300	1300
SHEAR MODULUS " "	580	510	4060	–	190	109	87	12300	4000
POISSON RATIO	0·18	0·13	0·22	–	0·33	0·5	0·56	0·3	0·32
COEFF. OF EXPANSION	30	14	5	-0·6	90	5	4	12	22
SPECIFIC GRAVITY.	1·5	1·7	2·5	1·95	1·2	0·6	0·4	7·8	2·7

FIG.1 COMPARISON OF MATERIAL PROPERTIES

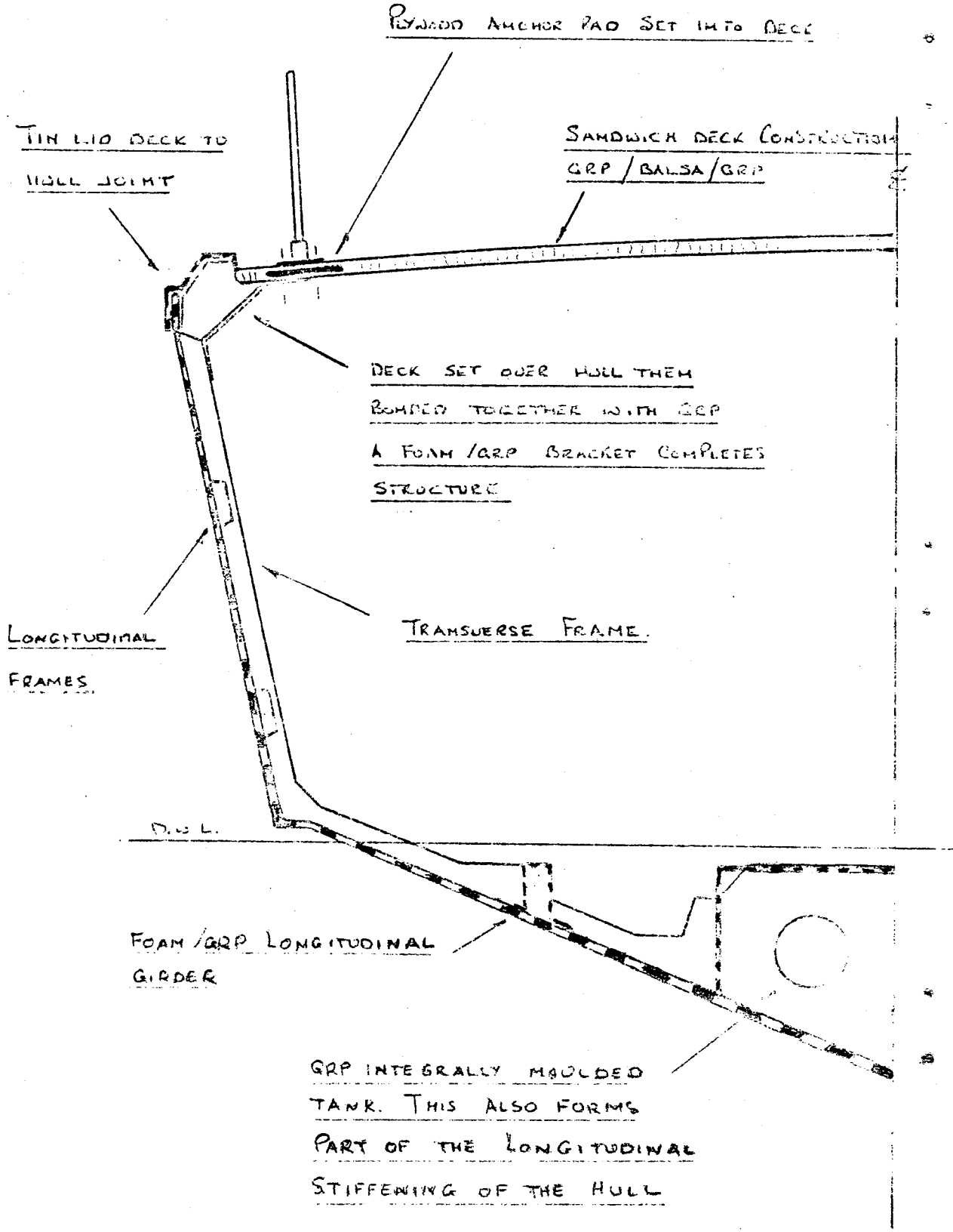


FIG. 2 TYPICAL SCANTLINGS OF POWER BOATS

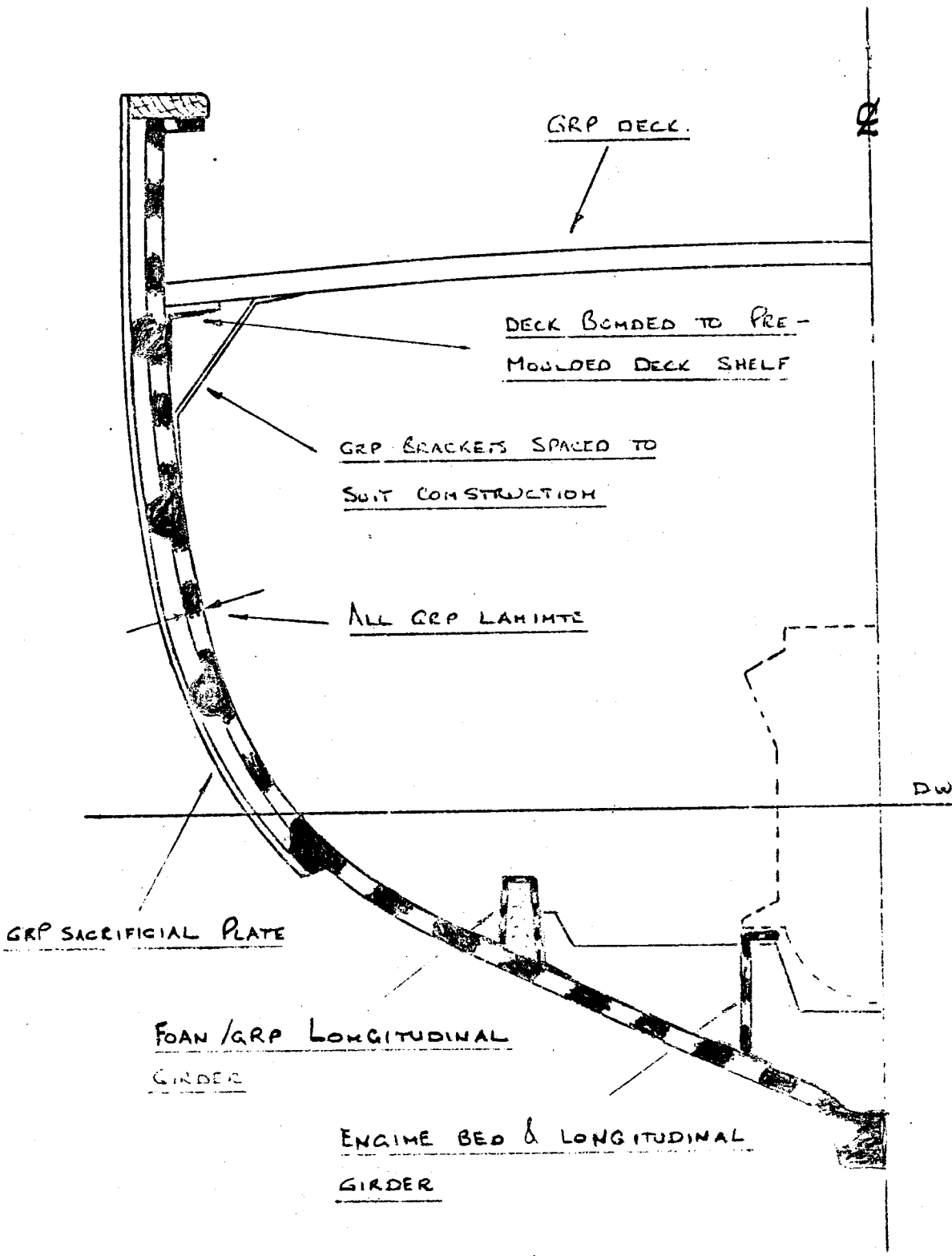
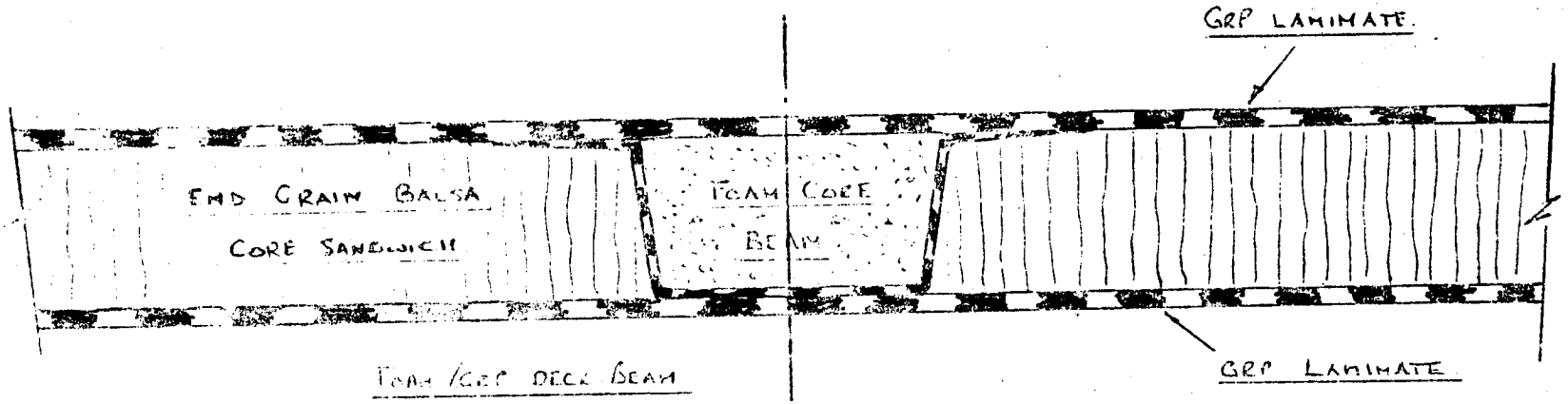
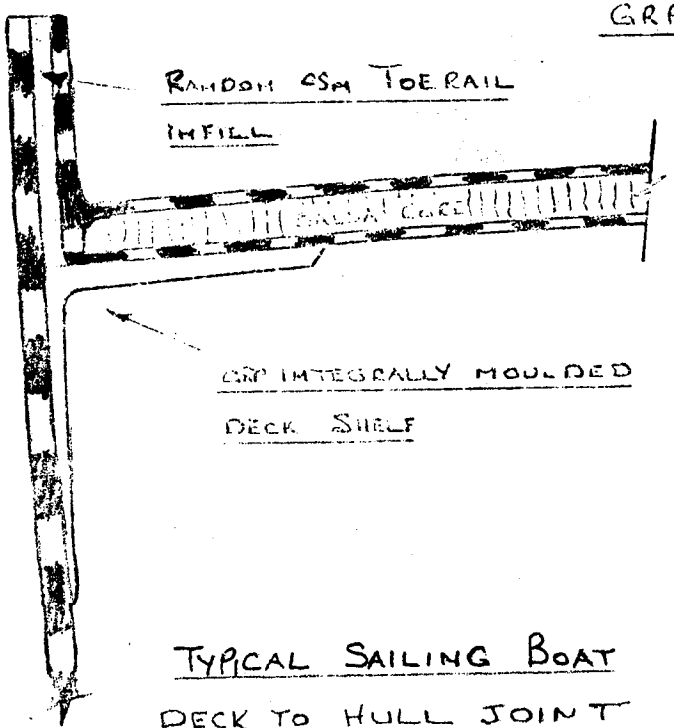


FIG. 3. TYPICAL SCANTLINGS OF GRP HEAVY SHELL HULL

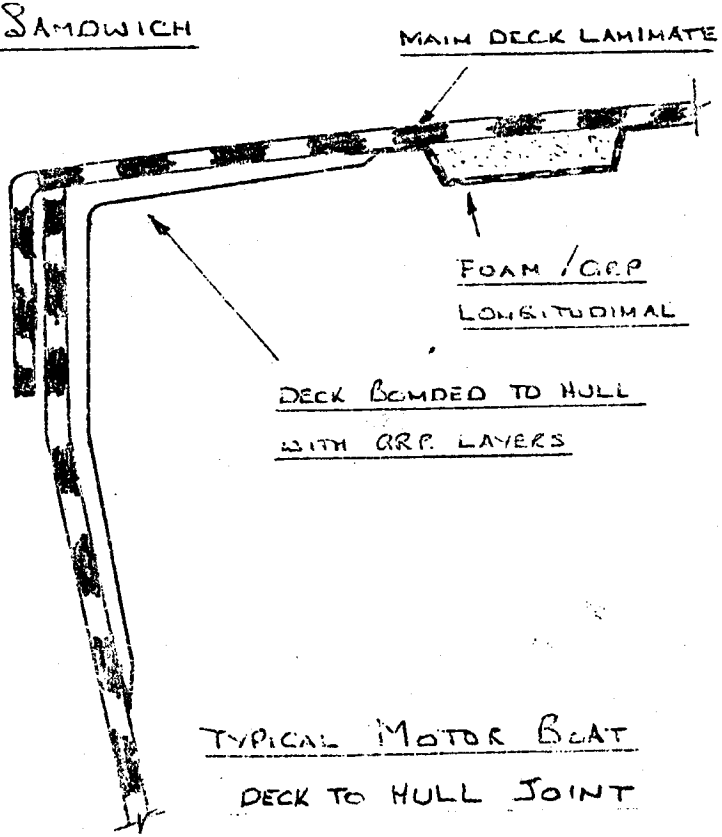


TYPICAL SECTION THRO SANDWICH

GRP DECK



TYPICAL SAILING BOAT
DECK TO HULL JOINT



TYPICAL MOTOR BOAT
DECK TO HULL JOINT

FIG. 4 TYPICAL SECTIONS

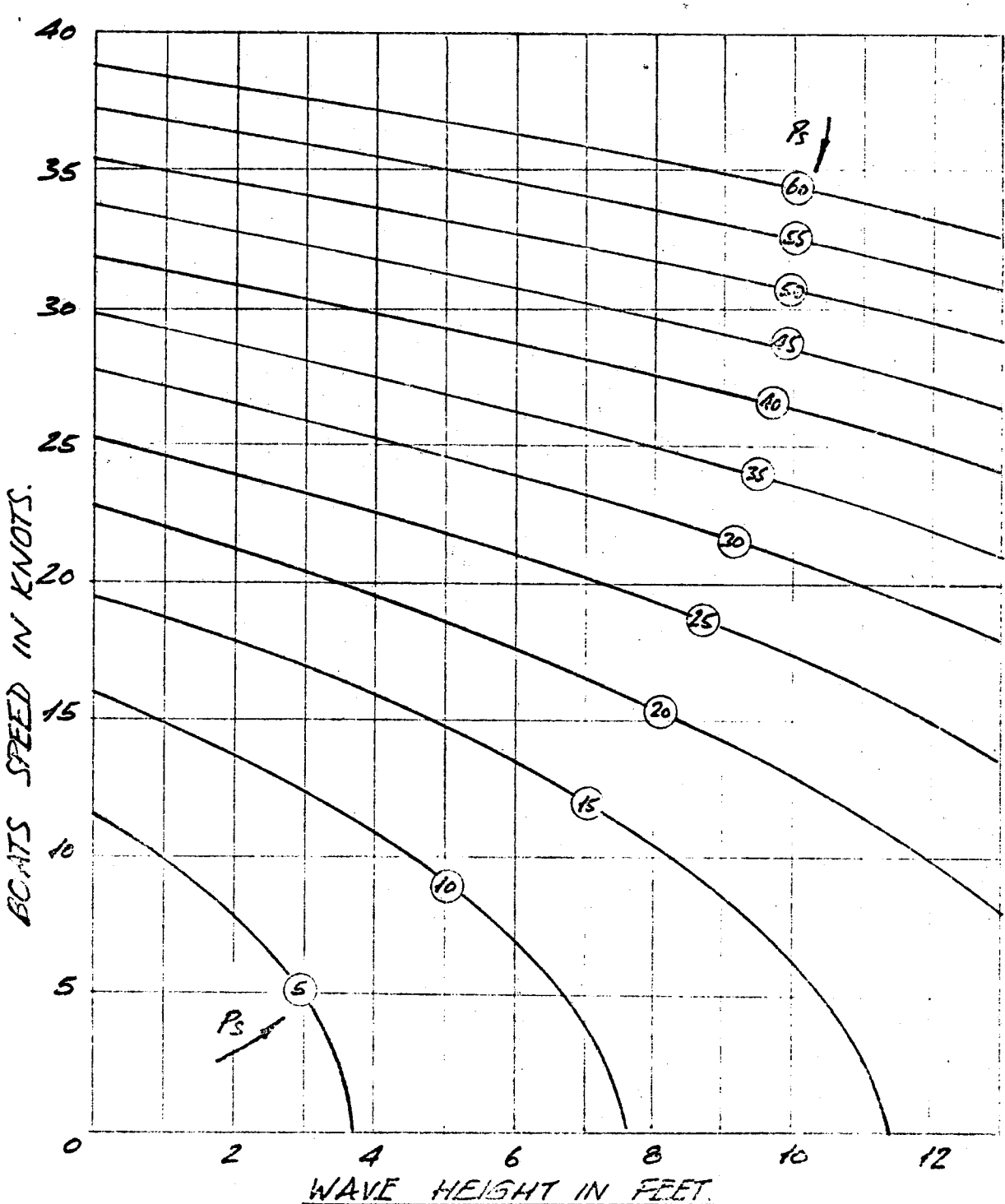


FIG. 5 EQUIVALENT PANEL DESIGN SLAMMING PRESSURE

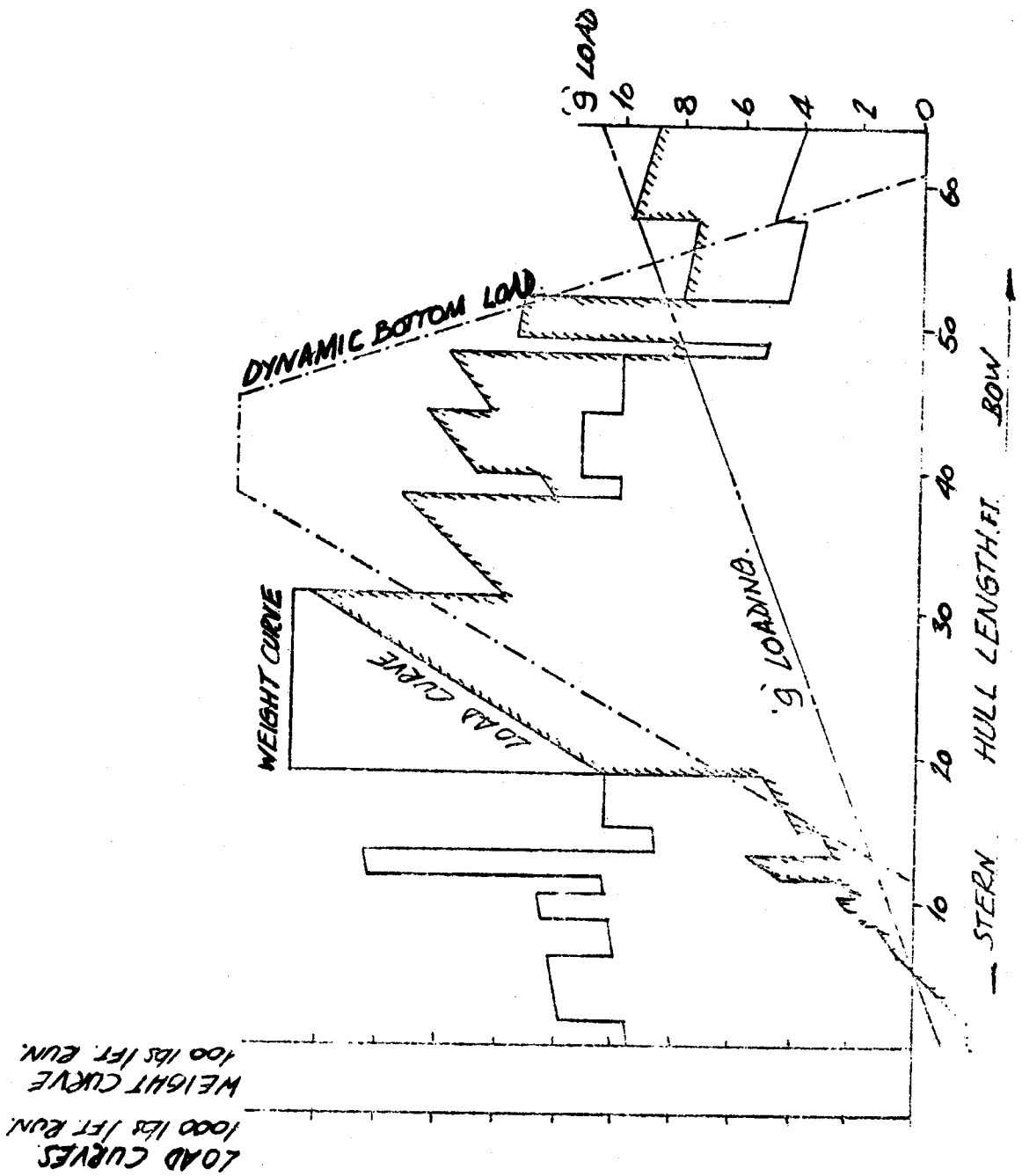


FIG. 6 PRIMARY LOAD CURVE

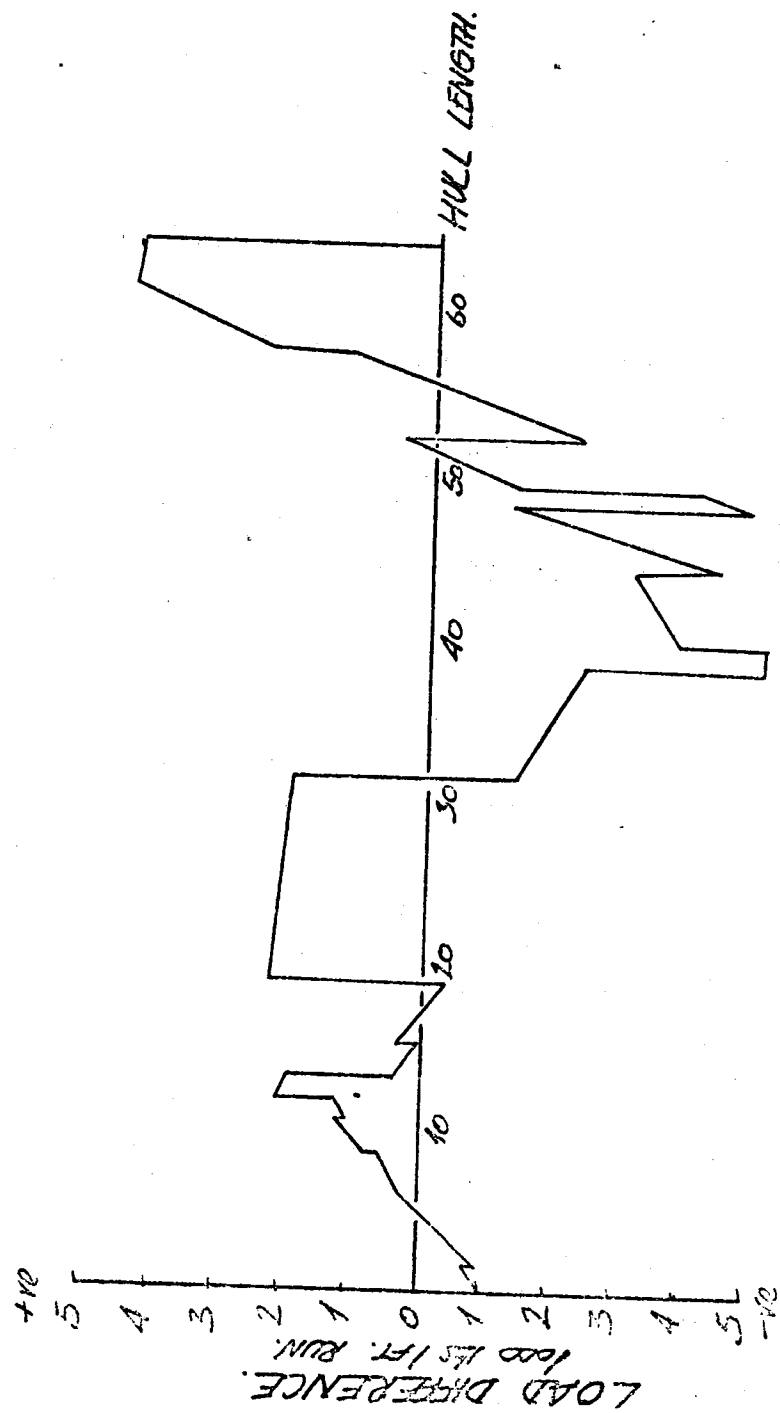


FIG. 7 LOAD DIFFERENCE CURVE

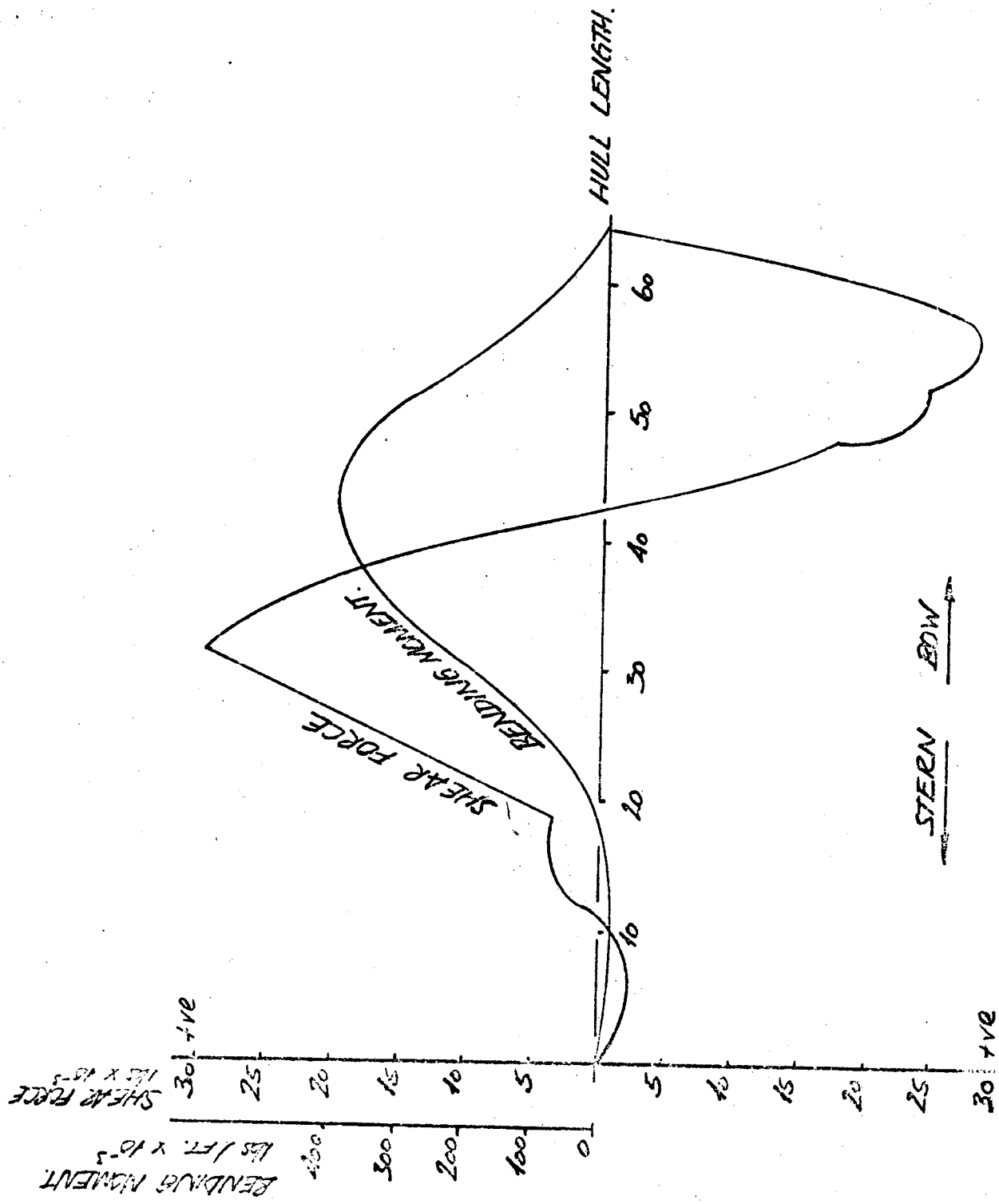


FIG. 8 BENDING MOMENT AND SHEAR FORCE

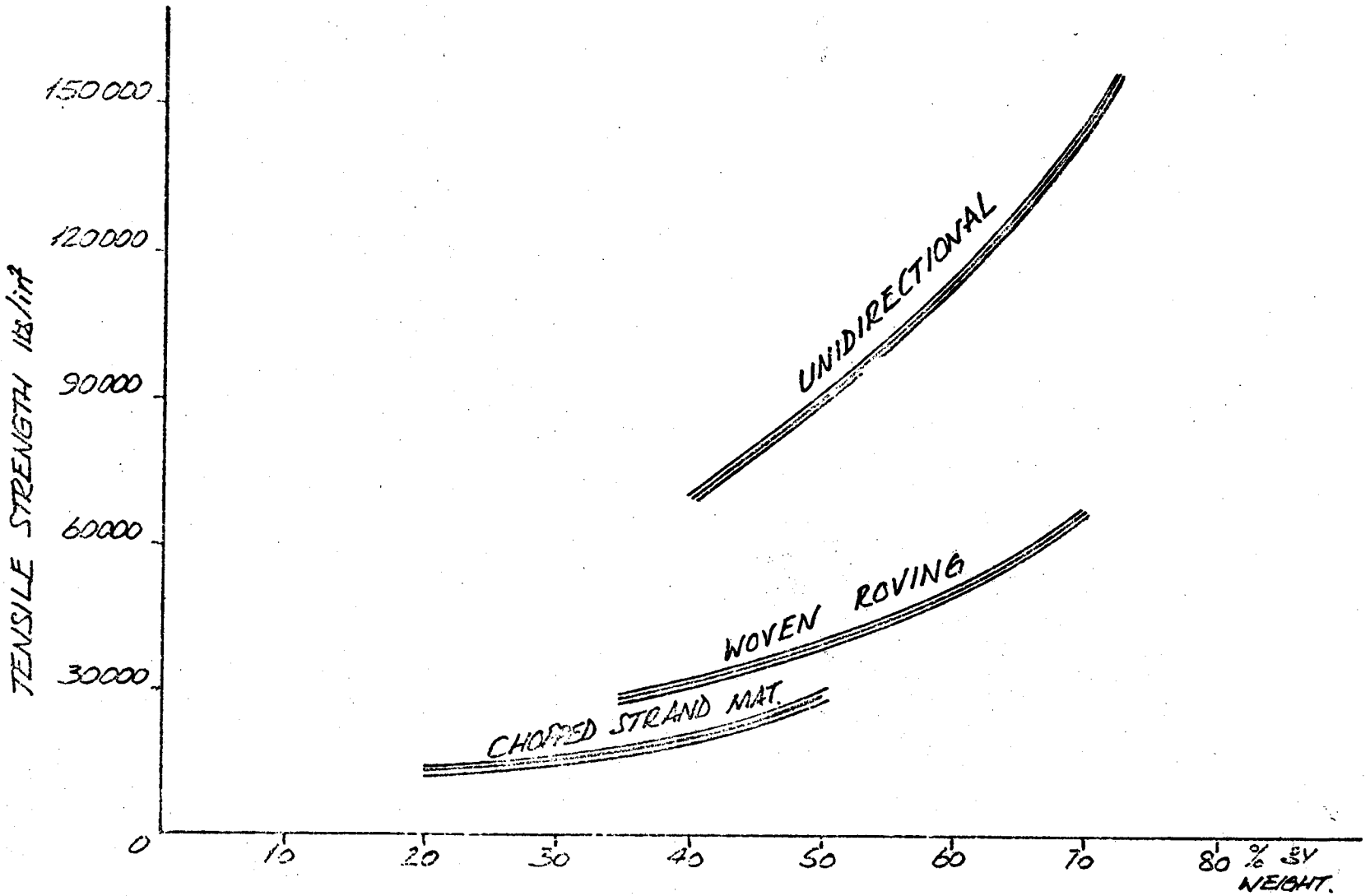


FIG. 9 GLASS CONTENT

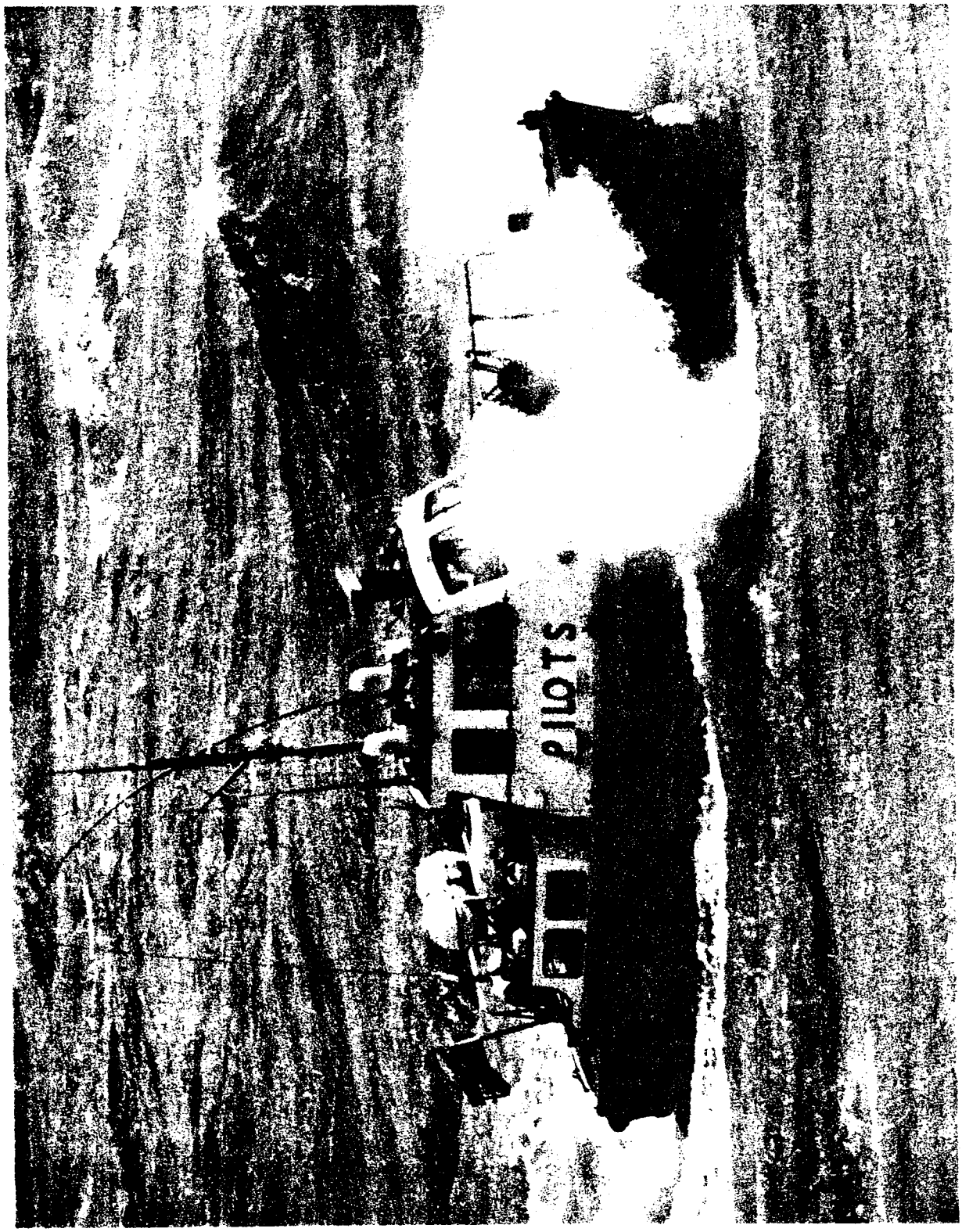
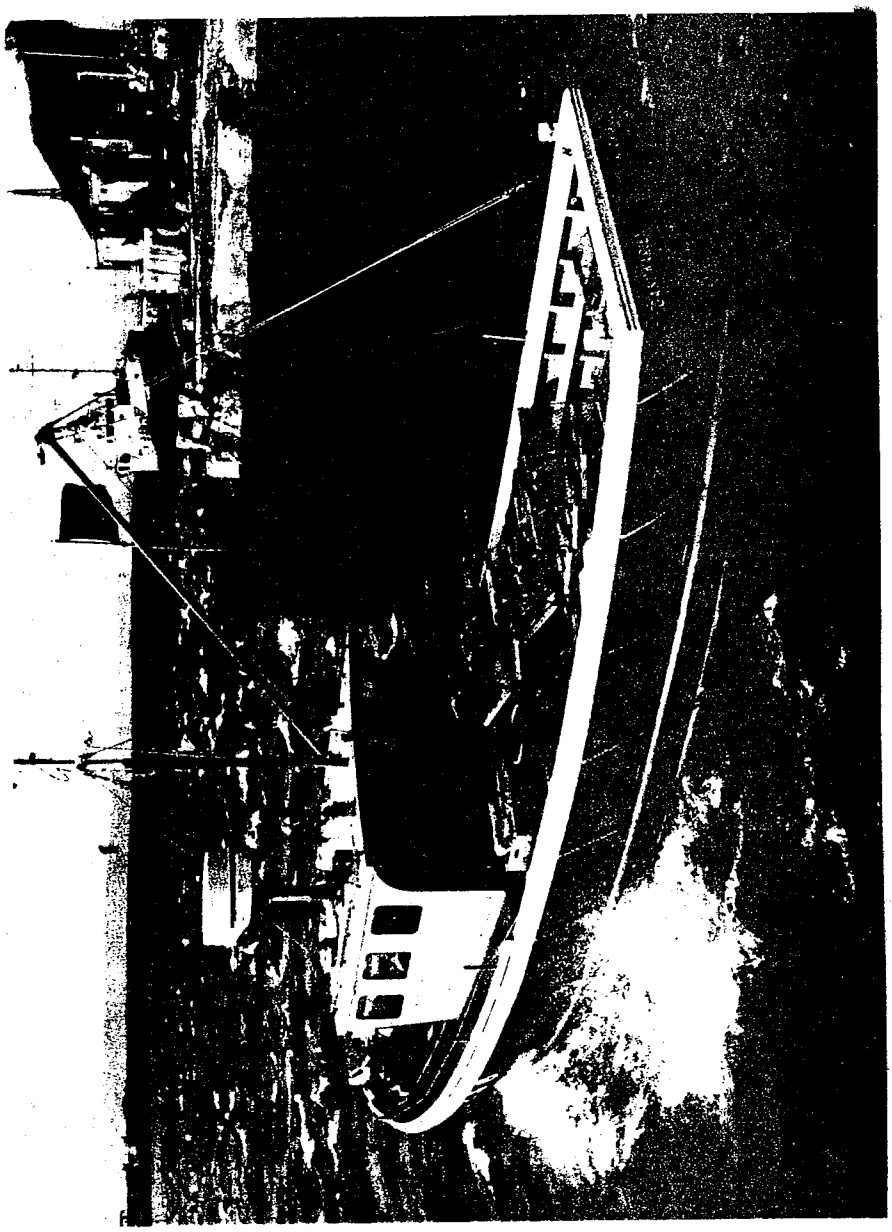


PLATE 1.

PLATE 24



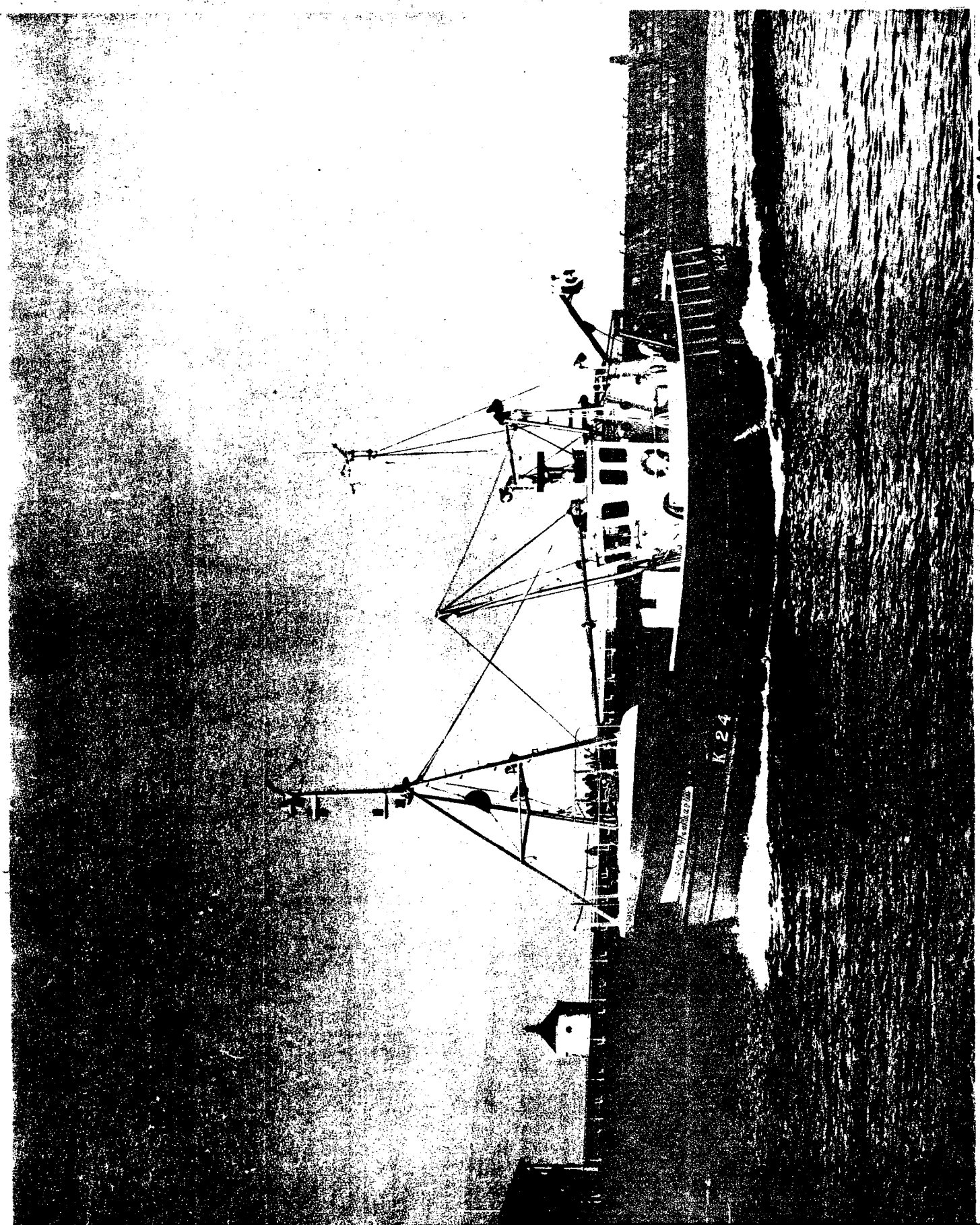
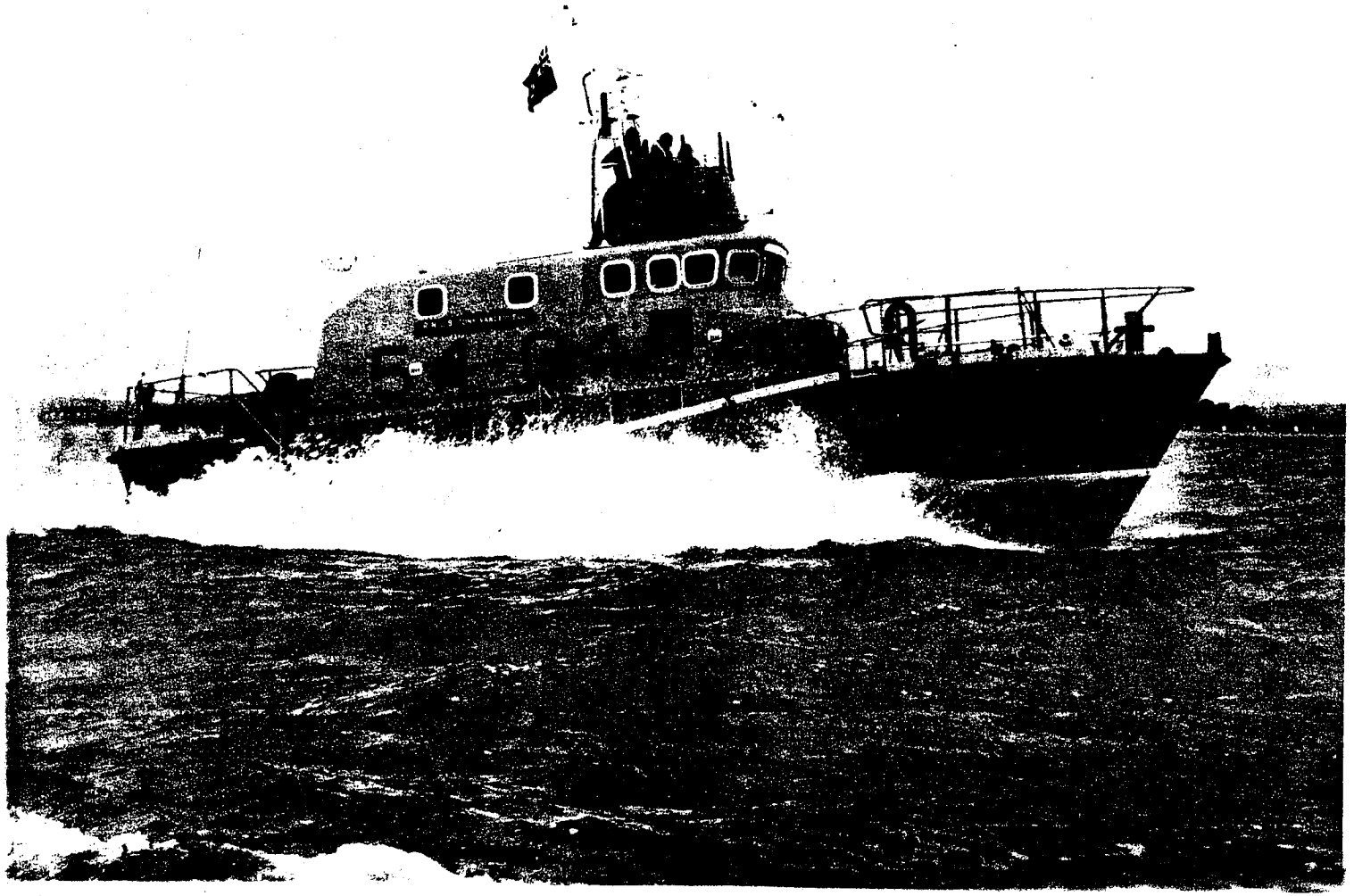


PLATE 3.



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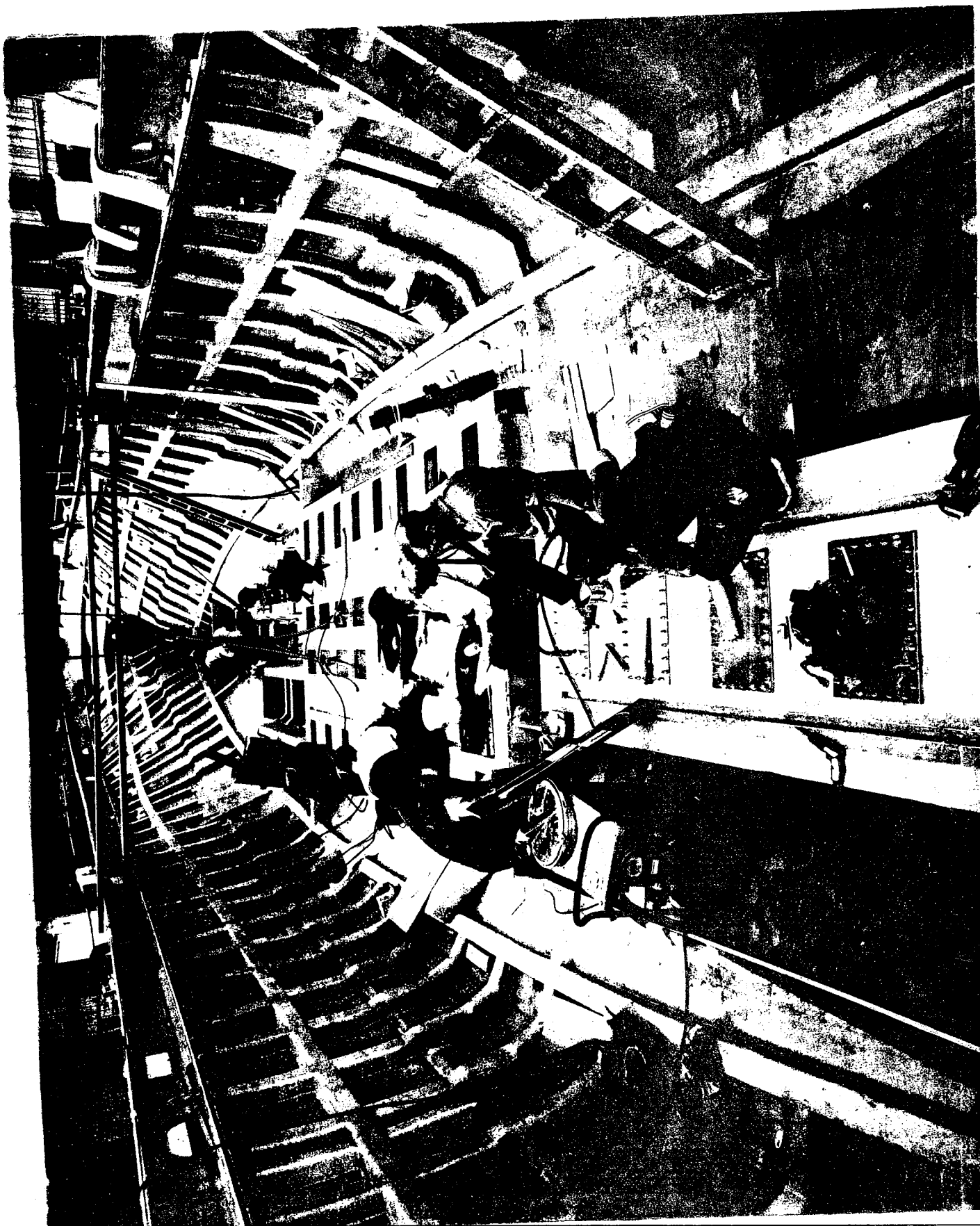
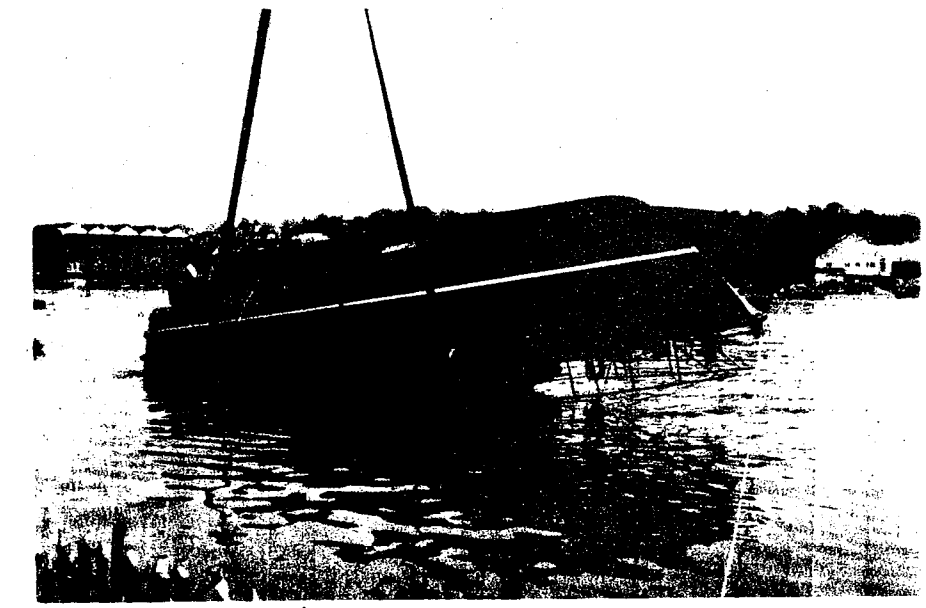
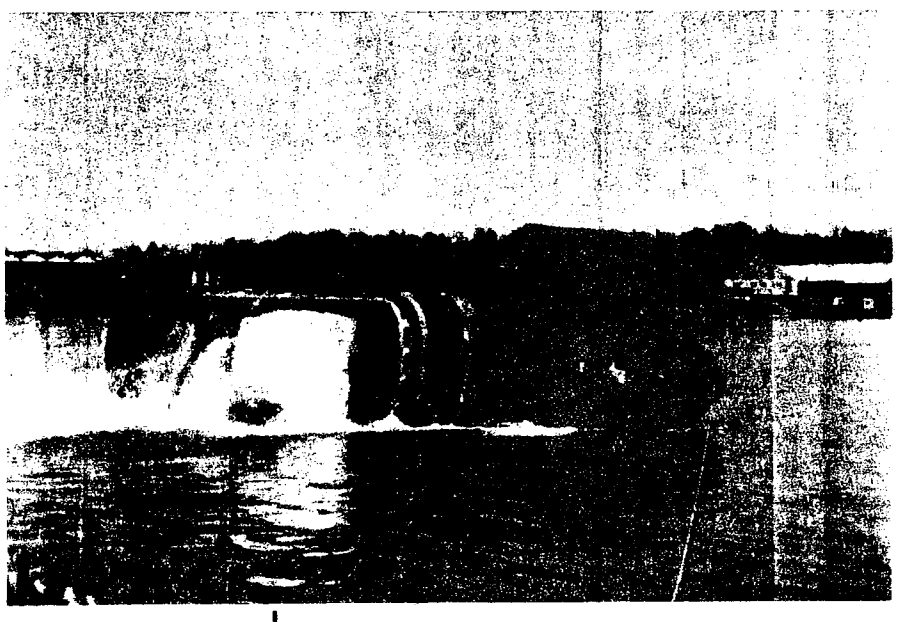


PLATE 5.

PLATE 6.





WOODEN COMMERCIAL VESSELS: VIRTUES AND FAULTS

by

Arthur N. Swinfield
Naval Architect
Sydney

Over past years most small commercial vessels have been built of timber and as such have given excellent service. The types of vessels called to mind are the earlier Sydney Harbour ferries, small tugs, lighters, timber decked punts and fishing boats. With the exception of fishing vessels most of the craft in question are subjected to continual impact either at wharves or when brought into contact with floating craft in the course of their normal duties.

Under such conditions it has long been recognised by the operators of such craft that a wooden vessel can withstand the subsequent punishment much better than a vessel of any other medium. Without the production of official records it is common knowledge that many of the older Sydney ferries operated over a period of some 40 years and some for as long as 60 years. It is also true to say that many of the small wooden tugs and lighters on the Harbour have equally good records of service.

Corrosion has been practically unknown in vessels copper or galvanised iron fastened, and hull planking in many instances has been unaffected by the years of service. However, the virtue of 'longlife' can mainly be attributed to a wooden vessel's resiliency, that is its ability to absorb violent impact and then rebound to its original shape and condition, and in spite of such punishment still keep maintenance at a minimum.

Resiliency is actually built into the vessel by virtue of its steam-bent frames or timbers, and longitudinal stringers particularly when Australian hardwoods are used in the construction of the vessels.

Over the years most Australian boat building establishments have had access to good stocks of local hardwoods in <u>good lengths</u> and of select quality. However, this no longer occurs. Suitable local hardwood is hard to come by and prices are high.

Nevertheless it is possible to design and build a wooden vessel with comparatively 'short length' timber. Such vessels have been produced and are still being produced with every success.

Wooden boat building came into its own during World War II during which hundreds of wooden craft were built throughout Australia. Design ranged from 300 ton cargo vessels to small life boats; wood workers from varied trades were co-opted to help produce the enormous numbers needed by the Armed Services, boat builders and shipwrights were at a premium. Steel and aluminium were in short supply, waterproof plywood was just coming into its own and 'fibreglass' was virtually unknown. However, designs were produced to utilize the available timber and many of the small craft so produced still operate today.

Among these can be mentioned, the 45'-0" towboat, the 66'-0" trawler, the 40'-0" work boat and the 112'-0" Fairmile.

Dry Rot

Few, if any vessels of the first three designs posed trouble in regard to 'dry rot' but the later suffered in this respect due perhaps to the access of fresh water between the laminations of the decking and planking. This could have been avoided as was done in the case of the 66'-0" trawler by fitting a false sheer strake over the outside of the top side laminated planking (see Figures 1 and 2).

Needless to say all wooden vessels come in for criticism in regard to dry rot, borer and teredo. Much is made of this and the uninitiated tend to 'fall' for such bogies.

Provided a wooden vessel is soundly constructed of suitable select timber and primed with one of the many excellent preservatives now available, it will out-last any other medium and retain its original appearance in the process.

As is well known the scourge of 'dry rot' was well recognised by the builders of old time wooden 'clippers' and commercial vessels. Then, as now, the focus of attention was directed at beam ends, stanchions knights-heads and counter frame work. It was here that 'dry rot' could be expected (as is still the case) and it was here that 'salt box work' was provided (built into the vessel) to combat such possibilities. To the author's knowledge this is no longer done, but wooden preservatives take over nevertheless, and provided correct rot prevention is carried out by the builder under careful supervision good timber rarely 'rots'. Plywood has at times attracted adverse attention in regard to dry rot and because plywood is made from timber, timber has suffered as a medium in boatbuilding. It is of course recognised that 'marine' plywood is specifically manufactured as such and that 'rot proofed marine' plywood is also manufactured but care must be exercised in the use of plywood as distinct from timber if trouble-free maintenance is required.

Borers

'Borer' attack results from using sap wood in the construction of a vessel; it rarely if ever, occurs in sound, mature timber. A faithful builder and careful supervision eliminates most fears of powder post borer attack.

Teredo

Teredo attack however, is another question coming as it does from the sea itself. Sheathing metal was extensively used but was of course expensive and subject to constant maintenance. However, with the use of modern anti-fouling paints it is now possible to keep a wooden vessel free from this scourge provided the craft is 'slipped' at regular periods. In any case slipping at regular periods is necessary for all vessels wooden or otherwise if fouling is to be avoided, so that it cannot be truly said that a wooden vessel needs more under water attention than any other type of vessel; it merely needs careful attention with a reputable anti-fouling paint.

Unfortunately the art of wooden boatbuilding appears to be dying out and few apprentices are forthcoming to carry on in the future.

However, good wooden boatbuilding establishments still exist in Australia as evidenced by the production of the many fishing craft launched year after year and many fishermen with years of experience in the operation of wooden fishing vessels still insist that timber is predominant as a medium for the

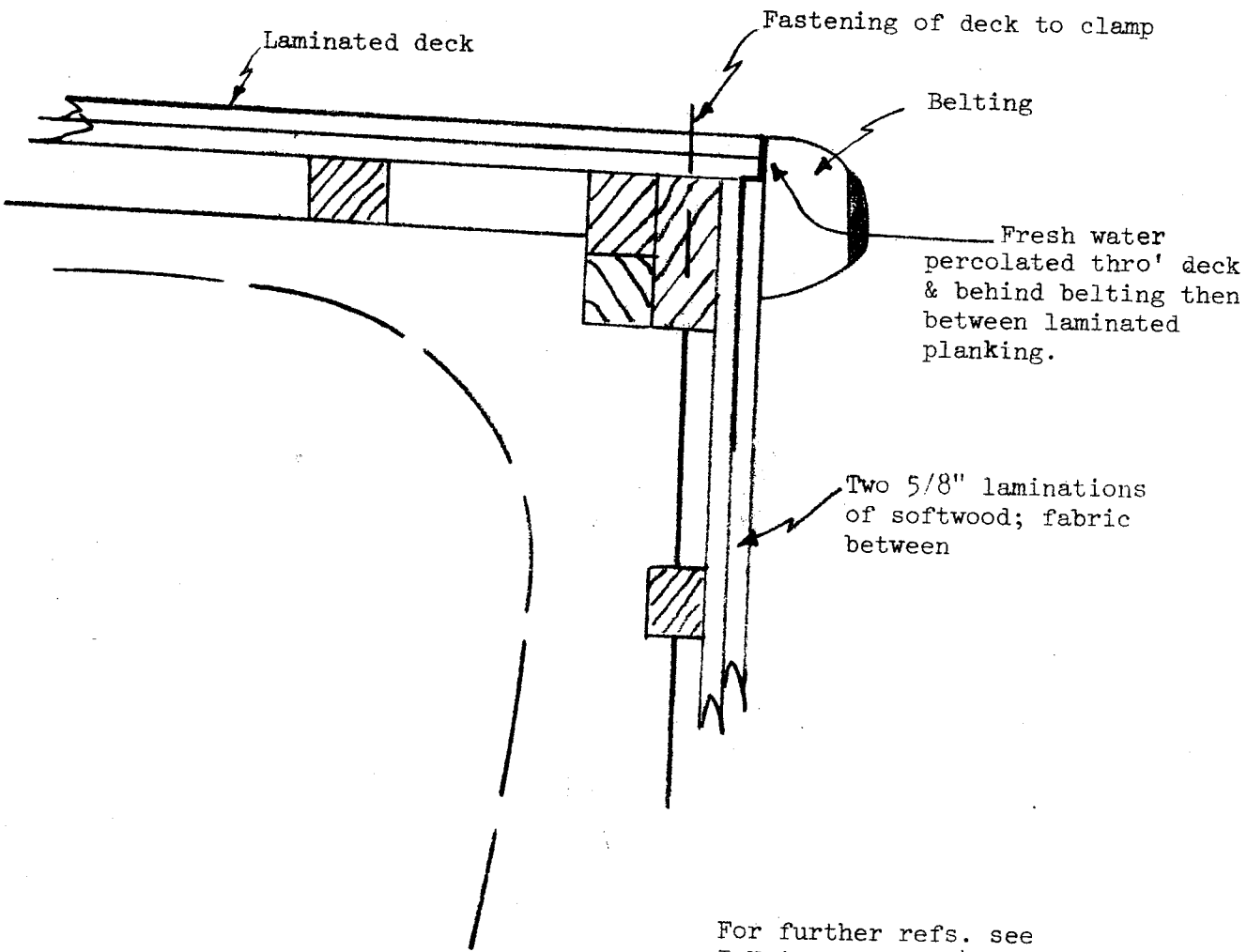
construction of a long life fishing boat.

No other medium presents the combined good features of timber. From time to time one hears of the possible future advantages that one medium or another will give in the long run, but timber has given decidedly good service in the past and will continue to give equal if not better service in the future without doubt as to its capabilities; in other words it has proved itself with a wonderful reputation.

In conclusion, the author of this small paper respectfully suggests that those in appropriate places give consideration to carefully designed wooden small craft for future emergency situations.

Australia produced many small craft during the last confrontation and could be called upon to repeat the performance. Conditions are much different now and this could be recognised with 'experienced' designs. Steel, aluminium, veneer, and the many sophisticated glues and plastics could again be in short supply.

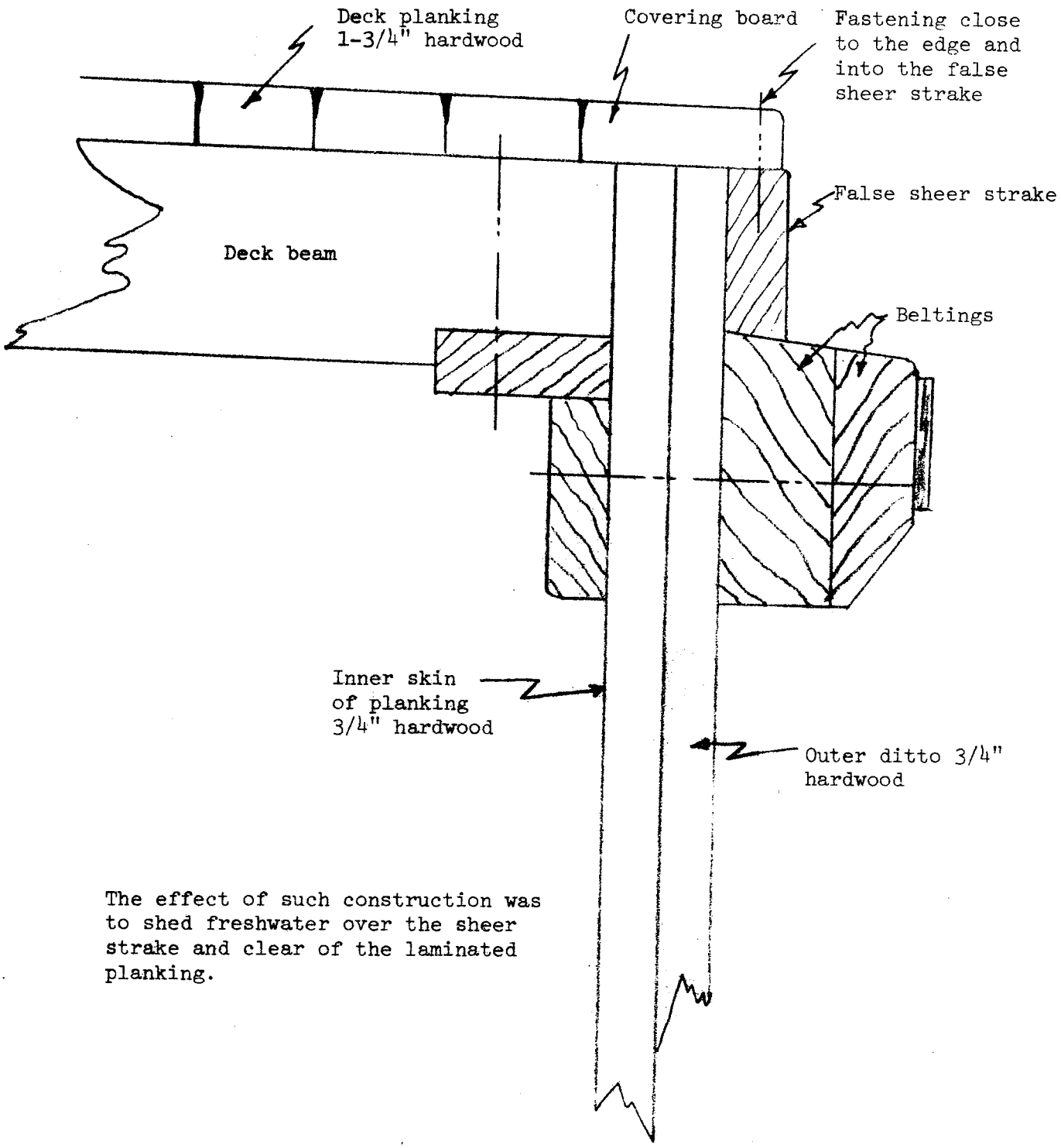
Designs of small craft using short length timber and designs of larger draft using composite construction would be a very worthwhile exercise.



For further refs. see
I.N.A. Trans. 1947 & 1958

This form of construction
tends to produce dry rot

FIG. 1. 112'-0" FAIRMILE



The effect of such construction was to shed freshwater over the sheer strake and clear of the laminated planking.

FIG. 2 66'-0" TRAWLER
(Designed by A.S.B.)

THE DESIGN AND CONSTRUCTION OF FAST ALUMINIUM ALLOY PATROL BOATS

by

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Sydney

and

J.A. Lund, Design Manager
De Havilland Marine
Sydney

SUMMARY

The paper outlines the design of a 16 metre aluminium patrol boat and the method of production together with contractual and other aspects involved in the implementation of the building program for the multiple production of six craft.

INTRODUCTION

This paper presents some of the technigues used, and the problems encountered, in the design and construction of a series of fast aluminium alloy patrol boats.

To illustrate the paper with a specific example, reference is made to the 16 metre patrol boats designed by the authors' company. Six of these boats are currently under construction, and are described in the paper.

The overall design of any vessel, can, of course, have a marked affect on the ease, or otherwise, of construction. Close liaison between designer and builder must take place at all stages of design. This is especially true of multiple production. Some of the design features which have been considered firstly for multiple production, and secondly for construction in aluminium alloy, will be discussed before describing the actual construction of the vessels.

Constructional aspects covered in the paper include:-

contractual conditions
site considerations
production planning and control
production tooling
construction techniques.

THE 9300 SERIES 16 METRE PATROL BOATS

PART I - DESIGN

GENERAL DESCRIPTION

The craft is intended for general coastal, estuaries and river patrol work in a variety of roles, such as police, customs, fisheries etc. It is constructed entirely of welded aluminium alloy and is powered by twin diesel engines giving a top speed of around 30 knots. Full living accommodation is provided for a crew of nine. A pictorial profile of a typical version of the boat is shown in Fig. 1. The hull is of hard chine form with fully developable plating surfaces.

Principal Dimensions

Length Overall	15.7m
Length Waterline	14.0m
Breadth (moulded)	4.7m
Depth (moulded)	2.5m
Draft (designed)	1.2m

Machinery

Main Engines: Two M.T.U. 6V-331-TC
Maximum rating (each) 700 BHP at 2340 RPM
Continuous rating (each) 630 BHP at 2260 RPM

Auxiliary Generators: Two diesel driven generators, each providing 6KVA, 240V A.C. 50 Hz.

Performance

Maximum intermittent speed	30 knots
Maximum continuous speed	25 knots

(At a displacement of 21.0 tonnes).

Layout

The boat is divided into six watertight compartments by means of transverse bulkheads. Fuel and fresh water are stowed in integral double bottom and wing tanks. From forward, the layout is :-

Firepeak
No. 1 Crew cabin (four berths)
No. 2 Crew cabin (four berths)
Captain's cabin (one berth)
W.C. and Shower compartment
Engine room
Mess and galley
Steering gear compartment (Aft peak)

The enclosed wheelhouse is sited on the upper deck above the engine room, and contains a comprehensive outfit of electronic navigation and communication equipment. Portable plates are provided for engine removal. A secondary open control position is sited aft of the wheelhouse.

Systems

The following main systems are fitted :-

Bilge and Fire System, operated by main engine driven pumps.

Domestic Fresh Water System (pressurised).
Power Assisted Hydraulic Steering (main engine driven pump).

Fuel Distribution System.
B.C.F. fire extinguishing systems in engine room.

Structure

The structure is based on the longitudinal system of framing, with the following major scantlings :-

Bottom Plating	7mm
Side Plating	5mm
Deck Plating	4mm and 5mm
Bulkhead Plating	4mm and 5mm
Superstructure Plating	3mm
Transverse Frames	5mm plate, with 75 x 6 capping extrusions
Transverse Frame Spacing	850mm - 1000mm
Longitudinal Bottom Frames	65mm x 40mm x 5mm T. Section
Longitudinal Frame Spacing	270mm - 300mm

A typical structural section is shown in Fig. 2.

Materials

Hull Plating	-	Aluminium Alloy	A5086 - H32
Fabricated Frames	-	" "	A5086 - H32
Extruded Frames	-	" "	A6061 - T6
Propeller Shafts	-	Stainless Steel	Type 316
Rudders & Stocks	-	" "	Type 316
Bilge Piping	-	Aluminium Alloy	A6061 - T6
Hydraulic Piping	-	" "	A6061 - T6
Fuel Piping	-	" "	A6061 - T6

Fitting Out

All accommodation spaces all insulated with 50mm thick fibreglass insulation, and lined with either light gauge aluminium alloy sheet or plastic laminate.

DESIGN CONSIDERATIONS

Structure

The structural design of the vessel is based on the well known Heller and Jasper method (Ref. 1.). Further information on this and other methods for the analysis of planing vessel structure is contained in Ref. 2.

The Heller and Jasper data have been found by the author's company to produce satisfactory results in a wide range of planing craft. Although somewhat outside the size range of craft being considered in this Symposium, the following example of a practical application of the method may be of interest.

One of the 7 metre standard production boats built by the author's company suffered cracking of the forward bottom plating. These boats are usually used for pleasure or light commercial purposes and this was the first of about fifty boats to suffer serious structural problems. On investigation, it was found that the boat in question was being used for abalone fishing and carrying heavy loads through rough seas at up to 30 knots. A Heller and Jasper analysis of the structure, incorporating the abnormally high loadings, was made. The analysis confirmed that, with the normally satisfactory plating thickness of 3mm there was a high probability that failure would occur in the bottom plating. The plating for this particular service was subsequently increased to 4mm, and no further problems have been reported.

When assessing the allowable stress for an aluminium alloy boat structure, due consideration must, of course, be given to the substantial loss of strength which occurs on welding. For example, for two of the most commonly used alloys in marine work, a comparison between the minimum mechanical properties in the unwelded and welded condition is shown in Table. I. The values are taken from Ref. 3.

TABLE I

COMPARISON OF MINIMUM MECHANICAL PROPERTIES IN THE UNWELDED AND WELDED CONDITIONS

Alloy & Temper	U.T.S. (lb/m^2)		Tensile Yield (lb/m^2)	
	Unwelded	Welded	Unwelded	Welded
Plate 5086-H32	40,000	35,000	28,000	19,000
Extrusions 6061-T6	38,000	24,000	35,000	20,000

In most practical boat structures, many of the most highly stressed areas will occur in weld affected zones (e.g. the boundaries of plating panels and the flanges of fabricated frames). By careful design, maximum use can be made of the higher unwelded properties of the material. In doing this, however, consideration should be given to

the possibility of additional 'unplanned' welding occurring, during construction or later modifications, in areas which have been assumed to be unwelded.

Ease of Construction

For small aluminium alloy vessels, one important consideration is the relatively bulky nature (in comparison with steel) of the welding equipment. Good access for welding must be provided in the structural design, and in some cases will be the deciding factor in the structural layout. Consideration must also be given to the sequence and mode of erection, and the type of building jig to be used.

Aids to construction, which may not be necessary from a purely structural point of view, can be considered. An example of this is the use of round bars at the chine and gunwale, as shown in Fig. 2.

Especially when multiple production is required, the advantages of using specially designed aluminium alloy extrusions should be assessed. These may assist in speeding up fabrication, reducing the amount of welding required, or simply in improving appearance.

Some typical examples of special extrusions are shown in Fig. 3.

It is also worthwhile to consider the casting, in aluminium alloy, of certain components such as deck fittings, propeller brackets, stern gland housings etc.

The overall arrangement of the vessel can have a marked affect on the ease of construction. For example, it is very desirable, from a construction point of view, not to have any significant superstructure over the engine room. This means that engines can be installed at any stage, and that the interfacing of the various electrical, hydraulic, and mechanical system can proceed smoothly. Unfortunately it was not possible to incorporate this desirable feature of layout into the 16 Metre design. As a result, extremely careful planning is required to ensure that congestion and delays are kept to a minimum.

Materials for Outfitting

Fittings for aluminium alloy boats must be selected with great care, taking account of weight, cost, availability, durability and the possibilities of galvanic corrosion.

To minimise the chance of galvanic corrosion occurring, the ideal material for fittings is, of course, aluminium alloy. Usually this can be readily used for such items as deck fittings, hatches, ladders, built-in furniture, gratings, gland housings, most piping etc. Where allowed by survey authorities, plastic fittings are also excellent for the minimisation of corrosion problems.

There are, however, many components which are not available in aluminium alloy, or for which the use of this material would be impractical or undesirable. These include propeller shafts, propellers, rudder stocks etc. Where fittings other than aluminium alloy have to be used, they must be electrically isolated by using rubber or plastic gaskets, or butyl or polysulfide sealants, and where necessary by using insulating washers and sleeves on the fastenings.

Piping systems, including valves and pipe fittings, can pose problems. Due to the low volume of usage in this country, the availability of aluminium valves and pipe fittings is poor, although at the time of writing a promising source of supply is being investigated. Copper bearing materials give rise to the greatest galvanic corrosion problems. Copper corrosion products will cause pitting of aluminium if they are washed off, either above decks by rain or sea water, or below decks by condensation. If copper pipes have to be used, they should be sheathed with P.V.C. tubing. Upper deck bronze or brass fittings should be chrome plated, and similarly, if bronze valves are used, their bodies should be coated externally with a suitable paint.

Despite the almost inevitable use of dissimilar metals, it has been found that careful attention to detail will overcome the potential corrosion problems. A properly designed and maintained system of sacrificial anodes will satisfactorily protect the vessel. In addition to anodes placed on the external underwater portions of the hull, it may be necessary, depending on the actual materials present, to consider placing additional anodes in the bilge areas. On high speed vessels, where it is important to minimise appendage drag, it may be considered undesirable to place anodes in the floor line. In this case, it has been found that satisfactory results can be achieved by placing the majority of the anodes on the lower edge of the transom, and providing a portable bar anode, sited forward, which is lowered into the water when the vessel is moored.

PART II

CONSTRUCTION

It is important for the efficient production building of aluminium patrol craft to consider all aspects of the construction program, including :-

- contractual conditions
- site considerations
- production planning and control
- production tooling
- construction techniques

Contractual Conditions

Whilst it is not intended to discuss contractual conditions in depth, it is important to appreciate where the terms of the contract can exercise constraints on the build program.

In the present days of high inflation and interest rates it is an absolute prerequisite of any contract to include a satisfactory rise and fall clause covering :-

- labour rate
- materials
- sub-contract work
- conditions of employment
- overhead related costs
- profit - particularly in a contract extending over a long period.

There is no doubt that the inclusion of a satisfactory rise and fall clause in a contract greatly reduces the strain on the management of the contract.

Equally important is the inclusion of a progress payment clause. Ideally this clause should provide for monthly progress payments on labour and materials up to 90% of actual costs and where major acquisitions are involved, such as main engines, a 100% claim should be sought. Putting aside the obvious advantages from the financial point of view, a progress claim clause does ease the construction situation by virtue of :-

* allowing bulk purchases of material and sensible procurement planning

* optimisation of labour, i.e. the cash is available to pay the work force when they are needed.

Site Considerations

The advantages of aluminium as a structural material begin to emerge when considering site requirements. Whilst a site adjacent to water has obvious benefits, the relatively lighter aluminium craft makes the use of heavy haulage road transport more feasible and the limitations become the length and height of the craft. The authors company's experience to date shows it quite practical to move a vessel of 20 tonnes and 51 ft. in length without major problems.

Similarly the light-weight of aluminium negates the need for heavy lifting equipment. Quite large panels and sub-assemblies can be man handled easily giving the benefits of :-

* reducing the need for heavy lifting structure on the building site

* saving time usually wasted when waiting for cranage.

Covered and clean work area is essential for the whole build period. During the structural build stage all weather protection is necesssary when using the gas shielded M.I.G. and T.I.G. welding and full weather protection during fit out has obvious advantages and definitely reduces production time. Head height is a major consideration when employing the cyclic building techniques where certain structural units, such as wheelhouse and cabin tops are built in parallel with hull structure and need to be lifted on and fastened to the hull cover.

Yard space is required if sand blasting and spray painting are required.

Launching of vessels up to 150 ft. can be safely conducted by the use of a winch and trailer down a sound concrete ramp.

Site Layout

Invariably site layout is constrained by the physical shape and size of the available space. However, for smooth and efficient work flow of production building the following points are worth considering :-

* Major machinery such as folding machine guillotine, linishers, band and radial arm saws should be positioned in an area adjacent to both the structural build stages and the fitting out area.

* Details for the assembly stage can be built in an area remote from the assembly site provided accurate drawings, templates and jigs are provided.

* Power, water and air supplies to all work areas should be neatly grouped to prevent unnecessary leads causing congestion and safety hazards.

* Bench space be provided at the work areas rather than in a centralised position.

* A separate area be set aside for the noisy operation of cutting plate by rip saws.

* Fitting out machinery - bench saw, band saw, radial arm saw, wood working equipment be sited on a mezzanine level flush with the boats main deck. This saves many hours in walking up and down stairs.

Production Planning and Control

In formulating the construction plan we found like many things in life, it was best to start at the end, i.e. contract delivery dates, and work back to ascertain the resourcesneeded in theoretical terms to meet these targets. Naturally the theoretical answers in terms of manpower, floor space or time did not suit the overall production scene with its various constraints. However, this ideal situation served as a most useful method by which a more realistic plan could be developed. Such items as :-

(i) Manpower requirements vs availability.
(ii) Capital expenditure
(iii) Purchasing plan
(iv) Production sequence - parallel and series operations including balance of trade, time requirements for each stage and learning curve implications
(v) The degree of production tooling
(vi) Sub-contract work

were readily identified and put into their true perspective in relationship to the total picture.

Manpower Requirements

Theoretically these are comparatively easy to determine. In practice they can be a nightmare. One must ask the questions :-

* What allowance does one make for absenteeism ?

* Can you afford to pay the price of recruiting labour early to ensure you have it when you want it or do you gamble on it being available at the right time ?

* How can you balance the work force evenly over the whole period of the contract in order to avoid a staff reduction problem towards the end of the program and hence the likelihood of a of a slow down resulting in late delivery and loss of profit ?

* Is overtime planned into the program or do you hold that in reserve as a float, and if so, how much overtime can you afford ?

No apology is made for not answering these questions as the answers lie within each organisation. However, the ultimate production plan must reflect this thinking.

Capital Expenditure

In the early days of making up the tender, capital expenditure would be considered. But, with the passage of time between tender submission and contract award, the scene is bound to change. Therefore, this must be reconsidered and included in the make up of the production plan.

Purchasing Plan

Again the fine detail varies greatly from day to day, e.g. in 1974 supply was a massive problem, whilst in 1975 what were long lead items in 1974 are now short lead items whilst the reverse has occurred with other items.

It is essential therefore at contract award to make a supply survey and list items into the categories of :-

Long lead
Intermediate lead
Short lead

and if possible, worn supplies of the likely requirements against a given time scale. If forward ordering against a given delivery date can be arranged, all the better. But this does have its problems in that orders are lost or supplier sold against an earlier delivery. The answer lies in regular reviews and expediting.

Production Sequence

This really is the key to planning successful multiple production. In the case of the patrol craft being discussed, we had the problem of a delivery program for six vessels over a period of one year, to an unproven design and where the second craft would be well advanced prior to prototype trials. In such a tight program it is not possible to eliminate risk, but it must be reduced to the minimum.

Firstly, the design risks were analysed and considered to be low when bearing in mind that the design of structure was based on proven procedures and the precaution was taken to have model tests conducted at the N.S.M.B. Holland to prove the lines and to attain powering predictions. Also all installed systems were merely extensions of systems installed successfully in previous vessels.

Secondly, the production sequence was looked at. We had in 1973/74 constructed seven 45 ft. patrol boat on the cyclic assembly principle and achieved the objective of completing all craft within the planned time and costs. This seemed a sound basis on which to prepare the more ambitious 16 metre F.P.B. program. However, on analysis of our previous performance we realised that improvements could be made with the injection of more efficient production techniques. Consequently, Mr. Simmonds toured the United States of America to update his knowledge and in particular view techniques employed in the multiple production of aluminium alloy crew boats in Louisiana. Much was learnt from that trip. Design was reviewed and modified for ease of production and new assembly techniques employed.

Thus, it was decided to continue on the simply cyclic assembly basis, but with the benefits of the lessons learnt during the previous program and the knowledge gained in the United States.

The sequence adopted was :-

(i) After lofting cut one set of hull frames and set and prove in the jig.

(ii) Once lines were proved, mass production (profile milling) of all frames, hull plate sections, stringers, intercostals and other components was done.

(iii) Assembly of the prototype craft to be four months in advance of the 1st production craft thence seven week intervals between remaining vessels.

(iv) Set defined production stages to give balanced work throuhgout program and maximise learning. Stage crew limits were set at seven personnel each. The fine timing on work out put from each stage was adjusted by change of work content or overtime depending on the cause.

(v) Parallel stage production of cabin assemblies.

(vi) Continual review of details with the object of increasing parallel operations.

Fig. 4 shows the outline production plan.

Production control was achieved by the simple method of identifying discrete work packages (100 hrs. approx.) into numerical listings and groupings against the production program. The packages were compared weekly with the program and the age old judgement applied to give the final ruling of progress against program.

Production Tooling

The aim was to make this as simple and as low cost as possible commensurate with maximum efficiency.

Hull - This was the major piece of production tooling made up from 3" galvanised steel water pipe and steel angle sections to form a support structure into which the keel, frames and bulkheads could be accurately located and rigidly held.

Components - Simple templates and position jigs were used for the multiple production of components.

Construction Techniques

The use of extrusions has been mentioned in Part I and must not be overlooked when considering construction techniques. Perhaps the maximisation of extrusion is the biggest single gain to be made, but, the additional costs need to be weighed against the productive hours saved. In volume production extrusions will win.

The fundamental construction technique employed was to build the craft upside down on a supporting jig. This method greatly assisted in maintaining fairness of the hull lines and the physical process of precut wrapping the plate to the frames. Precut plates were laid on the skeleton structure of frames and stringers and levered by pull lift and chain to wrap around the structure whilst tack welding from the underside. Aluminium welding is more easy when working overhead.

All longitudinal stringers were made up from intercostals of Tee section and cropped at each end with a 45° angle and set between each frame or bulkhead. This technique eliminated the danger of creating triaxial stresses at weld junctions and gave the added advantages of providing limber holes and eliminating water tight bulkhead penetrations with the need for subsequent sealing.

The use of the sheer and chine bar - see Fig. 2 - provided a rigid structure prior to fitting intercostals and also provided useful conjunctions for plate termination.

Once all the hull plating was complete, the structure was released from the jig, turn over by crane and all the grid deck structure deck plating and curtain bulkheads installed.

Main engines were then placed in the vessel and the cabin section welded to the hull. The vessel was then sealed and sand blasted followed immediately by a priming paint coat.

The vessel then moved to the fitting out area.

Other useful techniques employed were :-

(i) Shaft alignment using a Rank Taylor alignment telescope.
(ii) Wiring looms.
(iii) Off site manufacture of joinery.
(iv) Repetitive use of fitting out teams to defined areas.

The foregoing is a brief outline of a project now underway. It is not yet complete, however, with the experience gained from a similar program together with increased knowledge and thought we hold a high confidence level for success. The yard stick used to measure success will be a production which meets the customers requirements, delivered on time and within the planned costs - time will tell.

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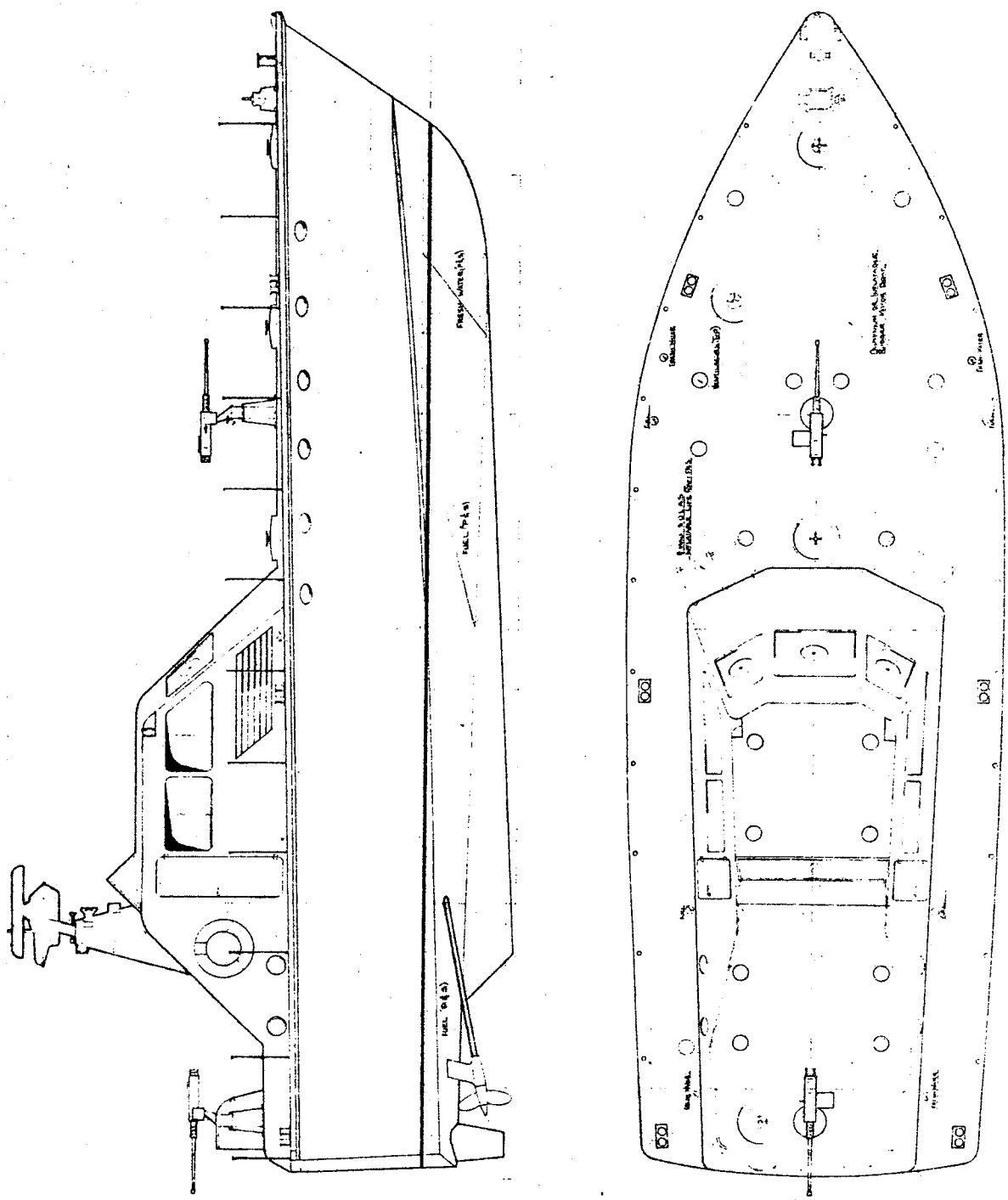

FIG 1. 16 METRE PATROL BOAT

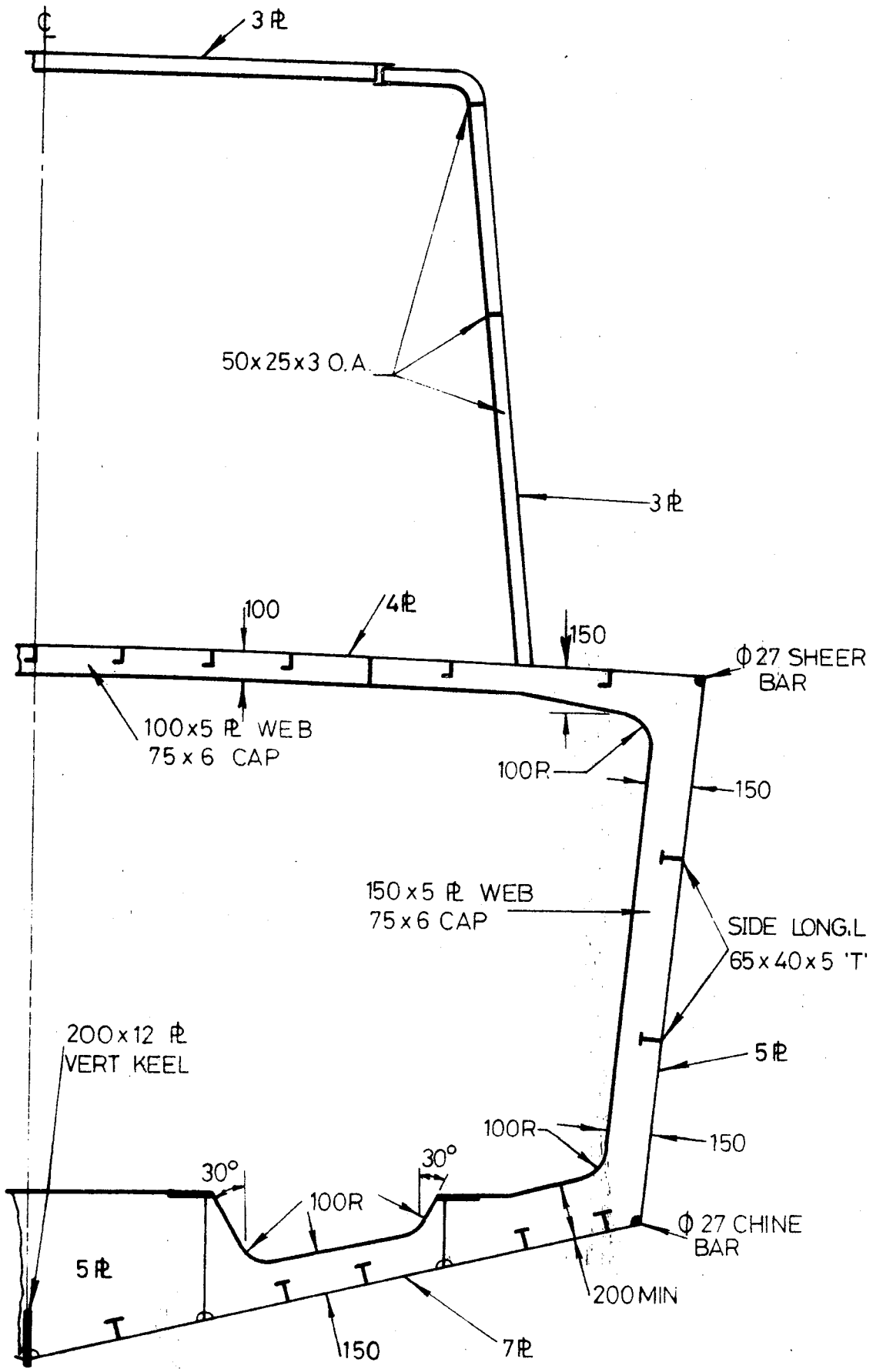

FIG 2. TYPICAL STRUCTURAL SECTION. 16 METRE PATROL BOAT.

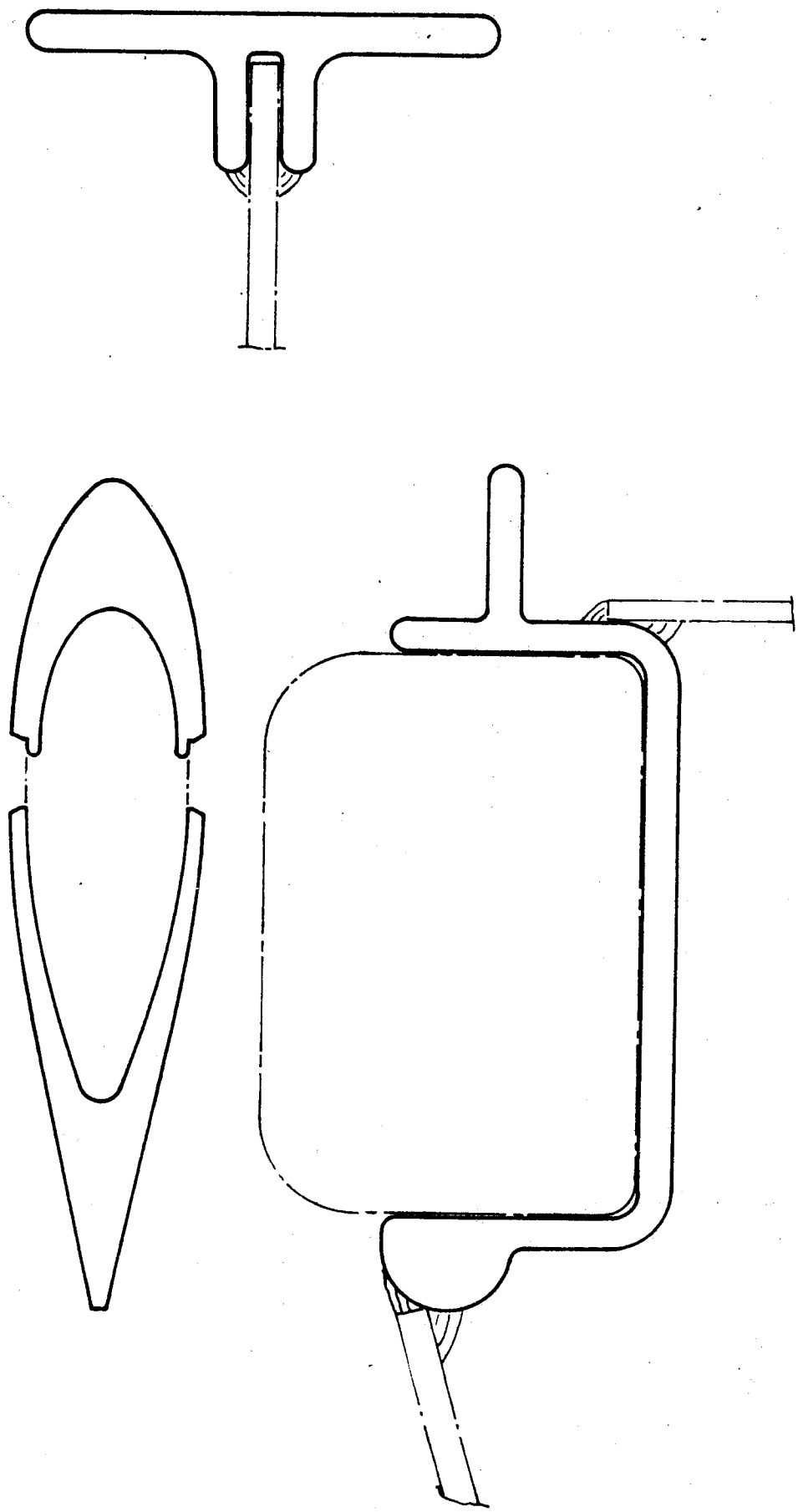

FIG 3. EXAMPLES OF SPECIAL ALUMINIUM ALLOY EXTRUSIONS.

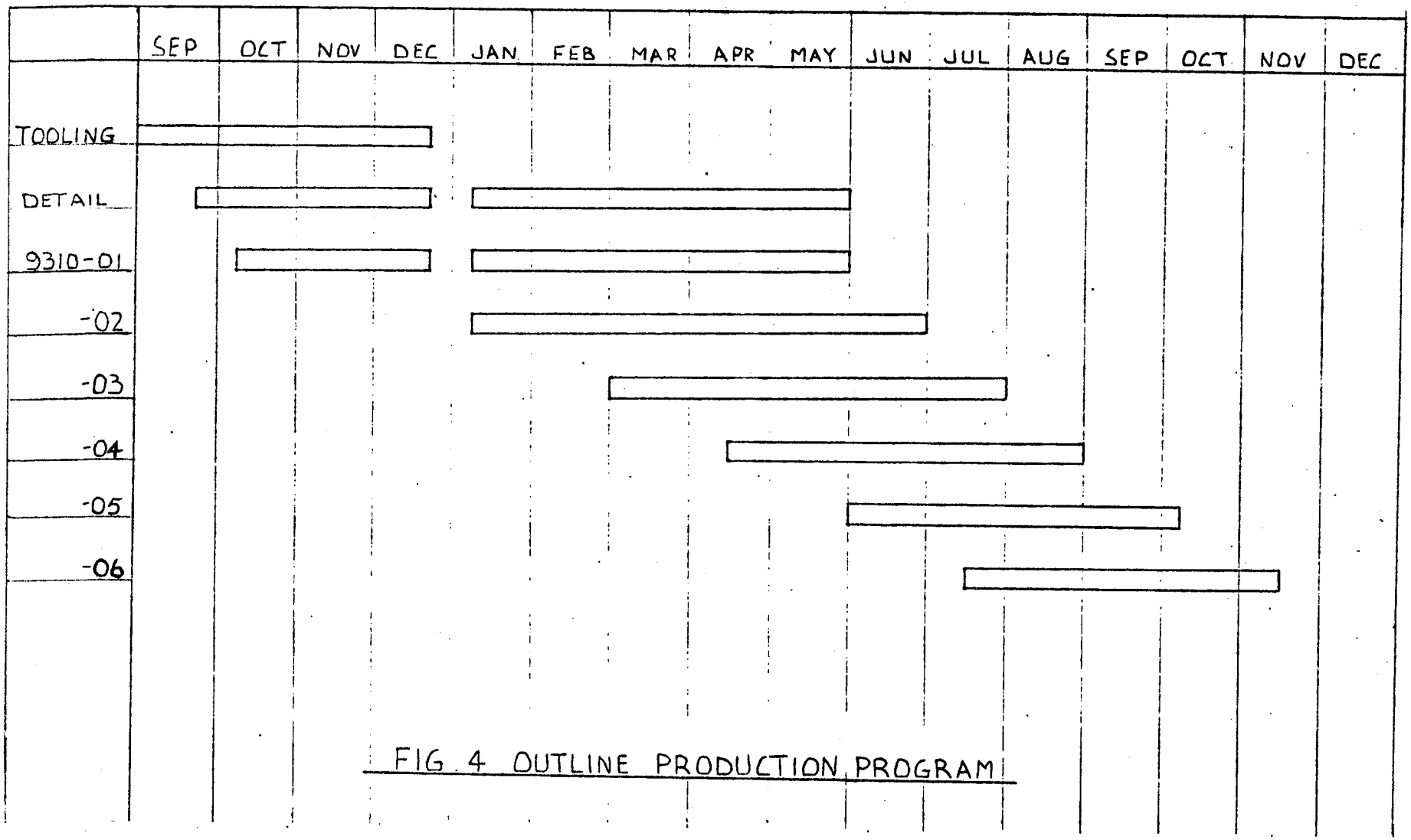

FIG 4 OUTLINE PRODUCTION PROGRAM

Role of the Army will not change. Government policy changes with Govt

ATTACK CLASS PATROL VESSEL: EXTENDED OPERATING EXPERIENCE WITH NAVAL RESERVE CREW

by

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SUMMARY

A description is given of some teething troubles in the operation of one of a class of small ships and of their rectification in service.

I. INTRODUCTION

My first introduction to H.M.A.S. Archer was early in 1968 when it was suggested that I, as Reserve Engineer Officer, become familiar with the class.

I boarded the vessel, which was still crewed by Permanent Naval Forces, one Saturday to find that we were to act that day, in the T.V. series "Contrabandits" duly proceeding to sea loaded with Television Personnel and their equipment.

My most vivid impression at the time was the wardrobe mistress who, on sighting the only wooden fitting on board (The Jackstaff) wrapped her arms around it, and could not be dislodged until we returned to harbour.

Now, some six years and 40,000 miles later, I recount some of the minor problems that we faced, evaluated and overcame with the unstinted support of H.M.A.S. "Waterhen" Base Staff and certain outside engineering concerns.

"Archer", as you may be aware, has been presented to the Indonesians, and we like to think that this was because she was a good ship that never let the Navy or the Reserve down.

The comments made in this paper should not in any way, be taken as a condemnation of any design aspects of the Attack Class Patrol Vessel, but as pointers to certain areas in the craft that required further investigation and/or rectification so as to improve what was initially a fine Coastguard Patrol Vessel.

II. THE SHIP AND SOME OF ITS SYSTEMS

Hull

This is basically a flush deck design subdivided by one pierced and four unpierced watertight bulkheads. Double bottom integrity is established by a combination of watertight void spaces (used as stores) and fuel and fresh-water tanks. In addition to the main double bottom tanks, small sullage tanks that accept wash water from basins and showers etc are also incorporated in the lower hull structure. Pump out is by small integral motor pump units operated by capacitance type level probes.

Access to accommodation from the upper deck is via a watertight hatch to the aft section, or by watertight doors through the midship superstructure to the forward and midship sections. Additional major upperdeck penetrations

are to the cable locker, and emergency exits to forward accommodation, engine room and steering flat.

A raked bow and square stern hull, surmounted by a streamlined superstructure and funnel present a rather pleasing but somewhat squat appearance though the waterline length appears to be somewhat short when compared to the height of the vessel.

The hull flare could be considered to be severe, angling out rapidly toward the upperdeck. The effect of the rapidly increasing buoyancy results in a violent elevator effect in the forward accommodation in even a moderate head sea, with the foredeck continuously taking green water, when heading into a short steep sea at only moderate speeds. The foregoing thus necessitates careful sleeping positions for all those accommodated in this area.

As an illustration of buoyancy lift in the forward accommodation, the writer placed a two pound weight in the tray of the galley scales, the latter being placed on the forward bunks. Consistent readings of three pounds were registered with occasional readings to four pounds indicating 1½ to 2G acceleration in that area in head seas.

Initially, the class had a tendency to squat by the stern at speed, thus exposing a considerable portion of forefoot and underside to angled water flow. In addition, severe pounding was in evidence at moderate speeds. A secondary effect of this squat was to direct flow of aerated water to the engine salt water intakes, the effects of which will be discussed later in this paper. Modifications to the underside of the stern by the fitting of wedges (like aircraft horizontal stabilizers) tended to reduce the squat or angle of attack by lifting the stern when at speed.

Access to the aft accommodation could be somewhat difficult in a seaway due to the hatch opening from forward to aft. The canvas dodger fitted does not prevent the ingress of water and spray below deck due to its facing forward and acting as a scoop. In calm seas, however, this scoop provided excellent ventilation to the after living spaces. Considerable modifications to underdeck areas would have been necessary to allow rotation of the aft access ladder so as to establish reverse hinging of this upper deck hatch.

Main Machinery

Two 16 cylinder turbo-charged Paxman Ventura diesels driving through Z.F. reversing gearboxes provided the propulsion power. The output shafting driving either three or five bladed propellers. Control from the bridge, after an electrically programmed start, was by directional selection followed by an increase of the integral hydraulic governor set point which resulted in more fuel being fed to the engines.

Difficulty was initially experienced with fine operating tolerances in the gearbox reversing levers, in that the neutral position was sometimes difficult to establish. This could result in an engine starting when direction was already selected. Clutch limit switches and indicator lights were incorporated in the starting sequence to prevent a start occurring unless the clutches were in neutral.

The start sequence is straightforward, and following manual readiness checks, the engine start button is depressed. This results in an auxiliary lubricating oil pump commencing to prime the engine lubricating oil system for some twelve seconds. On timing out, the electrical starting motors are energized and the engine will begin to turn. A centrifugal switch on the engine camshaft will de-energize the starting control circuit at 300 rpm.

Should the centrifugal switch fail, or the engine fail to start, a timer will de-energize the control circuit after some ten seconds.

Difficulties were experienced initially with the centrifugal switches. However, careful maintenance overcame this problem. The main starting battery paralleling circuits at first caused some problems in that the solenoid coils were not continuously rated. Also, contacts were inclined to draw arcs, thus burning the contact faces. Replacement of coils, and the fitting of diodes across the contacts overcame this problem.

However, one further starting problem occurred following the seeking of shelter in Broken Bay from particularly heavy weather. On attempting to start, and at the same time knowing the batteries were at full charge, rotation of even the generators was not possible. Inspection of the battery terminals revealed that movement of the battery in the heavy sea and the non-flexing of the heavy leads caused a terminal breakage flush with the battery case. Careful facing of the remains of the terminal block and connector followed by the fitting of a block and wedge to achieve face pressure and prevent arcing, enabled a start to be effected. It should be said that a fire extinguisher was kept handy. The lesson here is to provide flexible leads, not flexible batteries.

Fuel Systems

Fuel from deep and double botton tanks is pumped via primary filters to two, i.e. port and starboard, 100 gallon service tanks which provide gravity feed to the engines and generators. A degree of caution is required in fuel management as the service tanks are not baffled. This causes surging during heavy rolling, especially when the tanks are below 50% capacity. Rolling can be so severe as to momentarily uncover the tank outlets and allow air to be entrained in the fuel lines. Whilst the main engines are fitted with special automatic air bleeds, the auxiliary diesels are not. This can result in a loss of electrical power which may cause the gyro compass to topple. Re-alignment of this component cannot be achieved with any accuracy whilst at sea.

Cooling Systems

Salt-water provides the main extraction channel for heat from the main engine. Salt-water enters via high and low sea suctions through strainers and cross connections to the engine driven salt-water pumps. It then passes to the gearbox heat exchangers, turbo-charged coolers, and main engine fresh to salt-water heat exchangers and thence overboard via a syphon pipe. Lubricating oil is cooled with main engine freshwater. Two sixteen gallon freshwater header tanks are mounted in the funnel casing to provide the necessary elevated freshwater boiling point in the primary coolant system, and to act as expansion vessels.

Initial cooling difficulties were experienced in the salt-water circuits, despite attention to the air bleed points which are necessary to keep the salt-water syphon effective. The overall effect of loss of salt-water is extremely rapid, a high temperature alarm being followed almost immediately by a deluge of almost boiling water from the elevated freshwater header tanks vents. Whilst the high temperature would, in itself, not cause an engine trip, it was almost impossible to open the high to low suction crossover as it was directly under the deluge. It was necessary therefore to seek a speed reduction so as to reduce the boiling effect and thus enable the crossover to be opened.

At first, salt-water restrictions were attributed to foreign material in

the strainers and strict cleaning details were introduced. However, it was also discovered, that by putting the fire pump on line at any speed above 1100 rpm could also initiate an engine overheat. A system of steaming with both sea suctions open gave temporary relief pending further investigations.

By fitting plastic piping to the engine cooling system bleed points and placing the ends in a bucket of water it was noted that the air discharge increased with speed (wedges not fitted), so all system points were kept open. However, this necessitated almost continuous bilge pumping. A water manometer was therefore fitted across the main suction strainers. This manometer had 5'0" legs and when connected immediately lost its fluid. Mercury was substituted and it was noted that strainer differential amounted to some 6" Hg. At the same time, overboard discharge quantities were noted so that comparisons could be made. Temporary removal of the suction strainer improved flow quantities and caused the main engine FW bypass control to open out indicating that cooling was becoming more effective.

The lessons here were:

i. Give adequate thought and design expertise to all cooling water services. They are not just another hole in the side.

ii. Consider the latent problems of such things as header and expansion tanks. Make sure that overflow or venting do not add to existing problems in the engine room.

iii. In the case of "Archer", damage requiring the use of the fire pump would most likely occur at high speed. However, in this case, one would have to choose between speed or fire.

iv. Following an engine overheat, the wax element in the fresh-water cooling thermostat would melt, thus causing the affected engine to run cold. This could be rectified by removing the element, gently re-heating and then allowing the wax to solidify before replacing it in the controller.

It was therefore decided to have a closer look at the strainer grid and to check the cross-sectional area of the grid. This appeared to be adequate, but all the holes were sharp edged and the plate was some 0.25 inches thick. We decided to try and eliminate the high strainer differential by drilling the holes to a venturi shape thus achieving a better pressure recovery. Special drills and reamers were obtained and the 2000 holes were duly modified. However, just as the above modification was completed the craft was drydocked for the fitting of the stern wedges. Following docking, sea trials were carried out and the improvement in cooling effect was quite marked. Strainer differentials had dropped to 1½" Hg, but it was not possible to attribute this solely to strainer modifications. Perhaps we can say 50% to strainer modifications and 50% to the stern wedges.

Additional difficulties were experienced with the main engine cylinder head inlet valve spring bridge pieces (one push-rod operating two valves). These would fracture without warning, and cause severe damage in the valve box area and in addition starve that cylinder of air. Unburned fuel would then accumulate in the cylinder and run down the walls to contaminate the lubricating oil in the crankcase. An inspection routine coupled with dye penetrant checks of bridge pieces held this problem at bay. When running it was difficult to isolate this fault as exhaust thermocouples were common to each pair of cylinders. Irregular noise, engine exhaust colour, and crankcase oil levels are indications of bridge piece failure.

Flexible fuel pump drive shafts also needed continuous attention. Although they were fitted with bolt locking devices slackening always occurred and loss of a fuel pump was the penalty for an inspection omission.

The main engine turbo-chargers always seemed undersized although no figures are available to support this theory. Despite meticulous attention to fuel pumps, injectors and timing, we always had dirty exhausts. This may have been the result of a European designed engine running in a temperate climate. Turbo-charger oil levels were difficult to read due to engine slope, and oil changes usually resulted in oil spillages on the exhaust lagging which then proceeded to smoke for a considerable period of time.

Clutches and gearboxes gave very little trouble providing those manoeuvring the engine gave a definite position selection and did not try and inch the controls. The latter resulted in excessive slippage and clutch overheat.

On the subject of controls the writer once neglected to check the blow tube rods following maintenance. On leaving the wharf the maintained control was not used, however, subsequent selection caused some concern when we went in the wrong direction. (Murphy's Law - If it can be reversed, it will be).

The foregoing main engine problems were quite minor and with adequate attention to troublesome areas we found the machinery to be completely reliable.

Engine instrumentation should have received more consideration in the design stages, i.e. items such as thermocouple readouts, pressure gauges, etc should have been mounted clear of the machinery. The shaft salt-water flow indicators which were fitted with limit switches were unreliable and inclined to stick in the alarm position.

Consequently, items such as the foregoing, and additional problems like surging in the service tanks caused continuous intermittent alarms. They were then inevitably switched off audible and thus required continuous visual monitoring - a problem that became acute in bad weather.

Auxiliary Machinery

Two Detroit diesels coupled to 4 pole 40 Kw alternators supplied all electrical power for the following:-

Battery charging	Radar (via M.G. set)
Windlass	Galley
Steering	Refrigeration
Pumping	Deep Freezers
Air-conditioning	Main Armament

All systems are 220V, 50 Hertz two wire, thus enabling the use of standard commercial motors, water heaters, refrigerators, sound reproduction equipment, etc. Distribution from the main switchboard in the engine room was via small automatic circuit breakers to sub-panels in various locations throughout the vessel, each sub-board or panel being fitted with miniature circuit breakers. Reliability of the normal commercial equipment has been excellent in both the rotating and static fields.

Pumping equipment is of the "Mono" or positive displacement type for both fuel and water, the only exception being the integral salt-water pumps on the main engines. An accessability problem exists with the small motor pumps

located on the sullage tanks. Access is through a watertight manhole on the lower deck to both motor and probes. The latter require periodical cleaning of soap scum, etc. However, we discovered that a cup full of Gamlen in the drain each week gave vastly improved probe performance.

Because of their location and the wiring arrangements to the motors, exceptional care must be taken during maintenance, i.e. poor electrical isolation can result in death due to a full 220V shock. Re-design of the sullage area is long overdue and in all fairness is very difficult to achieve.

Automatic battery charging has given trouble in all ships of the class, and when operating, requires constant attention to avoid boiling of the electrolyte and subsequent cell damage. On noting this deficiency we resorted to manual charge, i.e. hydrometer check followed by manual cut-off. Great care is needed in this area: no batteries, no engine starts.

Air-Conditioning

There are three separate units, two forward and one aft each being of the direct expansion type. Respective thermostats are located in each compartment. Capacity appears ample due, no doubt, to the compartments being below deck level so that cool air cannot tumble out of the living area when doors are open. The after conditioning unit is critical as the compartment sleeps twelve men and is usually operated in a closed down state at sea. The cool air circulating fans were of a weak design in all units and this resulted in the fan boss being torn out in a very short operating period, thus leaving the vessel without air-conditioning.

Repair advantages possessed by Naval Reserve personnel were quickly realized in this instance, where one of our airline workshops redesigned, repaired, dynamically balanced and returned the fan rotors in one week. Replacement was carried out by ourselves just prior to a weekend voyage.

In addition, our electrical staff from C.S.R., County Council and International Combustion modified the starting circuits to prevent the sudden starting acceleration which caused the initial damage. In this case, there was no paperwork or explanations, just a repair in a workman-like manner.

Steering

The system is a "Mathway" hydraulically assisted unit. Mechanical coupling is always in engagement and loss of the power assistance is inconvenient but not disastrous. Modifications to engine speed may be necessary to overcome the effect of wind and sea when in the unassisted mode. There is an aft steering position, but provision has not been made for a Gyro repeater compass in that location.

Rapid operation of the wheel in either of the two steering positions can result in an apparent stiffening of the control. This is caused by a lack of feed forward to the hydraulic assistance. Thus, it is possible to beat the boost, momentarily giving the impression of a loss of hydraulics. Semi-balanced spade type rudders give excellent response, the turning radius being some two ship lengths.

Pumping Systems

These are confined to:

Fuel	Bilge and Main Suction
Fresh Water	Salt Water

Fuel

Oil can be pumped from or transferred to various deep and double bottom tanks via a small mono-type pump with a manual semi-rotary back up pump.

Fuel tank contents gauges are either of the float or slack diaphragm type, the former subject to heavy surging owing to the lack of stilling wells in the tanks. The latter could only be used as content guides. Dipping by tape is necessary for accurate readings at the beginning or end of a voyage.

All fuel oil is filtered before passing to the main engines and generators. We suffered our only complete machinery failure after fuelling at Gladstone, Queensland. This followed the receipt of fuel heavily contaminated with what looked like alumina powder. Clearing of the system was extremely difficult despite isolation of the offending tank and draining down of the settling tanks, the resulting filter blockage being almost instantaneous.

Fresh Water

A straight forward air pressurized system is used taking water from forward or aft tanks. Capacities are somewhat limited, and an engine waste heat system for the evaporation of sea water should be fitted.

Bilge

A 25 ton per hour Mono pump handles both bilge and salt water, plus emergency salt water for generator cooling via the firemain. Engine room bilge suction locations have, as usual, been misplaced - the positions being selected prior to other piping being installed. Consequently, it is almost impossible to clear engine room strainers rapidly as it necessitates removal of deck plating and the physical action of climbing into and around the restricting pipework. If you can imagine this action coupled with the violent movement of the craft in a seaway and the ever present threat of seasickness, you will understand the necessity of a strict bilge inspection routine and careful attention to any loose rags and/or rubbish that may be about.

III. SOME OPERATIONAL ASPECTS

Habitability

This can be considered in two modes; viz. at sea and in port. In the first instance we have to consider two major problems, these being:-

i. conditions within the vessel
ii. condition of the crew, and as you will appreciate, this depends entirely on the state of the sea at any particular time.

I have witnessed the ideal situation where all hands were available for duty, i.e. 19 including officers, and the worst, i.e. 2 hands, the Captain and the writer in weather up to Force 7, spelling each other on the wheel whilst I, as engineer, also went below for routine checks and fuel management. In this case the vessel was in a closed down state with wind from ahead and the after accommodation hatch fully secured with anyone emerging requiring more than two hands to re-dog the hatch and hold on at the same time.

A side elevation of the vessel reveals that the funnel cowl is slightly below the flying bridge. With wind from ahead, a low pressure area is generated aft of the superstructure into which is drawn large volumes of exhaust gas fumes. These are promptly distributed into the engine room ventilation fan suctions which push contaminated air below and into the accommodation via galley ports, flying bridge access hatch, and the air-conditioning fans to give a choking fug below. Combine this with the effects of seasickness and you have a real problem of resting and recovering your already indisposed crew.

The ventilation problem has been partly rectified by increasing funnel height, but to make even a dent in the seasickness problem requires travel sickness tablets to be visibly taken by all hands that will be affected. Even taking all known precautions the majority of the crew resort to a spanner in one hand and a bucket in the other routine in even moderate weather.

It is in these conditions that trouble can, and will arise, i.e. bilge levels, fuel levels, neglect to top up header tanks etc. Only stabilization could reduce motion sickness, but attention to ventilation can make the closed down conditions more liveable, especially when engine room conditions are further aggravated by crankcase breather fumes being drawn in and extremely high noise levels which require ear protectors to be worn at all times.

Comments have been previously made on living conditions forward. One must also consider the aft accommodation, which sleeps twelve men and has two screws thrashing away about 2'0" below an acoustically unprotected deck. Noise levels are very high and are sufficient to suppress conversation and also loud speaker comments which could decide the safety of the vessel. Some improvement has been achieved by fitting five-bladed propellers. One must also look at the engine noise being transmitted through the structure, not unlike a large sounding board. This, in the writer's opinion, is amplified by the comparatively light structure of the class.

Whilst cooking and food preservation systems were of a high order, we again have the problem of cooking smells permeating the vessel, and also as the engine room is pressurized, opening of the access door within the accommodation, immediately discharges the odours peculiar to the "whirling death department" into the already highly charged internal atmosphere.

In calm conditions the foregoing problems are minimised but with the ship closed down and at a time when alertness is necessary, the crew is subjected to outside influences which are directly controllable in the design stages. Also, port conditions are quite comfortable for a small vessel. As always, one has to contend with sleeping twelve men in a space some 16'0" x 8'0" so all sharp corners have to be rubbed off various individuals and a good coxswain is worth his weight in gold.

Damage Control and Fire Precautions

All crew members have passed the normal permanent service, ordinary or advanced damage control courses. However, in the case of "Archer", damage control was quite a simple operation and only necessitated dogging of one bulkhead door plus various scuttles and upper deck hatches and doors.

There was one aspect, however, that caused us considerable concern, this being the emergency evacuations from the engine room, forward and aft accommodation. The flush deck emergency hatches were initially secured by an underside manhole dog held firm by a single start square thread. Release took some considerable time, and could be troublesome in an emergency. To check this possible deficiency, crew members were told to lay in their bunks,

and then initiate an emergency evacuation procedure when the accommodation lighting was switched off. The first man did not emerge until some three and a half minutes had passed. This was most unsatisfactory, so training was concentrated on this aspect. Following many practices in complete darkness all hands could evacuate the after mess in forty-five seconds, this was inclusive of hatch release time.

As previously mentioned, the galley and engine room access doors are adjacent to each other and open out into a small alleyway. Fire in the galley therefore, could prevent access to the engine room and its pumping equipment, and as the emergency hatch could not be released from outside, loss of the vessel by fire could be a distinct possibility. This was more a port problem where the small ship practice of a fry-up on returning to the craft at night was the dangerous situation. We therefore, constructed an engine room emergency hatch collar for port use. This collar was placed under the hatch after release, preventing people from falling into the hole and at the same time keeping water out. Access below was simply by lifting the hatch off the collar. These emergency hatches have now been redesigned to allow release from outside the hull.

As always, the galley, especially an electric one, is a potential fire hazard and care must therefore be taken with deep frys etc and the removal of all fatty build-ups from vent fans, ovens and grills. Facilities for tripping all power supplies should be located outside the area. This was a subsequent modification to all ships in the class.

In the engine room, attention is always given to fuel pump high pressure discharge lines. Fracture of these can spray fuel oil on the exhaust ducting and manifolds with subsequent high fire risks. Regular inspection of these items coupled with an annealing process minimises breakage risks.

As all electrical distribution is via miniature circuit breakers the fire risk problem due to fencing wire fuses has been all but eliminated.

Fire fighting appliances consist of two hydrant points on the upper deck, foam branches on the port and starboard sides adjacent to the engine room plus the normal CO_2 foam, and gas water extinguishers.

Training of Reserve Technical Personnel

There appears in most minds, and I include senior politicians a misconceived idea that the "Rockies" are a group of Sunday afternoon fine weather sailors but nothing could be further from the truth. Nevertheless, how do you train a group of men that can competently handle a $500,000 vessel over many ocean voyages and what type of person makes up this group?

In the technical area, we decided that as the problem was one of basic marine know-how, officers in the main were ex-merchant service with a First Class Steam and Motor Certificate as a minimum qualification. Electrical and electronic officers were graduates in their profession and a typical cross section of officers and their civilian occupations are:-

Senior Technical Officer	-	Instruments and Automation
Engineering Officer	-	Plant Engineer, A.M.P. Society
Senior Electrical Officer	-	Sydney County Council
Electrical Officer	-	International Combustion

Each officer would spend a considerable period at sea in "Archer" until the necessary level of competence was achieved by a normal crew.

A typical crew group is listed below:-

	Naval Rating	Civilian Occupation
Chief Engineer	ERAD 1	Senior Mechanical Inspector, M.W.S.D.B.
2nd Engineer	ERAD 1	Foreman Motor Mechanic
1st Motor Mechanic	AERAD 2	Fitter and Turner, Garden Island
2nd Motor Mechanic	AERAD 2	Fitter and Turner, N.S.W.T.D.

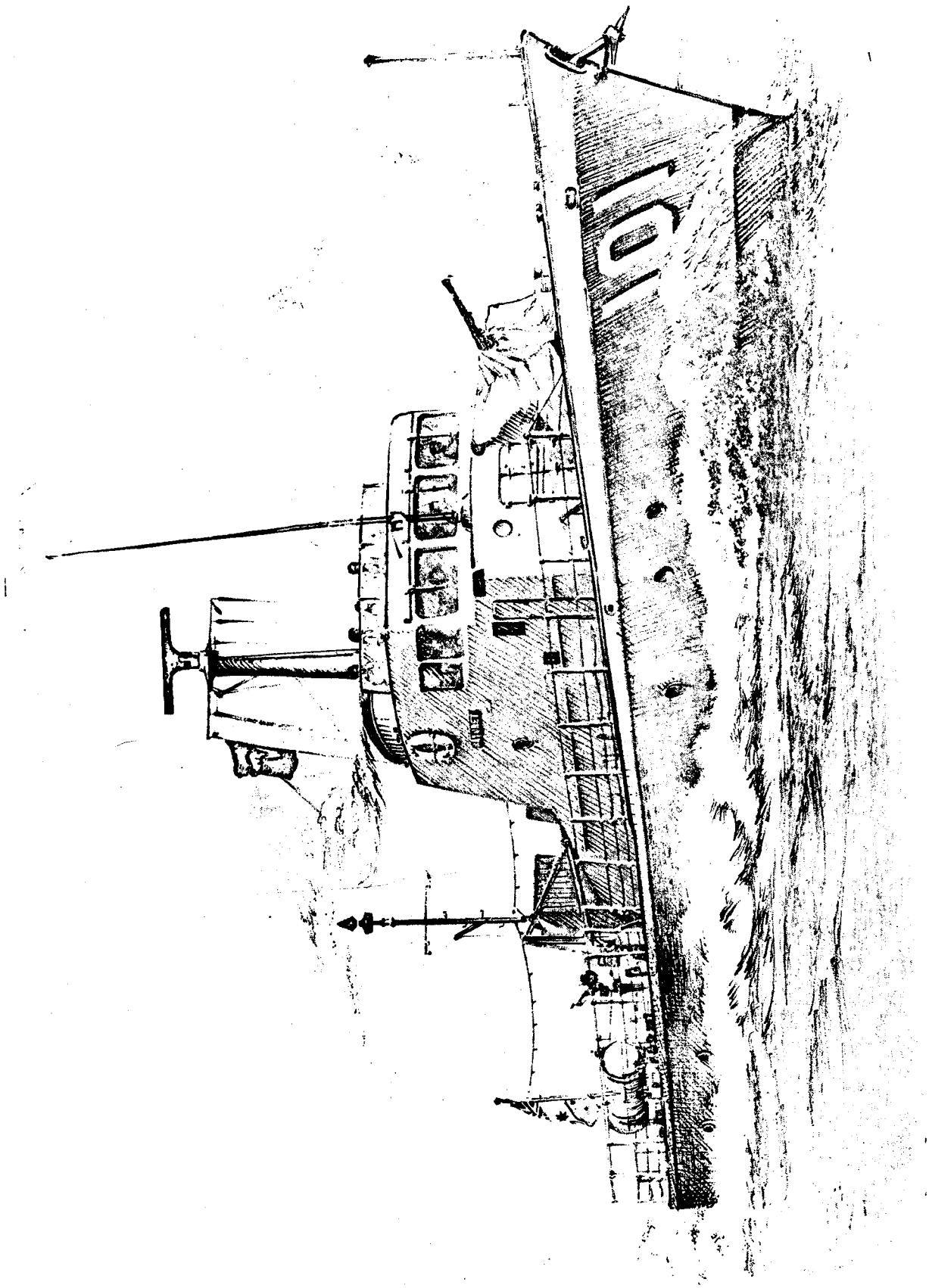
A similar grouping would be found in the Electrical Department, these being divided into Power and Communications.

Because of the training necessary to bring non-tradesmen to an operational level we tended to recruit only tradesmen on the assumption that fitting competence was the primary objective, the seagoing knowledge already resting in the hands of some of the officers and senior petty officers. This proved to be reasonably successful. Even when a Senior Technical Officer, the Commander, was acting as a training level evaluator there were often times when he could not be recognized from the sailors. This group effort was the only major difference between ourselves and the permanent Naval Forces and the reasons to some people were not always clear. By way of explanation one could find that the Chief Petty Officer of yesterday is the prospective customer to-day.

As previously mentioned all hands completed the standard and advanced courses in N.B.C.D. at H.M.A.S. "Penguin" or "Creswell", Senior Petty Officers passing the same examinations for rank as their permanent service counterparts. Time between examinations was, of course, much longer because of our part-time involvement. Officers were obliged to complete thirteen days continuous training each year, and where possible this was in ships of the fleet. Petty Officers sailed H.M.A.S. "Archer" on an average of three two-week trips per year to complete their required thirteen day training periods. With one exception our training methods appear to have worked, in that we were always available to join either a survey workforce or a joint Services exercise.

IV. CONCLUDING REMARK

The writer has now been retired to what is called List 12, i.e. unpaid but available. However, the years 1955 to 1974 in the Reserve were most rewarding and proved beyond doubt that in small ship operation the Reserve Forces are second to none. The views expressed here are those of the writer alone.



OPERATION AND MAINTENANCE OF PASSENGER FERRIES ON SYDNEY HARBOUR

by

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SUMMARY

The paper discusses the problems contained in operating a passenger service on Sydney Harbour. Section one deals with conventional ferries whilst Section two deals with hydrofoil vessels. The problems for each are somewhat different but the main emphasis is given to hydrofoils as they present a new dimension to water transport.

I. CONVENTIONAL FERRIES

The services operated by the Passenger Transport Commission of New South Wales are many and involve a number of different types of ferry, ranging from the wooden-hulled "Lady Denman" built in 1913 to the steel-hulled "Lady Northcott" built in 1974. The following vessels are at present in service:

	Length	Hull Construction	Engines	Year Built
Lady Denman	110ft.	Wood	Crossley	1913
Lady Edeline	110ft.	Wood	"	1914
Karrabee	107ft.	Wood	"	1914
Karingal	104ft.	Wood	"	1913
Kameruka	108ft.	Wood	"	1913
Kooleen	69ft.	Steel	"	1956
Kanangra	149ft.	Steel	"	1913
Lady Cutler	120ft.	Steel	M.W.M	1968
Lady Woodward	120ft.	Steel	"	1970
Lady McKell	120ft.	Steel	"	1970
Lady Northcott	143ft.	Steel	Lister Blackstone	1974
North Head	210ft.	Steel	English Electric	1913
Baragoola	199ft.	Steel	English Electric	1922

All the above vessels are of double-ended construction and with the exception of the "Lady Edeline" and "Lady Denman" all have a propeller at each end. The "Lady Denman" and "Lady Edeline" have only a single propeller so that on the outwards journey the propeller "pulls" and on the inwards journey it "pushes".

The propulsion machinery varies from direct reversing diesels to diesel electric machinery. All the vessels fitted with Crossley diesel engines are of the direct reversing type, whilst the "Lady Cutler", "Lady Woodward" and "Lady McKell" are fitted with a single M.W.M. diesel engine with clutches to engage the fore and aft propellers.

During service the leading propeller is trailing and of course revolves at a speed proportional to the vessel speed. To stop the vessel, on engaging astern, the clutch on the leading propeller is activated. As the propeller is already turning in ahead direction, this puts a heavy strain on to the clutches and hence the engine.

* The views expressed in the paper are those held by the author and not necessarily those of the Public Transport Commission of New South Wales.

The "Lady Northcott" is an enlarged version of the previously mentioned class with two Lister Blackstone engines for main propulsion. The addition of a second engine has meant the inclusion of a gearbox between the engine and clutches but it allows greater flexibility in operation.

The "North Head" and "Baragoola" are the two largest vessels in our fleet and technically the most interesting. The propulsion engines are coupled direct to a 500 KW D.C. generator. Each propeller is driven by 2-600 HP motors driving through a 5.1 reduction gearbox. The control of speed and direction is by a stepped controller in each wheelhouse. The motors are supplied with a constant current of 1000 Amps and by varying the voltage by use of an amplidyne control system, the necessary change in speed is obtained. Various safety devices are inbuilt to prevent misuse and subsequent damage. It may be of interest to note that experiments have shown that the best speed is obtained when the forward or trailing propeller is driven at 25% of normal power.

Service

The main terminal for our service is of course Circular Quay, from this terminal services run to Manly, Hunters Hill, Taronga Park, Neutral Bay and Mosman. The frequency of service to each point varies. During peak hours a heavy frequency is maintained but in off-peak hours it is substantially reduced.

Crew

With amalgamation of the inner and outer harbour services, two different crew requirements exist. For the inner harbour service, vessels are generally crewed with a Master, Engineer and Deckhand. The Master is required to hold a Harbour & Rivers Master Certificate issued by the Maritime Services Board. The Engineer holds an Engine Driver's Certificate, also issued by the Maritime Services Board.

In the Outer or Manly service the crew comprises a Master, Engineer, 4 Deckhands and a Greaser. The Master holds a similar qualification to that held within the inner harbour service. The Engineer by law must hold an Engine Driver's Certificate. However, because of complexity of the machinery we have concluded that a 2nd class Certificate of Competency issued by the Ministry of Transport is essential.

Survey Requirements

All ferries are under survey by the Maritime Services Board. This involves an annual docking and engine survey. In the case of multi-engined installations, half must be surveyed each year.

Maintenance and Operational Hazards

Maintenance requirements are under two main headings, Machinery and Hull.

Hull Maintenance: As previously stated, annual dockings are required for survey but in dealing with the wooden-hulled vessels, six-monthly dockings are necessary. All the wooden-hulled vessels are old and in order to keep them watertight, an increasing number of timbers require replacement. A constant cycle of recaulking is essential at this time in their life cycle and with the apparent demise of skilled tradesmen this is becoming increasingly difficult.

The steel-hulled vessels do not have the same problems naturally, but once again age is our greatest barrier. The "North Head" and"Baragoola" are reaching the veteran class. The "North Head" is 62 years old whilst the "Baragoola" is 53 years old. Comparatively little of the original hull has been replaced

in either vessel which is a tribute to their builders but the time has been reached when new vessels are required. Both these vessels were sand-blasted last year in an endeavour to establish their exact condition. The results of this investigation are best illustrated by the appointment of Burness Corlett & Partners,Australia, to do preliminary design studies for new vessels.

Machinery Maintenance: Because of the annual survey requirement for survey on the vessels, regular maintenance is confined to the engine manufacturer's recommended list of duties. These involve specific routines at 250 hours, 500 hours and 1000 hours and apart from this, little is necessary to maintain the vessels in a satisfactory condition.

However, the "North Head" and "Baragoola", because of the diesel electric drive, require strict attention to the condition of brush gear contactors etc. A six monthly cleaning and adjustment has been found necessary in addition to annual overhaul. Without this, earth leakages become apparent with the associated risks.

As a generalization the main machinery causes little trouble, the major problems are the smaller auxiliary machines and pipelines. Pipes have a habit of bursting in the most inaccessible section of the vessel or immediately below a generator or motor. But of course, this can be considered normal for any ship.

Operational Hazards

Possibly the biggest hazard we encounter is the sponson band. Granted it saves damage to the vessel in event of contact with the wharf, but invariably it becomes dislodged and subsequently removed when hitting the next wharf.

Plastic bags even have an effect on conventional ferries as well as hydrofoils. The results are identical, that is, boiling the main engine, but the removal of them is harder. It is necessary to call in divers to remove them, whereas with the hydrofoil, going astern will clear them.

In recent times we have been involved in two spectacular accidents at Circular Quay, in both instances the engines were put ahead instead of astern. The fore ends of both vessels were demolished along with sections of the walkway at the Quay.

Not all accidents are through human error. However, mechanical component failure can cause similar results. The "Lady Wakehurst" in its first week of operation snapped a ball joint on the gearbox, resulting in an unwanted grounding next to the Aquarium at Manly. Again with the "Lady Wakehurst" seven days later, the main fuel line burst resulting in stoppage with a mid-ocean transfer of the passenger load.

Despite these and other mishaps, our record for completed trips to timetable is very good with a 97% success factor.

II. HYDROFOILS

In 1964 the Port Jackson & Manly Steamship Company introduced hydrofoils to Sydney Harbour. The first was the "Manly", a PT20 seating 72 passengers, built by Hitachi Zosen under licence from Supramar A.G.

The principal particulars of this vessel are:-

Length overall	67 ft.
Beam across foils	26 ft. 5 in.
Beam across hull	16 ft. 5 in.
Draught hull borne	10 ft. 2 in.
Draught foil borne	4 ft. 6 in.
Displacement fully loaded	32.5 tons
Displacement unloaded	24.1 tons
Maximum speed	34 knots
Engine	1350 HP

The main engine is a Maybach Mercedes Benz turbo-charged V12 diesel with all auxiliaries engine driven. High pressure hudraulics for operation of the steering gear and bow foil actuating mechanism are provided by an engine driven pump.

The engine starting system is 24V DC from 360 Amp. hour batteries. All lighting is 24V DC fluorescent and the battery charging generator is also engine driven.

The propeller drive is Vee form through a ZF BW800HS electro hydraulic gearbox with integral thrust bearing. The direction of rotation and engine speed are controlled from a single lever controller situated in the wheel-house. The four shaft bearings that support the propeller shafting are of the Cutlass type and are lubricated by the engine driven saltwater pump.

At the time of delivery, the vessel was fitted with only one rudder with the propeller mounted in front of the rear bearing. In 1970 a new rear foil was fitted with two rudders and the propeller shaft lengthened to allow the propeller to be mounted aft of the foil. The reasons for this will be discussed a little later.

The hull is of hard chine rivetted light metal alloy construction and is fully transverse framed.

Both foils are standard Schertel Sachsenburg surface piercing type with the forward foil supporting 60% of the weight whilst the aft foil supports the remaining 40%. The forward foil is a uniform structure with a support tube through the hull. The adjustment of the angle of incidence is by a hydraulically operated lever attached to the support tube. The aft foil is again a uniform structure formed by a girder, two rudders, and two struts which transmit the foil lift to the hull.

Following the public acceptance of this vessel and the increased demands made upon it, a further vessel was ordered. Due to this increase in demand, the vessel ordered was a PT50 seating 140 passengers. The builder on this occasion was Canteri Navali Rodriguez of Messina. Rodriguez have had a long association with Supramar A.G. and, in fact, built for them the first PT20 which, I may add, is still in service across the Messina Strait.

The vessel "Fairlight" arrived in 1968 and its principal particulars are:-

Length	96 ft. 4 in.
Beam across the deck	20 ft.
Beam across the foils	35 ft.
Draught foil borne	4 ft. 6 in.
Draught hull borne	11 ft. 9 in.
Displacement loaded	66 tons
Maximum speed	35 knots
Engine power	2 x 1350 HP

The main engines are Maybach Mercedes Benz diesel turbo-charged V12 with all auxiliaries engine driven. High pressure hydraulics for flap and steering control are provided by engine driven pumps, each pump engine driven supplying either flaps or steering.

The main engine and auxiliary engine starting is 24 DC. The batteries are charged by main engine driven generators with an additional battery charger from the main power source. All lighting is 240V AC; ventilation fans are 240V AC also and power is from a 12.5 KVA alternator driven by a four cylinder OM636 Mercedes Benz diesel. Each engine propeller drive is straight through a ZFBW800 HS20 gearbox with built-in thrust bearings. The direction of rotation and engine speed are controlled by a single lever control for each engine situated in the wheelhouse. The propellers are situated behind the rear foil. The shaft is supported by four water-cooled and lubricated cutlass bearings.

The hull is of hard chine construction and is transversely framed in the bottom and longitudinally framed in the side and deck structure. The material used is a sea-water resistant aluminium alloy and the construction is all rivetted.

The foil units are of standard Schertel-Sachsenburg surface piercing type with 60% of the vessel's weight supported by the forward foil and the remainder by the rear foil. The forward foil unit consists of uniform structure with two flanges which attach it to the full foil fitting. The foil is connected by two fins and two struts to the hull flanges. The foil is provided with two hydraulically operated flaps at the trailing edge which are used to facilitate take-off, to adjust flying height and for turns in the foil borne condition.

The rear foil construction is similar to that of the "Manly" and does not warrant further discussion at this point.

Following the continued success of these vessels, further orders were placed and in 1970 a further PT50 - the "Dee Why" - arrived, followed in 1973 by the RHS 140 "Curl Curl". Both the above were built by Canteri Navali Rodriguez. The RHS 140 is similar to a Supramar PT50 but is a Rodriguez design. In May of this year the Public Transport Commission of New South Wales purchased a further PT50 named "Palm Beach". This vessel had been operating on the Hong Kong to Macau route for several years. Modifications have been carried out to make the vessel identical to those already in service.

Service

At this point it is necessary to consider the schedule under which vessels operate. The schedule demands that a vessel leaves the Quay or Manly every ten minutes. This is a particularly demanding schedule when the short distance involved is considered. The vessel leaves the Quay, accelerates to foil borne speed, proceeds at cruising power for nine minutes, berths at Manly, waits six minutes and then returns to the Quay. This imposes considerable strain on both hull and the main machinery.

Crew

For operation within the Harbour, the crew requirements are one Master, one Engineer and one Deckhand. Their training is similar to that used by other hydrofoil operators and involves on-board instruction from experienced personnel before taking charge of their own vessel.

Survey Requirements

All the vessels are built in accordance with Lloyd's rules and are classified 100 A1 Hydrofoil. Because of their service within Sydney Harbour, the Maritime Services Board issue the safety certificate. Normally, the full survey would be undertaken by the Maritime Services Board, but because of Government legislation, the remainder of the survey is conducted by Lloyd's Registrar of Shipping.

Maintenance Aspects

Maintenance requirements can be broken down into main headings - namely Hull and Machinery.

Hull maintenance is of primary importance to the successful operation of any hydrofoil. Our own experience has shown that the hydrofoils must be docked every three months, any increase in the period results in a fall-off in performance. This fall-off in performance results in a reduction in the number of passengers that can be carried. Over the past eight years, we have experimented with a variety of underwater paints and preparations. For the past twelve months, we have used a three coat system - one primer, one polymer undercoat and one coat anti-fouling. To date this system has proved to be very successful. A problem that is not fully resolved is maintaining the anti-fouling coating, some difficulty is experienced with this coating adhering to the polymer undercoat. At 35 knots the water flow washes the coating off the leading edges of the foils and the rudder. This, of course, means an increase in the weed growth with resultant loss of speed. The techniques of applying the coating have improved in recent times; previously the coatings were applied by a brush or roller. However, an air spray is now used and the improvement is quite remarkable. The quality of the paint application can be readily established immediately after docking - five-six seconds are added to the lifting times by poorly applied paint coatings.

Machinery maintenance is in accordance with the manufacturers' recommendations. With the main engines this consists of specific routines at 500 hours, 1000 hours and 6000 and 12000 hour intervals. The 6000 hour service consists of removal of all cylinder heads, turbo-chargers, heat exchangers, one liner and piston from each bank and both fuel pumps. In doing this routine, a considerable amount of time is required, partly due to the limited space available within the engine room. Consequently, we have modified the procedure so that the 6000 hour top overhaul is changed to the programme for 12000 hours. This involves engine removal for a complete strip down and overhaul. We are fortunate in having a complete spare engine so that at 6000 hours the engine is removed and replaced. This takes four to five days compared with 10 - 11 days for the top overhaul. The increase in cost for a major overhaul is covered by the increase in revenue obtained from the five-six days spent in service.

During the complete overhaul it is usual to replace all cylinder liners, main bearings, piston rings and connecting rod bearings. The replacement of liners is not done because of liner wear, but rather to prevent failure due to holing of the liner. This holing of the liners is a common problem for this type of engine in hydrofoils throughout the world. Italian and Hong Kong operators report similar failures at intervals ranging from 3000 hours to 5000 hours. The failure takes the form of a pin hole straight through the liner, the result - loss of water from the cooling circuit and overheating. The exact cause is hard to determine, as if the hole is plugged and the liner replaced in a position 90 degrees to the original failure, the liner will last a further 3000 hours. The engine manufacturer has stringent rules regarding the treatment of the cooling water but this has no effect on the problem. This leads to some supposition as to the cause of the failure.

As stated, all bearings are replaced, as generally after 6000 hours the bearing surface is reduced to two-thirds white metal and one-third brass. Although the clearances may be still in order, the incidence of bearing failure rapidly increases if brass is present. During this overhaul the turbo-chargers and fuel pumps are also subjected to a complete overhaul.

The turbo-chargers have caused us some problems, the principal difficulty being splitting of the compressor wheel. As the failure takes place at over 36,000 r.p.m., the resultant damage is severe. The volute housing, bearings, and turbine shaft and partition walls are destroyed. The cause of the failure is under investigation, but to date no reason can be found to explain the occurrence.

Fuel pumps have also caused some difficulties. The governors have failed, racks have jammed, both resulting in overspeeding and considerable discomfort to operating staff. It is not a pleasant feeling to be in the engine room with a 1500 r.p.m. engine doing in excess of 1700 r.p.m. To shut the engine down in this situation involves pushing the emergency shut-down lever which is above the flywheel in the Vee of the engine.

Calibration of the fuel pumps has proved difficult due to a lack of information from the engine manufacturer. By experimentation we have arrived at an average figure and have had no difficulties to date. The engine manufacturer has given us an involved formula to determine the correct fuel setting but unfortunately, it involves engine removal in order to determine the engine horsepower. As the fuel pumps are overhauled every 3000 hours, this would prove rather expensive.

Although the governor failure usually results in engine overspeeding, there was one notable occasion when the "Manly" completed her trip from Manly to Circular Quay with the engineer crouched over the pumps holding the racks open with a screwdriver. The passengers were none the wiser and the trip was made on schedule. The following trips for the day, however, were cancelled.

The gearboxes are electro-hydraulic as already mentioned; however, the "Manly" and "Fairlight" were originally fitted with electric gearboxes. The failure rate of the coils varied between as little as 40 hours to a maximum of 2000 hours. The "Dee Why" was fitted with electro-hydraulic boxes which have proved to be a great success. Consequently, the "Manly" and "Fairlight" have been converted to electro-hydraulic action. The plate life is now in the order of 8000 hours which, when the frequency of engagement and disengagement is considered, is quite reasonable. The electric clutches, besides having a remarkable frequency of failure, did present one very interesting occurrence. The "Manly" clutch for no apparent reason would engage or disengage; after much investigation it was discovered that operation of the radio telephone operated the clutch.

Operational Hazards

One major hazard still remaining to our operation is debris. This comes in the form of floating ropes, small timber, submerged piles, rubber tyres and plastic bags. The plastic bag is a particularly nasty hazard. They block the water intakes and cause overheating. The time element is particularly important as the blockage inevitably takes place at full speed; the engine will boil in about 30 seconds if the loss of cooling water is not noticed. The "boiling" has further consequences as it damages the cylinder seals and the liner rubber sealing rings. The removal of the plastic bags is generally simple, the vessel is stopped and put astern, a short run astern is usually enough to clear the intake.

Ropes and timber cause a very sharp reduction in speed, at the same time, causing a sharp veer in course. The ropes and timber and tyres also jam the propeller shaft, lodging between the shaft and the rear foil and causing a rise in exhaust temperature. In this case a diver is necessary to free the obstructions.

The "Fairlight" struck an unknown object, suspected to be a submerged pile, which brought the vessel to an abrupt halt. Somewhat the same as hitting a brick wall at 25 mph in your car. When everyone had recovered from the violent stop, the vessel was put astern and then ahead. Unfortunately, the vessel would not fly. It was decided to dock the vessel for further examination. This revealed that the foil had moved from an angle of incidence of +2.5 degree to -2.5 degree. To do this, eight 1" dowel pins had been partially sheared. To correct the fault, the pins were renewed and as an added safety margin, all the holding bolts were made into fitted bolts.

Although the "Fairlight's" performance was restored to what it had been previously, it was not really satisfactory. We had been concerned for some time about the take-off time; with a full load it was generally in the order of 3½ minutes. The exhaust temperatures at the end of this time were reaching 720 degrees celsius. It was thought that the main engines were down on performance, but after replacing them, no noticeable increase in performance was noted. Consequently, Supramar A.G. were contacted and eventually details of improvement to foil area were sent to us. The alterations consisted of lengthening the chord length by 2% and the length of the foil by adding 10" to the tips of the forward foil. The chord length of the inclined sections of the aft foil were also increased by 2%. After these alterations, the first trials were undertaken with a certain amount of anxiety as the alterations seemed to be rather minute. However, our anxiety was not warranted; the vessel's lifting time with a full load was 55 seconds with exhaust temperatures reaching 600 degrees celsius. The handling characteristics had altered a great deal. The response to rudder movements was a good deal quicker and the flying height of the vessel had been increased by 12 - 15 inches. This meant that it was necessary to fly with 0 degree flap angle instead of +3 degree.

Previously it was mentioned that the "Manly" rear foil had been changed. The reasons were principally because of the impossible steering obtained from the single rudder and the constant propeller damage caused by the propeller being mounted in front of the foil.

The steering was impossible, movement of the rudder sometimes induced a turn in the required direction, but other times the turn was in the opposite direction. On other occasions, the only method of course correction was to stop the vessel, line up on the new course and then fly until the next course correction was needed. The propeller, because of its exposed position, frequently suffered damage. In fact, in two years' operation, the propeller was damaged some 50 times. Generally, divers are able to repair the damage but on other occasions, a docking is necessary in order to change the propeller.

The new design of rear foil with twin rudders and propeller mounted behind the foil has overcome both problems. Although as with all vessels, the propeller is still susceptible to damage from driftwood.

The propeller used at present is 770 mm diameter with 1011 mm pitch and turns at 1300 r.p.m. It frequently suffers from errosion damage mainly on the pressure face at half blade length. Each blade has two holes drilled through the blade near the blade base. The propeller theorists may scoff at this but the results have been quite remarkable.

Prior to the drilling of the holes, the propeller life was very short, erosion eating through the blade in as little as three months. The expected life of a propeller now is two years - after this time the blade has been thinned down too much due to the constant need for balancing. New propeller designs having an increased diameter and a reduced pitch are under consideration at present. Trials have been held with a 780 mm diameter and 985 mm pitch propeller and the results are encouraging. The take-off time is reduced and the speed has been maintained - in fact, a slight increase is present. Erosion damage is reduced indicating that the propeller efficiency is increased.

In the early days, hydrofoil operation was much more demanding than it is today. The schedule was very demanding and any breakdown had to be dealt with immediately, regardless of the time or day. Now with the addition of a fifth vessel, we have two spare vessels to enable us to carry out routine maintenance without disruption to the service. In addition, some minor but important changes in main engine design have been introduced. The most important one from the operator's viewpoint is the introduction of the hard head seal. The original design of a soft head seal was subject to an incredible failure rate. Seals would be changed one night and fail the following night; at other times they would last for two weeks. The new head seal is not perfect but a properly installed seal can be expected to last twelve months.

The "Manly" after it arrived in Sydney underwent some harrowing experiences. In its first week of operation the Master went astern forgetting that the foil protrudes from the side of the vessel. This resulted in the foil ram being torn from its mountings. On another occasion, whilst on an excursion which went outside the Heads, it tried to go through a wave instead of over it. This resulted in the forward cabin roof being stove in. After this, stanchions were added to the cabin and the roof was strengthened. This of course brings us to another important part of hydrofoil operation, namely the sea conditions.

The Harbour is generally calm and benign, but crossing the Heads can be quite an experience. The sea is always a beam sea and the self-righting characteristic of the foil is evident during the crossing. Approaching Manly, a slight following sea can be encountered; this presents some problems to the crew. First, to be able to hold the vessel on a wave similar to surf riding and secondly, to prevent the vessel overtaking the waves too quickly which results in a violent shuddering. This shudder breaks the foil holding bolts with similar results to what happened to the "Fairlight" when it struck the submerged object. If the vessel is slowed down too much, it falls off the wave and becomes hull-borne, so that the take-off procedure has to be repeated.

Recently we have experienced some problems with one of our later hydrofoils, the "Curl Curl". This started with the breaking and loss of the port shaft intermediate strut bracket. After replacing it and returning to service, the starboard intermediate strut bearing holding bolts sheared. These were replaced and everything appeared satisfactory. However, our state of euphoria was rudely shattered when the starboard shaft small strut tore loose from the hull. The process of lining up shafting for these vessels is somewhat difficult due to the extremely flexible nature of their construction. In order to do this it is necessary to support the vessel on the rear foil and to support the forward end as near to the forward foil mounting plate as is practical.

The vessel is then loaded with weights totalling six tons, spread through the cabins in proportion to the number of seats. From this point on,

the process of lining up is as per a conventional vessel. However, one must be careful that no one moves about on board whilst the sights are being taken, as it has a pronounced effect on the accuracy of the line-up. The results obtained from the line-up showed that all the bearings were misaligned by amounts varying from 0.100 in. to 0.375 in. These amounts do not indicate any serious misalignment as all bearings are cutlass rubber with clearances up to 0.120 in. with shaft lengths of 12 ft. between bearings. The cause was no doubt due to striking a submerged object combined with an inherent weakness in the welding of the strut flange.

Towards the end of the repairs to the "Curl Curl", the "Dee Why" broke a shaft. Thus for the first time - and we sincerely hope the last - two PT50's were nose to tail on the wharf at Vickers Cockatoo Dockyard. Having mentioned some of the things that go wrong, it must be pointed out that the hydrofoil has proved to be a robust and safe vessel. This was evident during the heavy storms which have struck Sydney over the past twelve months. Although the services have at times been suspended, the cause is not so much a question of the hydrofoil's ability to navigate seas us to 20 ft., but rather due to the difficulty of berthing at Manly. The berthing platform at Manly is a floating pontoon and because of its violent movements, it is not possible to lay alongside with any degree of safety during a storm. The height of the seas encountered raised some interesting points - the designers of the foils have given the maximum height for operation at 6 ft. for PT20 and 10 ft. for PT50.

The arrival of the fifth vessel has meant a complete revision of our maintenance scheduling. It is proposed that in order to provide the travelling public with the most efficient water transport system, reliability must be increased. To that end it is envisaged that every twelve months each vessel will be completely overhauled. There will always be the unavoidable breakdown, but by thoroughly overhauling at the stated intervals these interruptions should be reduced.

III. CONCLUDING REMARKS

From the preceding it may be seen that areas still exist in which a good deal of co-operation between designers and operators is essential. In reviewing our operation and deciding upon our major single difficulty, one is forced to say the sponson band. By coincidence, this is an area where designers and operators can combine to reduce and ultimately eliminate a problem. The sponson band absorbs the shock of berthing; it is by tradition made from wood with a steel band to hold it in position and provide an unbroken face. In recent years a number of synthetic materials have appeared overseas that seem to offer the ideal solution. These materials have a high impact resistance, low coefficient of friction and are extremely easy to install and replace.

What is the future of water transport in New South Wales? The Public Transport Commission are actively engaged in up-grading the present system. New ferry designs are being studied and new services are being introduced. The hydrofoil fleet is increasing so that a completely reliable service may be offered to the public. It is envisaged that sufficient vessels will be available to enable a complete overhaul of each vessel every twelve months. During this overhaul period the service will not be reduced and a spare vessel will be available for the unexpected breakdown.

By updating and increasing the fleet of ferries and hydrofoils, it is hoped that the public can be drawn back to water transport and reduce the congestion which exists on the roads.

RESEARCH ON THE FLUID DYNAMICS OF AIR-CUSHION VEHICLES

by

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SUMMARY

Research on air-cushion vehicles (ACVs) may be divided into two broad areas: a generally theoretical drive into the aerodynamics and hydrodynamics (carried out mainly by universities and research institutions), and a more practical approach by ACV constructors centred on skirt design and controllability.

The principal theoretical studies described in this paper cover the following three areas: the generation of the lift by the air cushion, the resistance of the craft due to forces generated by the air and water, and the motion of the ACV in a seaway.

To varying degrees, all of these problems have been solved on a theoretical basis. Experiments on models or full-size craft have also been carried out, in order to test these theories and to advance their development.

SYMBOLS USED IN FIGURES

B = craft beam
c = craft velocity
C = craft perimeter
d = water depth
D_c = discharge coefficient
F = Froude number = $c/\sqrt{gL}$
g = acceleration of gravity
h = hoverheight
h_k = skirt height
h_w = wave amplitude
L = craft length
n = number of wave profiles
N = number of Fourier terms
p_c = cushion pressure
p_J = total pressure in jet
P = power in air flow
Q = air flow
r = radius of turn
R = wave resistance
R_c = wave resistance coefficient = $R\rho gL/2Wp_c$
S = induced side force
S_c = induced side force coefficient = $S\rho gL/2Wp_c$
t = jet thickness; time
W = weight of craft
x = longitudinal coordinate
y = transverse coordinate
z^* = dimensionless heave = z/h_w
α = longitudinal smoothness parameter
α_w = wave slope amplitude
β = transverse smoothness parameter
ε = yaw angle; stability skirt location
ζ = wave elevation
θ^* = dimensionless pitch = θ/α_w
ρ = water density
ρ_a = air density
ω_a = wave encounter frequency

I. INTRODUCTION

The air-cushion vehicle (ACV) first made its appearance in the late 1950's, principally in Great Britain and the United States. Early workers were mainly concerned with achieving an adequate lift, so that the clearance between the base of the craft and the ground or water would be adequate to allow sufficiently unrestricted travel. To this end, the simple plenum chamber design (in which air was pumped into an inverted volume, and allowed

to escape around the edges) was quickly replaced by the annular-jet concept, which proved to be more efficient in terms of minimizing the lift power.

However with the first trials, it became clear that there were a number of other problems to be solved - in addition to the basic one of lift. These were: adequate static stability, reduction of drag in forward travel, minimizing heave and pitch accelerations over rough surfaces, and achieving adequate control.

It can be said, that all of these problems have been attacked, and to some degree solved, by the major ACV builders, as well as workers in universities and government research institutions. Thus the ACV has now found a place in the transport spectrum. Its role is still limited, primarily due to the high cost of operation - a direct result of the level of technology required to build these craft.

In the following sections of the paper, some of these different aspects will be discussed, and their contribution to ACV development will be assessed.

II. LIFT SYSTEMS

Plenum Chamber

This design of lift system is the simplest and is illustrated together with the notation, in Fig. 1. The theory predicting the clearance is given, for example, by Elsley and Devereux (1968), and is based on Bernoulli's theorem assuming no losses in the cushion.

As indicated by the equation in Fig.1, the power is seen to increase non-linearly with cushion pressure - indicating the importance of keeping the craft weight at a low value. An inwardly facing lip reduces the discharge coefficient - if upstream separation can be avoided - and minimizes the power requirement.

Over water, the cushion pressure depresses the water surface, and this alters the effective clearance above, say, the undisturbed free surface. Jones (1966) has studied this problem and developed a theory which adequately predicts the hover height.

Peripheral-Jet

Much more work was initially expended on this system of lift, and this was described by Mair (1964), amongst others. The basic principle is illustrated in Fig. 2. The simplest theory assumes the jet is thin with respect to the clearance, and is based on the momentum of the jet. The so-called "exponential theory" takes into account some of the features of the geometry of a jet of finite thickness. This second theory is seen to be a good predictor of the cushion pressure. The annular jet is between two and three times as efficient as the plenum chamber, depending on the hover height.

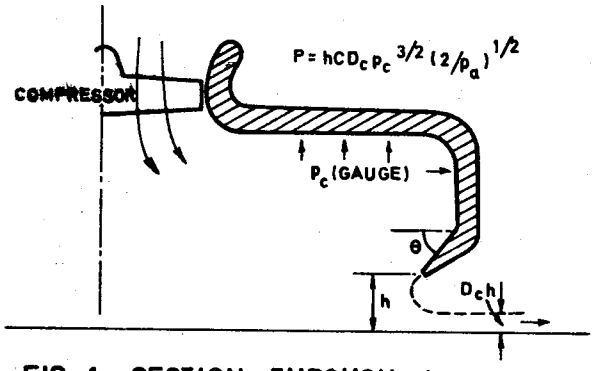
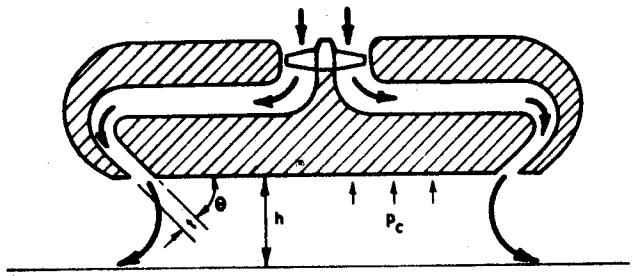


FIG. 1 SECTION THROUGH A PLENUM CHAMBER CRAFT

However, the superiority of the annular-jet system is partly reduced when one considers the extra weight of ducting required, as well as the associated frictional losses.



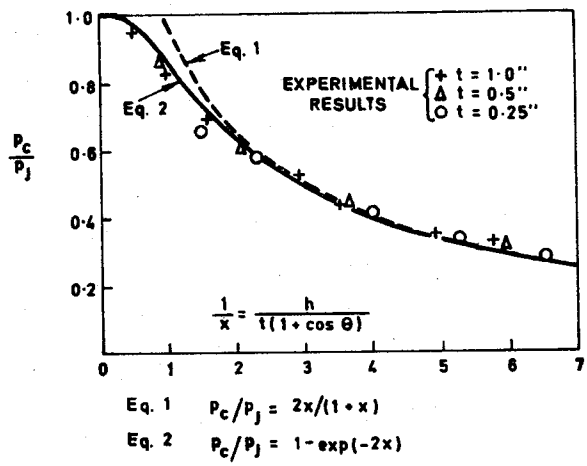


FIG. 2 THE ANNULAR JET

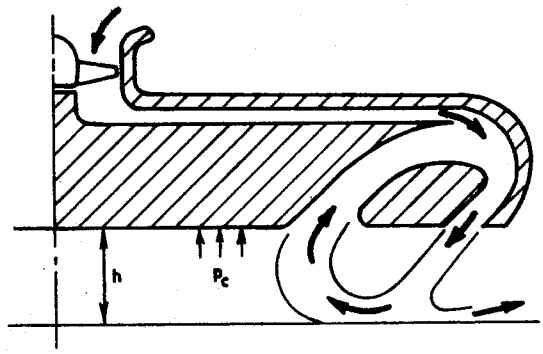


FIG. 3 THE RECIRCULATION PRINCIPLE

The static performance of the annular jet over water was considered by Hogben (1966a), Alexander (1966) and others. It is found that the clearance under the craft, measured to the bottom of the depression, is approximately the same as the clearance over land.

The actual details of the shape of the jet nozzle have some bearing on the efficiency of the system, and some work by Lowenstein and others (1969) covered this point. A slight degree of converging taper on the nozzle increases the cushion pressure generated by a given power.

The air velocity in the jet varies of course, with the size of the ACV. It may reach 80 m/s on a craft of mass 160 t. The effect of compressibility is thus only marginal, and this has been verified by the calculations of West (1968).

When the ACV moves forward, the external aerodynamics play an ever-increasingly important role in affecting the cushion pressure distribution. Alexander (1968), Ozawa, H. and others (1971) and Cooke and Duffey (1972) have examined this problem.

Basically one finds that due to the ram pressure of the air stream on the bow region of the craft, the air jet in the forward region of the craft is over-fed relative to the rest. This results in a bow-up tendency of the craft; the overall result is some augmentation of the ground clearance.

Some work has been done on the recirculation principle, in which an attempt is made to improve on the basic peripheral jet by reusing its momentum. One such system (Murao and others (1968)) uses an outer peripheral jet at the edge of the craft as shown in Fig. 3. A portion of the air from this jet is not lost to atmosphere, but is picked up by an inner jet which passes the air back to the outer jet. The make-up air has to be supplied by a fan or a set of ejectors. The actual power required to run the system can be reduced by up to one half compared to the simple annular jet. However the complexity of the system, its tendency to pick up gravel and water, which can damage the ducting, and some inherent instabilities have precluded its use in all but two or three full-size craft.

Flexible Skirts

It was recognized quite early in the development of ACVs that excessively large amounts of power would be required to achieve a sufficient clearance for

operation in realistic seaways. Furthermore, the air cushion has a drag - due to the fact that air ingested by the lift system has to be accelerated to the speed of the vehicle. On some early designs, this momentum drag accounted for well over half the total resistance.

Some early work on flexible skirts was done by the Bell Aerosystems Company (1962). These skirts were referred to as trunks, and simply extended the length of the peripheral jet. Provided the height of the obstacle or wave to be negotiated was less than the combined skirt height and daylight clearance, then no structural damage to the craft would occur. This statement, of course, neglects any motion of the craft - in particular pitching - which might phase awkwardly with the surface and result in hard impact.

The flexible skirt concept was extended by Booz Allen Applied Research, Inc. (1962) to include some inflatable craft structures - principally the lower sections. This concept was not pursued for some years, but recently some smaller ACVs have been designed with inflatable sidebodies, which allow easy transport of the craft by ship or road.

The greatest development of skirts may be traced to the British Hovercraft Corporation and to Hovercraft Development Limited. This progress was covered by Wheeler (1968). The trend of the development is shown in Fig.4. The presently adopted skirt system consists of a peripheral bag with a section at the bow somewhat different to that at the sides and the stern. Individual fingers are suspended from the bag. These are of a lighter gauge material and are designed to follow the wave contours, and to be easily replaced should damage occur to them. The bag is of more sturdy construction and is intended to absorb impacts with the larger waves. It is pressurized to a level typically 30% above the cushion pressure. The cushion is fed from bleed holes in the bag. It is seen that the peripheral jet system has been

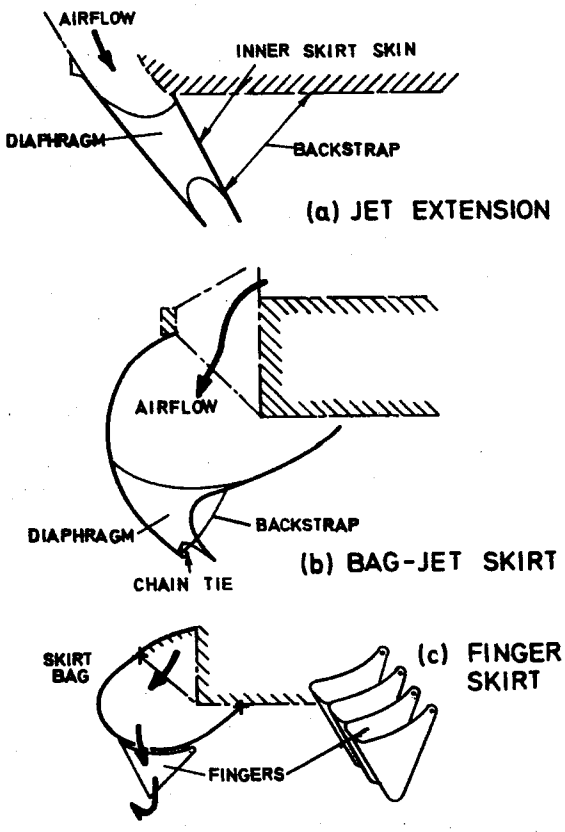


FIG. 4 SKIRT DEVELOPMENT

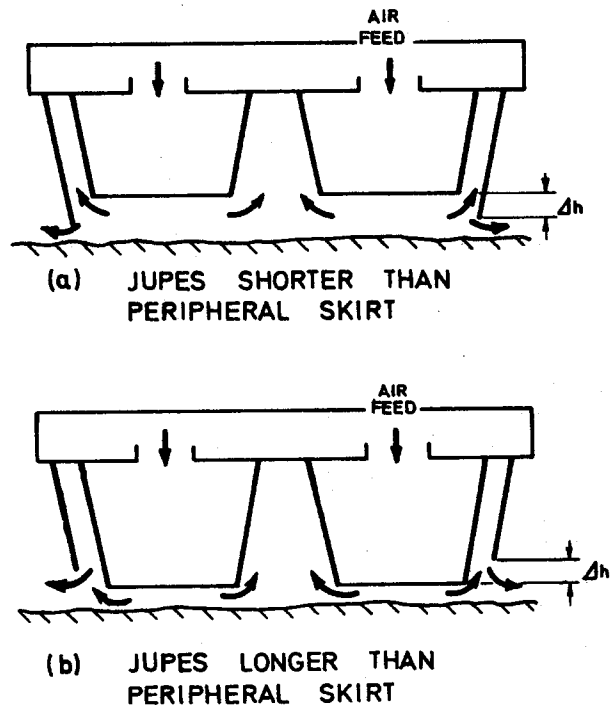


FIG. 5 SKIRT JUPES

essentially abandoned (although the cushion air is still fed around the periphery of the vehicle).

The skirt adopted by Bertin and Company in France is shown in Fig. 5. This consists, actually, of a number of individual skirts, known as jupes which are pressurized slightly relative to the rest of the cushion. A large skirt envelops the entire cushion.

Stanton-Jones (1968) also related the historical development of skirts. He pointed out the higher speeds and smaller motions achieved with the combination bag and finger skirt.

III. DRAG

Components of Drag

The total resistance to motion of an ACV is generally considered to consist of a number of components. These are: The aerodynamic profile drag on the craft which is approximately proportional to the square of the speed, the momentum drag due to the ingestion of the cushion air from the surrounding atmosphere into the moving vehicle which is equal to the product of the mass flow with the craft speed, the wave drag, and other interactive effects including water contact and spray (wetting drag). This breakdown is illustrated in Fig. 6, which also shows a typical curve of thrust due to a set of air propellers.

As previously mentioned, the introduction of the flexible skirt has permitted the operation of craft with very little daylight clearance - thus reducing the required air flow and the corresponding momentum drag.

The wave drag is found to exhibit a main peak (or hump) at a Froude number which depends on water depth and craft planform shape. In some cases - those of relatively high cushion pressure - it is this hump which imposes the minimum requirement of engine power, since the wave drag (and the total) drop beyond this speed before finally rising again.

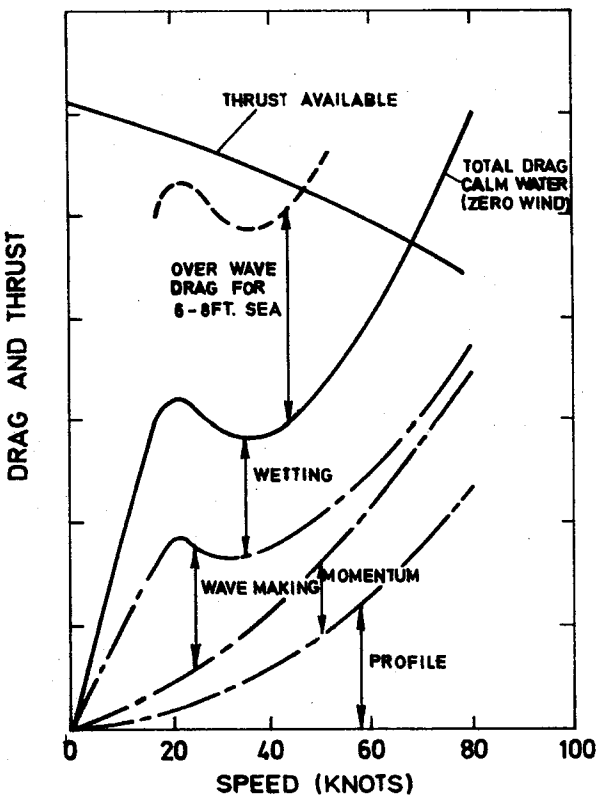


FIG. 6 TYPICAL DRAG BREAKDOWN

Steady-State Wave Resistance

The wave resistance of an ACV can be studied by assuming its action to be equivalent to that of a pressure distribution acting on the free surface of the water. This idealization neglects any physical contact of the lower edge of the craft with the water.

Havelock (1914 and 1932) was the first to develop the general expression for the theoretical wave resistance of an arbitrary pressure distribution travelling at a constant speed over deep water. The treatment neglects viscosity and surface tension in the water. The theory is also restricted to the case of small relative cushion pressure. (The latter assumption, referred to as the linear

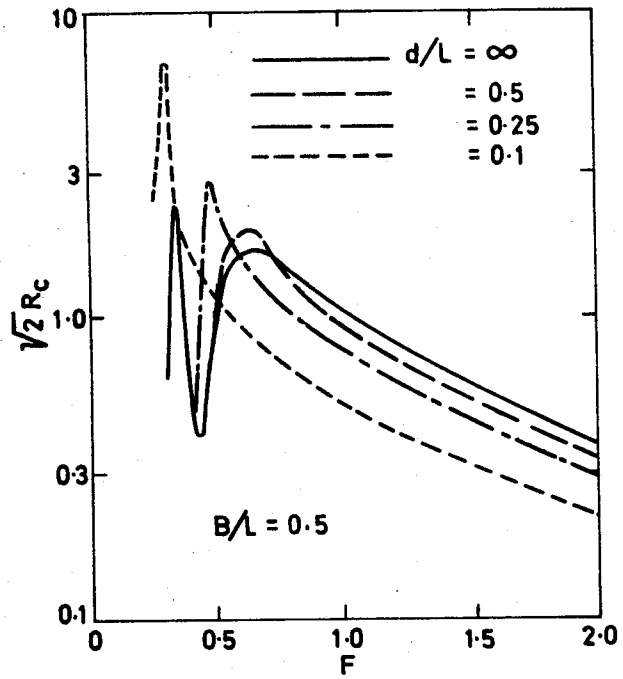
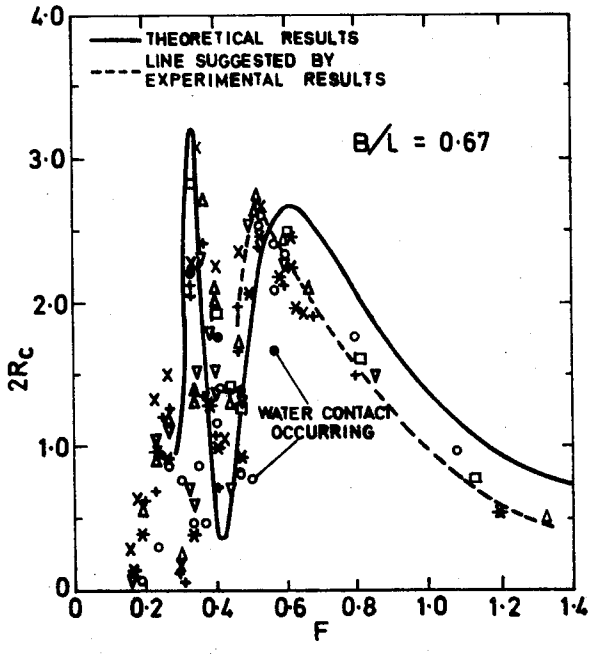


FIG. 7 WAVE RESISTANCE OF A RECTANGULAR PLANFORM HOVERCRAFT



DIFFERENT SYMBOLS CORRESPOND TO VARIOUS HOVERHEIGHTS & WEIGHTS

FIG. 8 MODEL WAVE RESISTANCE

approximation, basically considers the static depression of the water surface to be small compared to the craft length). Lunde (1951) advanced the work to cover the situation of finite-depth water, while numerical results applicable to an ACV were computed by Newman and Poole (1962) and Barratt (1965). In these calculations, the pressure was assumed constant over a rectangular, or elliptical area.

An example of Barratt's results is shown in Fig.7. The influence of depth is illustrated. In deep water the "hump" in the resistance curve occurs at a Froude number of about 0.6 (this depends on the beam-to-length ratio). As the water depth is reduced, so this speed drops, until the main hump occurs at a depth Froude number of unity. Additional higher-order humps at lower Froude numbers are also evident.

A number of experimental programs, chiefly by Everest (1966a and b), Everest and Hogben (1967) and Hogben (1965 and 1966b) have been carried out to check the above-mentioned results. All point out the difficulty of deducing the wave resistance from the model tests, since allowance must be made for the other drag components. An example of Everest's results for a rectangular model travelling over deep water is shown in Fig. 8. These particular calculations were based on measurement of the trim of the model - assuming it does so parallel to the average slope of the water surface. The overall agreement is generally good, but a large degree of scatter is present. The higher-order humps and hollows (except for the second) are not usually observed in practice due to spray and the increasing influence of nonlinearity, which the theory neglects.

Hydrodynamic Forces on a Maneuvering ACV

When an ACV is yawed relative to its direction of travel, the wave resistance is altered. In addition, a hydrodynamically-induced sideforce

acts on the craft. This problem has been studied by Everest and Willis (1968), Everest and Hogben (1969) and Murthy (1970). An example of the manner in which wave drag varies with the yaw angle, taken from Everest and Hogben's paper, is shown in Fig. 9. The linearized theory is seen to predict the form of the experimental curve accurately enough for design purposes. (The wave drag was computed here by an analysis of the wave pattern produced by the craft, and consequently the difficulty of estimating other components of drag is avoided).

The *transient* problem of a yawing ACV has been examined theoretically by Doctors (1972). Fig. 10 illustrates the effect of rate of yaw on the induced side force, after the vehicle has been travelling steadily with no yaw. The main effect of unsteadiness is a reduction in the side force compared to the steady-state value. The side force in this case, and in most other cases when the Froude number is greater than 0.5, is favourable in

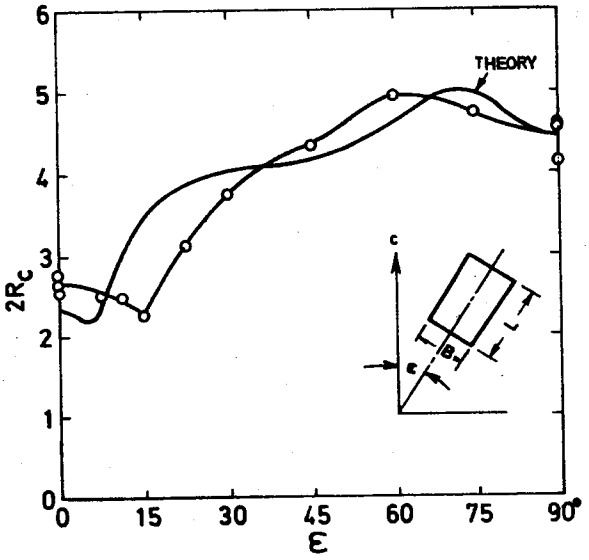


FIG. 9 WAVE RESISTANCE WHILE YAWED

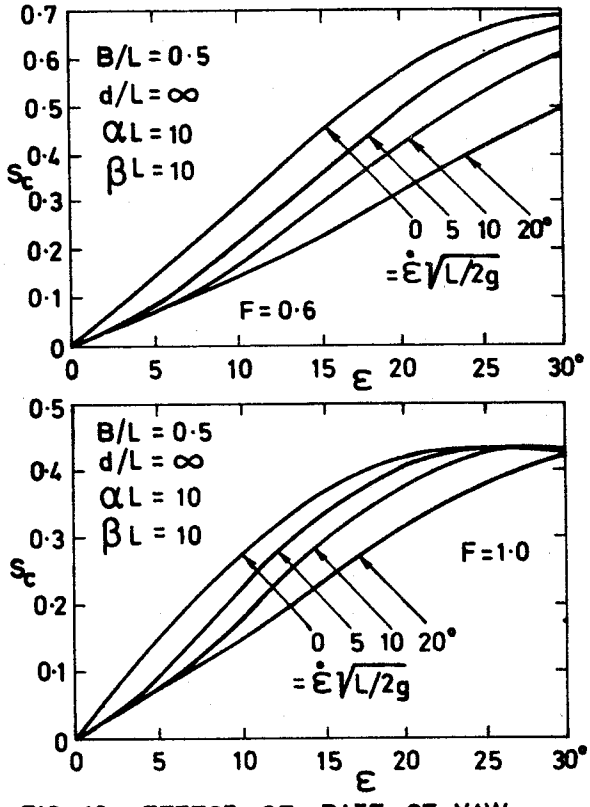


FIG. 10 EFFECT OF RATE OF YAW ON INDUCED SIDE FORCE

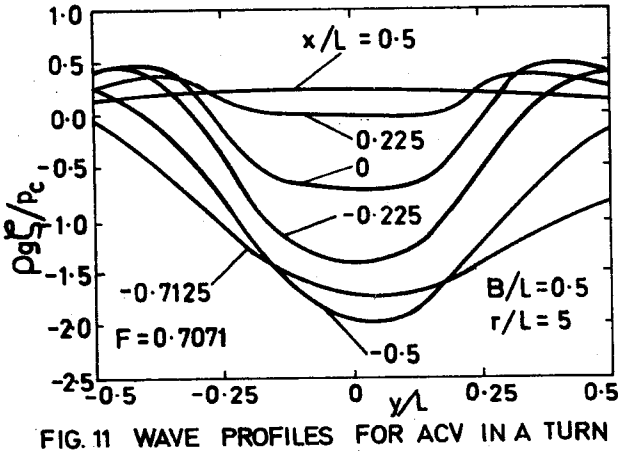


FIG. 11 WAVE PROFILES FOR ACV IN A TURN

that it aids the turning of the vehicle.

Yeung (1974) has extended this work to include the computation of the elevation of the free surface itself. This data is required for determining skirt contact forces, which contribute to the total force on the craft - particularly when maneuvering. An example of his work, for a craft executing a steady turn, is shown in Fig. 11. Here, the transverse wave profiles display asymmetry, and this results in a sideforce on the craft -

similar in origin to that shown in Fig. 10.

Accelerated Motion

Due to the somewhat increased magnitude of the main-hump drag in finite-depth water, some heavily loaded ACVs experience difficulty in accelerating through this critical condition. Consequently, some effort has been directed to solving the problem of *accelerated* motion - to determine its influence on the hump drag. Djachenko (1966) and Doctors and Sharma (1972) have examined this problem on a theoretical basis. Fig. 12 is taken from the latter paper and shows the influence of different levels of acceleration on the drag. In deep water, the main hump is delayed to a higher Froude number. In finite depth, there is, in addition, a substantial alleviation of the drag. Of course, in an overall assessment, one must include the inertia of the craft in a drag calculation to determine whether acceleration is beneficial or not.

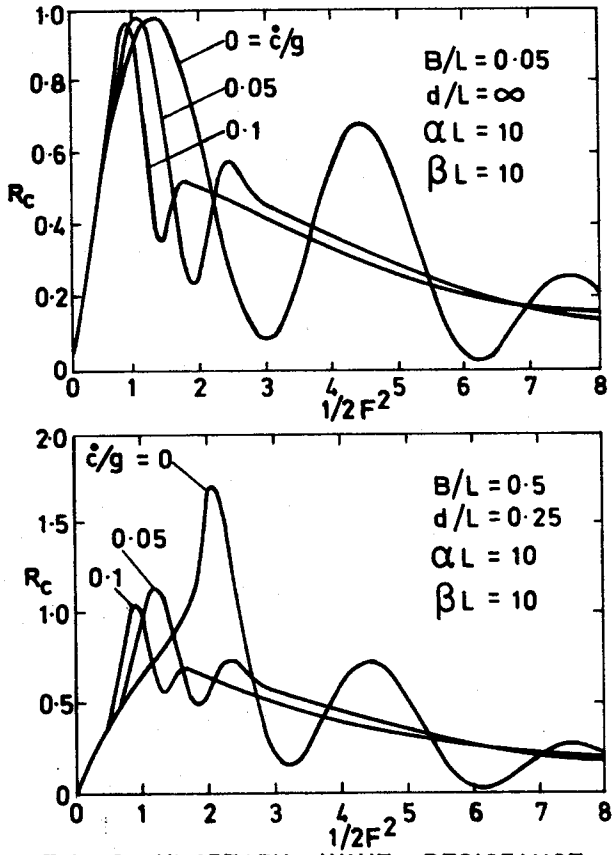


FIG. 12 UNSTEADY WAVE RESISTANCE

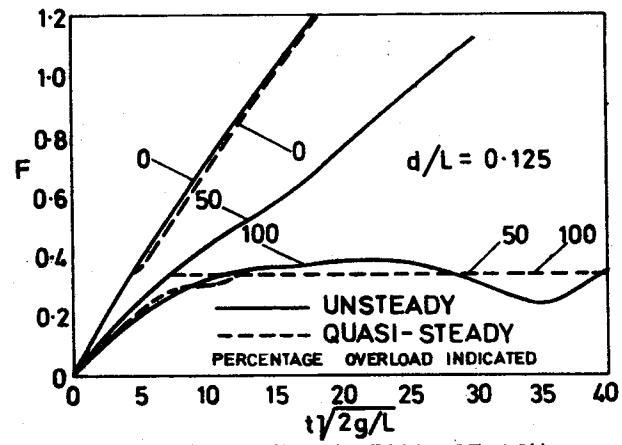


FIG. 13 VELOCITY HISTORY OF ACV

The *inverse* problem of computing the acceleration of an ACV versus time, due to the action of a propulsor of given characteristics, was studied by Doctors and Sharma (1973). One such set of results, pertaining to a 12 m long craft of mass 11.3 t, normal load, and propelled by a typical 3.0 m diameter air propeller turning at 1500 rpm, is shown in Fig. 13.

Comparison is also made with a quasi-steady theory - in which history effects are neglected in the wave-resistance calculation. In particular, looking at the case of the craft overloaded by 50%, the quasi-steady theory predicts the craft will not overcome the hump drag (occurring at a Froude number of 0.35 at this water depth), while the true unsteady theory indicates that the hump can easily be passed.

Finally, some experimental verification of the unsteady theory for wave resistance has been carried out by Doctors(1975). For simplicity, tests were carried out on a two-dimensional model which completely spanned a small channel. A uniform acceleration was achieved through a falling-weight system. The wave resistance was computed from wave-elevation records obtained from an electronic probe. One set of results is shown in Fig. 14. The general theoretical form of the curves is confirmed - although there are some phase differences in the oscillations. A region of negative wave resistance (occurring only for a two-dimensional pressure distribution in water of finite depth) is also verified.

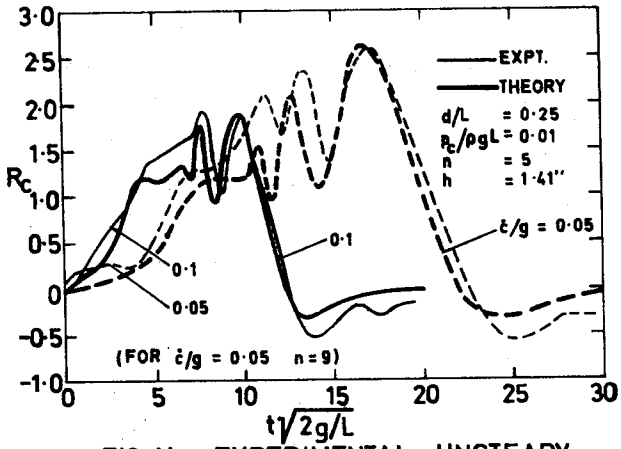


FIG. 14 EXPERIMENTAL UNSTEADY WAVE RESISTANCE

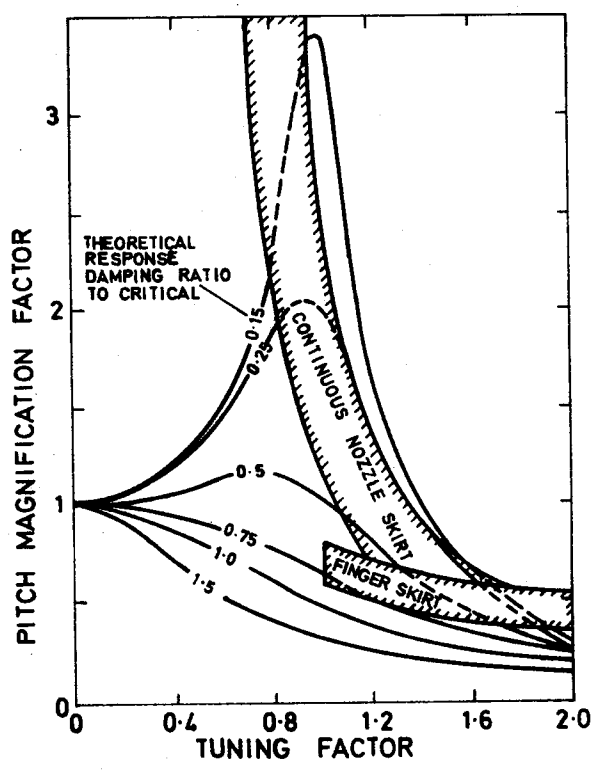


FIG. 15 SRN5 MODEL TESTS - PITCH RESPONSE WITH DIFFERENT SKIRTS

IV. MOTIONS IN A SEAWAY

Experimental Work

The motion of an air-cushion vehicle was studied by Swaan and Wahab (1965). They conducted towing-tank tests on a peripheral-jet model and tested it both with, and without, flexible skirts. The model was run in regular waves of various direction. The curves which displayed craft heave and pitch response as a function of forward speed (for a particular wave-length) were fairly flat indicating a high level of damping. Results were also presented for wave heights varying up to about 0.10 of the craft length, and these indicated some non-linearity in that the response was not proportional to the height of the waves.

Dyne (1968) restricted his model tests (also on a peripheral-jet craft) to regular head seas. The air cushion was compartmented into six sections. The model was excited on a flat surface and the stiffness and damping factors were measured and found to be in agreement with his theory. From these results, a prediction of the motion over a regular wavy surface was made, using a linear theory.

Van den Brug (1968) and Van den Brug and Van Staveren (1969) also performed model tests on an essentially plenum-chamber design. Forced oscillation tests in heave, pitch and roll above ground without forward velocity, and above water with forward velocity were carried out with a view to determine the coefficients in the linearized equations of motion. The manner in which these coefficients vary with forward speed and encounter frequency was displayed graphically. In particular, the added mass of the water was found to be negative - in sharp contradistinction with a ship, where it is positive and of the order of the ship mass.

A method of "equivalent linearization" was suggested by Murthy (1968) for the determination of the response spectrum of an ACV travelling in an irregular wind-generated seaway. He gave an example of the technique which requires a knowledge of the craft response to a regular wave.

The practical operation of ACVs in realistic waves has been entirely due to the development of the flexible skirt. In his review, Stanton-Jones (1968) referred to motion tests on a model of the 12 m SRN5 hovercraft. Tests were conducted with both an annular-jet skirt and with a finger skirt (See Fig.15).

In the former case, the damping ratio in heave was approximately 0.5, and for the pitch motion was somewhat lower, being about 0.25. Regarding the results for the craft fitted with finger skirts, these indicated a higher pitch damping ratio (in the region of 0.75) compared to the annular-jet skirt case. Thus the craft motion was measurably improved by the fitting of finger skirts. Stanton-Jones also noted that the unit response was less in higher waves, and that this would be a measure of the nonlinearity in the system.

Theoretical Work

In the theoretical field, Lin (1963) computed the dynamic behaviour of an unskirted annular-jet craft fitted with a transverse stability jet. The equations of motion were linearized. Comparisons were made with model tests and good agreement was found, particularly as the natural frequences and general magnitudes of the pitch and heave response were well predicted. The spring constants for both the static and dynamic cases for a peripheral-jet ACV executing a simple heaving motion were calculated by Ozawa, S. (1970) and then used to predict the linear heave motion due to a sinusoidal input.

Hogben (1966a), in his review of the behaviour of ACVs over water, also gave the basic theories for simple heave motion, and linearized these for both annular-jet and plenum-chamber craft. In addition, he covered various empirical approaches in his article.

The heaving response of an ACV moving over regular waves was studied by Reynolds (1972) and was later extended to include pitching by Reynolds and others (1972). In both cases the equations of motion were linearized. In the latter paper, the plenum-chamber vehicle considered (as in Fig.16, but neglecting skirt contact) had a single lift fan feeding an intermediate chamber (corresponding to the ducting and flexible supply bag utilized by many ACVs). The air was then fed to the fore and aft compartments of the cushion, which had a transverse stability skirt. The incompressible Bernoulli equation and the usual equations of continuity were used in this analysis, and the coupled pitch and heave motion for a particular vehicle was computed as a function of the ratio of craft length to wavelength.

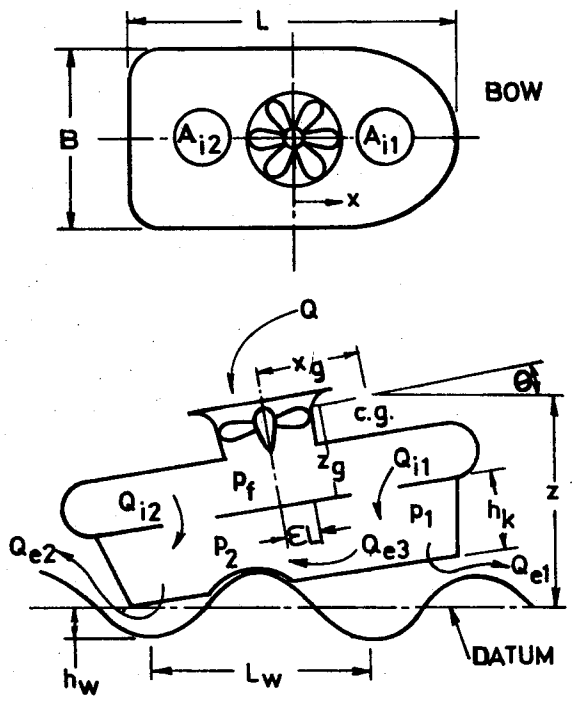


FIG. 16 GENERAL LAYOUT OF CRAFT AND NOTATION

One feature of the problem which renders this linearization questionable is that the daylight clearance under the skirt is usually quite small, so that skirt contact and deflection occurs in most situations, and it is ignored - as pointed out by Reynolds. This would be a very strong nonlinear effect. A second point of concern is related to the cross flow under the transverse stability skirt. The pressure drop across the skirt is proportional to the square of the flow and has the same sign. Consequently, the linearization process is only valid if there is a cross flow in the equilibrium condition, and if the changes during motion are small compared to it.

In fact, the equilibrium cross flow itself is usually very small in practice (the equilibrium pressures in the fore and aft compartments are virtually identical). Hence the changes in cross flow during the heave and pitch cycle swamp it entirely, so that this physical mechanism is essentially nonlinear to the first order.

Nonlinearity

These objections to linearized theory were considered recently by Doctors (1974a) who used the various nonlinear equations describing the air flow. He also took into account the effect of skirt contact with the wave surface. This was found to be of major importance, since the usual air clearance under the shirt is a fraction of both the encountered wave heights and the skirt depth. The equations were solved iteratively. The effect of nonlinearity on the craft in Fig.16 is shown in Fig. 17. The calculations relate to motion in a sinusoidal head sea. Minimum, maximum and root-mean-square values (the latter multiplied by $\sqrt{2}$) of non-dimensional heave and pitch are shown. The pitch response, in particular, is seen to be strongly nonlinear at small wave heights. Fig. 18 displays the response as a function of encounter frequency. A resonance is displayed. As the dimensionless response is different for different wave heights, the non-linearity is again revealed.

Yamamoto (1970) studied nonlinear pure heaving motion of a plenum-chamber ACV, including the effect of air compressibility.

Compressibility

Other workers who have considered the compressibility of air for simple heaving motion include Leatherwood, Dixon and Stephens (1969), Guienne(1970), Leatherwood (1971) and Genin, Ginsberg and Ting (1972). All of these employed linearized equations, which would be valid for small motions.

Incidentally, these reports, except the last, while assuming the air within the cushion obeys the polytropic process, used the *incompressible* Bernoulli equation for the discharge of the cushion air to atmosphere.

Coupled pitch and heave motion of a multiple-skirt ACV was analysed by Bickford and Olson (1969), utilizing the above-mentioned assumptions, and solving the equations on an analog computer.

Other aspects of the mechanics of ACV motion over waves were considered by Breslin (1969), Richardson (1970) and Trillo (1971). It was noted that if compressibility is to be represented correctly on a model, then one must scale the atmospheric pressure to suit it. This point is also stressed by Lavis, Bartholomew and Jones (1974), who applied a linear model to heave, pitch and roll motions of an ACV in a random seaway.

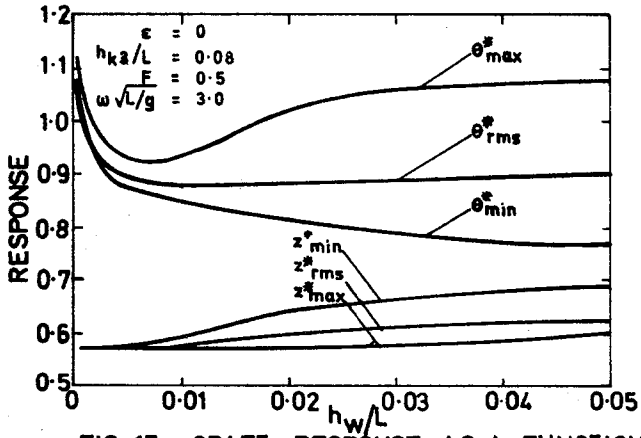


FIG. 17 CRAFT RESPONSE AS A FUNCTION OF WAVE HEIGHT

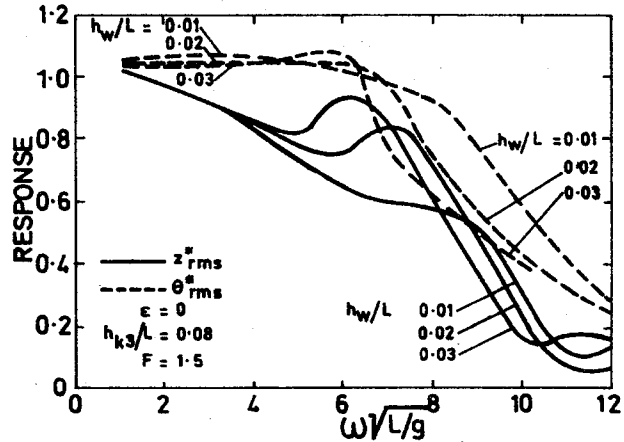


FIG. 18 CRAFT RESPONSE AS A FUNCTION OF FREQUENCY

Hydrodynamic Influence

An important effect which has not been discussed until now is the compliance of the water surface. It is clear that the pressure within the cushion (which is fluctuating) generates a wave system - which must influence the skirt clearance, and consequently the craft motion. Thus, in fact, one must consider the coupled problem of the craft motion and the water surface.

This point has been examined by Doctors (1974b) who used the usual linearized theory to solve the motion of the water surface due to a harmonically-varying pressure. The craft motion was found by stepping through time digitally, from a set of initial conditions. At the end of each cycle of the motion, a timewise Fourier series analysis of the cushion pressure was made and the influence of the water surface was input. This procedure was found to converge to a repetitive motion after only four or five cycles.

An example of these results for the heave motion for the craft in Fig. 16, is shown in Fig. 19. Considering the first two Fourier terms (the average cushion pressure, and the fundamental only), the water compliance is seen to increase the motion by about 10%. The pitch motion, however, shown in Fig.20, is seen to be affected by up to 30% - in the frequency range considered.

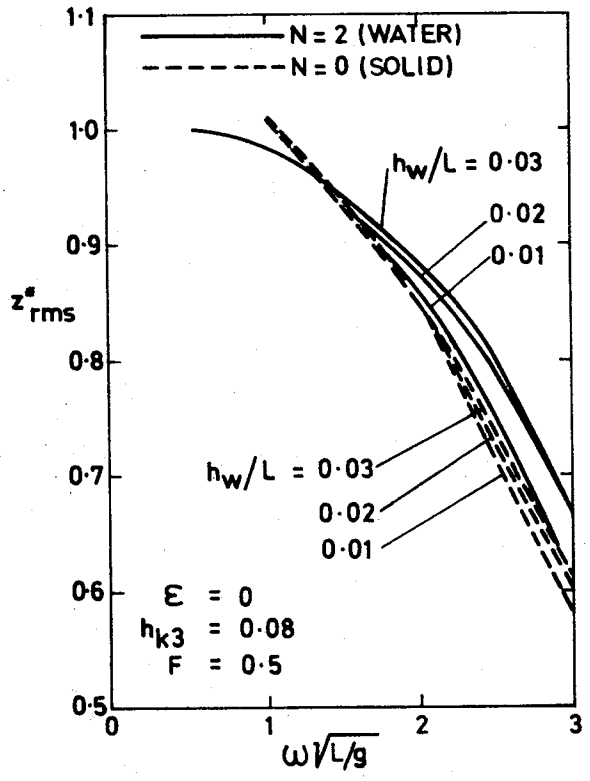


FIG. 19 HYDRODYNAMIC EFFECT ON CRAFT HEAVE MOTION

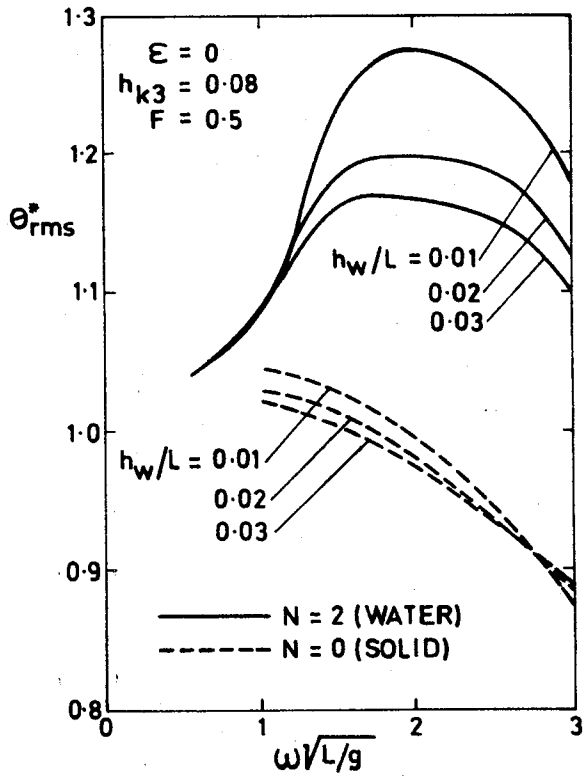


FIG. 20 HYDRODYNAMIC EFFECT ON CRAFT PITCH MOTION

V. CONCLUDING REMARKS

This paper has concentrated on three basic areas only. It must be stressed that other vital aspects of ACV technology include: static stability, control of the craft, structural design, and economics of craft operation.

In particular the reader is referred to the proceedings of the Advanced Marine Vehicles Conference held in San Diego, California, U.S.A., in February 1974 and organized by the American Institute of Aeronautics and Astronautics

together with the Society of Naval Architects and Marine Engineers. Some of these other problems are discussed there.

A further source of information is the series of Canadian Symposia on Air Cushion Technology, which is held annually, and is organized by the Canadian Aeronautics and Space Institute.

At the present time, a high proportion of the research is concentrated on the problem of craft motions, and the resulting structural loads, since these are the limiting factors in ACV operation. It would appear that this trend is unlikely to change in the near future.

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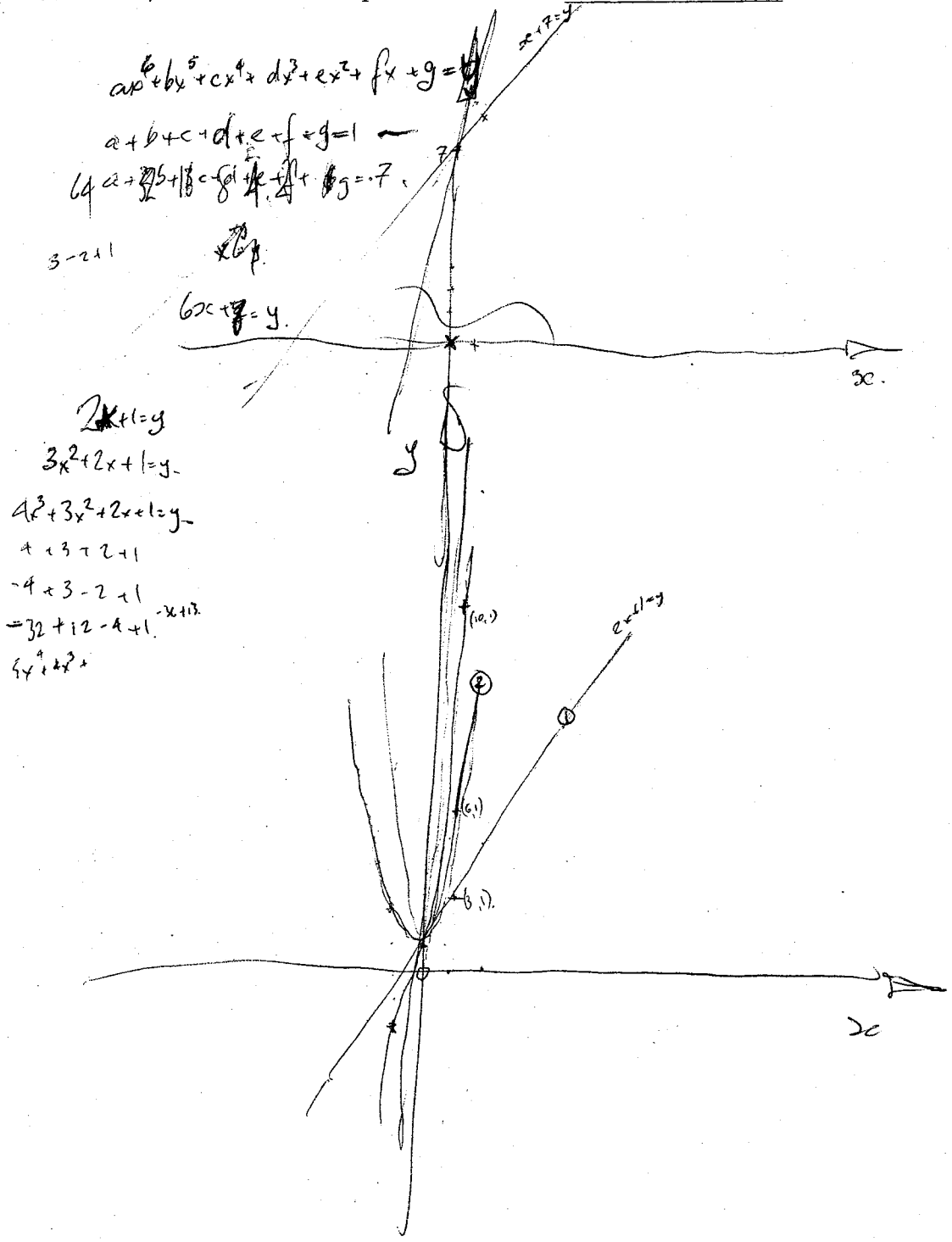

THE SMALL SHIP MODEL TANK: A USEFUL FACILITY OR AN EXPENSIVE TOY?

by

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SUMMARY

The performance of a ship may be predicted by measurements made on a model of that ship sailing on a model of an ocean or other waterway, provided certain physical laws are honoured. These laws strongly suggest that the bigger the model, and consequently the bigger the model waterway, the more precise and reliable will be the predictions. The laws also set a definite minimum size for the model waterway around 50 metres long by 3 metres wide by 1.5 metres deep. This is something like the maximum size which can be accommodated in the basement of a building provided to house a school of engineering on a university or college campus. Therefore such "tanks" are to be found in quite a number of teaching institutions around the world and there is no doubt that they are suitable for teaching and for a limited range of research. Whether they are suitable for model tests leading to the actual design of a new ship is a question often debated. Their usefulness and limitations will be discussed with particular reference to the small tank at the University of Sydney, and in the light of experience, some suggestions offered. While adopting a highly critical attitude, the author believes that with proper management, the existing small tank could offer a limited, yet valuable service to the Australian industry.

INTRODUCTION

The purpose of ship model tests is to predict ship performance using a model which can be made and run at a cost which is less than one percent of the cost of the ship. Proper choice of engine power is very important to ship economy and this is the first item to be studied. Systematic variations can be tried to ensure that the design is near to the optimum and reference to model test records for similar designs can be of great assistance. Sea-keeping, course-keeping and manoeuvrability can also be studied. The growing demand for such investigations is such that several very large test facilities have been commissioned in the last decade. Pencil and paper design methods, even when assisted by large automatic computers, have not yet displaced model tests.

Ship model tests are based on several physical laws, some honoured more in the breach than in the observance. Where a law is not obeyed completely, then some reliable procedure must be devised for estimating the error so caused, and for making an appropriate correction. Such a procedure is unlikely to be exact, and so model results will be subject to a residual error. Where the law is nearly satisfied the residual error is likely to be small, but where the law is badly strained, the reliability of the correction procedure becomes rather doubtful and the residual error is difficult to assess. Later in this paper tests with large models in large test facilities will be shown to satisfy more nearly the laws of modelling than do tests with small models in small facilities.

The ship model test tank is a basin filled with water, housed in a laboratory and dedicated to the simulation of navigable waterways varying from

the high seas to canals. While outdoor facilities are not uncommon, lack of control of the environment tends to interfere seriously with the work and planning gives way to opportunism and improvisation. The tank is almost always equipped with a moving platform which may tow the model or merely keep pace with it. The main purpose of the platform, or "towing carriage", is to provide a suitable base for measuring instruments and systems, but it is often big enough to carry several equipment operators and observers. Most test tanks are long and narrow so that they are easily straddled by the carriages. Others are roughly square or even round and the carriages must be hung from the underside of substantial bridges. While some of these bridges are fixed, some are capable of linear motion and others can be swung about a vertical axis through the centre of the tank. Where carriage and bridge allow two degrees of freedom in programming the course of the model, the manoeuvring qualities can be studied. Most tanks have wave-making machines able to produce regular head or following seas. Some have elaborate "servo" type machines programmed to produce confused seas with predetermined statistical properties. The square, or nearly square tanks can subject the model to bow, beam or quartering seas as well as head or following seas. Some tanks are specially equipped with false bottoms and false walls to simulate navigation in shallow water and canals. Such tanks may even be serviced by large pumping stations so that the effects of current and tide can be reproduced. One quite large tank has been built in a reinforced concrete vacuum chamber for the study of propeller induced hull vibration where cavitation is a factor. While it is not feasible to do ordinary ship model tests by holding the model stationary and setting the water in motion, there are important applications of this technique to the study of the wake belt (boundary layer) and some laboratories are equipped with large and expensive circulating water channels.

The tanks which are regularly used for checking the design of new ships are typically 300 metres long, 20 metres wide and 10 metres deep. They are usually found, with some of the other types mentioned, in major centres for applied research sponsored by national governments. However some notable tanks are run by shipbuilding groups and one very big complex seems to be autonomous. A few commerical research organisations, universities, technical colleges and naval academics operate tanks in the intermediate size range, typically 150 metres long. These are often concerned with special projects and small craft. Then there are the small tanks, typically 60 metres long, 3 metres wide and 1.5 metres deep, which are to be found in schools of engineering and naval architecture. The size of these tanks is usually determined by the space available in the basement of a university or college building while having regard for the minimum size set by the modelling laws. Their prime function is teaching, for which they are well suited, but they are usually available for both pure and applied research. The paper is concerned with these small tanks.

THE SIZE OF THE TANK AND THE LAWS OF MODELLING

Since the laws of modelling suggest that a large model in a large tank will yield more precise and reliable results than a small model in a small tank, there is an obvious motive for building the biggest possible tank permitted by the financial resources, and a few tanks are around 1000 metres long. What then are the penalities attaching to the small tank? The explanation starts with the laws of modelling, involves the interactions between tank size and model size, the hydraulic time constants of the tank, the dynamics of the towing carriage and the drive system. The first law of modelling is: If the work can be done with pencil and paper, then model tests are too expensive to be considered a feasible alternative. The complex interactions between the making of waves by the ship and the viscous friction on the far from simple hull shape have so far defied mathematical analysis.

But often some parts of the modelling scheme can be handled by simple arithmetic. A trifling example is the substitution of fresh water for salt water with a great saving in maintenance expense due to corrosion. The second law is that familiar to every schoolboy who has made a "scale model" of a ship or aircraft. It might be called "geometric similarity", and extended to require that the model be ballasted to float at the same draught, to scale, as the ship, and with the same trim. The third law is Froude's law of corresponding speeds which ensures that the wave pattern about the model is the same, to scale, as the wave pattern about the ship. This extends the concept of geometric similarity to the distortion of the surface of the water. In mathematical symbols, $F_N \equiv v/\sqrt{(Lg)}$, called the Froude Number must be the same for the model as the ship. Here v is speed in metres per second, L is length in metres and g is gravitation in metres per second per second. In brief this requires the speed to be scaled as the square root of the length ratio, a requirement which can be conveniently satisfied. The fourth law is the Reynolds Law of similar conditions in the wake belt (boundary layer). The wake belt around a ship is turbulent and characterised by eddies varying in size from a few millimetres up to about one percent of the length of the ship. The wake belt on the model should be similarly turbulent and would be if the impact pressures and shear stresses were in the same ratio. This necessarily vague concept is typified by $R_N \equiv vL/\nu$, called Reynolds' Number, which should be the same for model and ship. Here ν is the kinematic viscosity of water in metres squared per second. Now here is a dilemma! If Froude's law is obeyed, the Reynolds Number for the model is too small by the 1.5 power of the scale ratio. If R_N is sufficiently reduced, the viscous effects damp out the eddying motion in the wake belt and it becomes laminar. Then the performance of the model ceases to resemble the performance of the ship, and the model is no longer valid. Models of about 1 metre in length are the smallest that may be used and these must be fitted with turbulence stimulation devices. For larger models the gap between the Reynolds Numbers for model and ship is reduced and the patterns of stress and motion in the wake belt become more nearly similar. The fifth law states that for truly similar geometry and patterns of motion the propulsive force required is proportional to the density of the water, the velocity squared and the length squared. However, since it is not possible to satisfy the Reynolds Law, the measured model drag will be subject to a systematic error and must be corrected before scaling up to give an estimate of ship propulsive force. At the end of the last century William Froude proposed and tested a correction procedure which, with minor modifications, has continued in regular use. Froude's method gives results which are sufficiently precise and reliable for the design of ships, particularly when used with large models in large tanks. However, from the point of view of theoretical hydrodynamics, Froude's correction is very crude and it is amazing that predictions based on small models usually work out fairly well in practice. It seems likely that the various errors tend to systematically compensate for one another.

So far propellers have not been considered, but it is common practice to test models "bare" and with propellers. In the latter case the model propeller is driven by an electric dynamometer fitted into the model. These dynamometers measure thrust, torque and shaft speed. Since the Reynolds Law applies also to propeller blades there is a lower limit to the size of propeller, and hence to the size of the model, if the validity is to be retained. Generally self-propulsion tests are not attempted on models less than 4 metres long, and even then the results are subject to fairly large corrections for the discrepancy in Reynolds Number.

In this brief discussion the remaining point to be considered is the connection between tank size and model size, and the lower limit will provide a convenient example. Suppose models only one metre long must be used. As the model moves, the displaced water moves away from the bows, comes back in sweeping curves past the beam and closes in behind the stern. The presence

of the walls and bottom of the tank tend to cramp this flow field and alter the measured drag. Experimental work suggests that the water cross-section area should be 100 times the model cross-section area for this effect to be tolerable. The breadth of the tank is related to model length because the wave system radiating from the bows will be reflected by the tank walls back towards the stern. It is obviously important that the reflected wave pass well behind the stern and in round figures this suggests a tank width of at least 3 metres. If zig zag manoeuvres or wave pattern measurements are attempted, the width should be much greater. Associated with the waves generated by the model are orbital motions in the water which are still significant at a depth equal to one wavelength. Assuming the model represents a fast ship, then the speed is such as to set up waves with wavelength a little less than ship length, and a tank depth of 1.5 ship lengths is needed if cramping of the orbital flow is to be avoided. In shallow water both the wave pattern and the model drag are drastically changed, and 1.5 metre depth is required to simulate a deep ocean. The one percent rule will permit a model cross-section of 0.045 square metres, say 30 centimetres beam by 15 centimetres draught, which should be adequate. Again assuming that the model represents a fast ship, then speeds up to 2 metres per second will be required. If it represents a planing hull, speeds up to 10 metres per second might be desirable, but in the usual circumstances of a small tank, might be considered a luxury. Suppose that the tank is designed for a top speed of 3 metres per second. Then allowing 10 metres for acceleration, 30 metres at constant speed allowing 10 seconds for recording drag, etc., then 10 metres for braking and a margin of 10 metres to give some chance of coping with emergencies, the minimum length of tank is 60 metres. While these figures are suggested by practical experience, the use of higher accelerations and shorter recording times is discouraged by the following considerations: Higher accelerations lead to higher hydraulic and mechanical transients so that the whole system may not have settled down by the end of the recording period. The fluid flow fields set up around the model take a little time to settle down and then the model itself may take several seconds to approach its steady state trim. Planing forms can be slow to find the equilibrium trim, and drag depends a great deal on trim. Measuring instruments must be reasonably "soft" if they are not to be swamped by towing carriage vibration and so instrument periods are quite long. This is a critical factor and although a lot of work goes into reducing vibration, instrument systems must be helped by elaborate filters. The suggested recording period of 10 seconds is none too long and can be reduced only at the expense of accuracy. Of course much greater length is desirable for high speed planing hulls, particularly when running in a simulated ocean swell. Some tanks of this small cross-section are around 200 metres long, having been built for seaplane studies. However most small model test tanks are built by people who must house them in existing buildings and work on a tight budget, and therefore 60 metres by 3 metres by 1.5 metres is the typical tank size.

SOME EXAMPLES OF STUDIES IN A "SMALL" TANK

It is unlikely that a small tank would be asked to do model tests for the design of a large ship. The naval architect would recommend one of the large establishments to his client for a number of reasons: The time span of several years and the budget of many millions of dollars would nullify any advantage of a small local tank. The large tank could offer, on the whole, greater precision and reliability in predicting performance, not only because of the technical factors already discussed, but because the superintendent and his staff would have had more experience and developed greater skill in the interpretation of experimental results and applying the necessary corrections. In addition self-propulsion tests may be done and propeller performance checked. Often these comments are valid for quite small craft but in many cases the time span and the budget favour doing a small job in a small local

tank. Mostly these jobs arise because of some unusual feature in the design for which no precedent is available, and because of that additional advantage of the local tank, easy accessibility. The designer can himself witness the tests, and where appropriate, alter the course of the investigation. In this category are a number of tests carried out at Sydney University, and some examples are given below:

(i) A small ship was required to land cargo on a sheltered beach. The hull shape was something between a fairly normal ship and a wartime landing barge. The drag was checked.
(ii) Another craft had a flat bottom for fairly high speed but was sometimes required to handle heavy loads at lower speeds. The designer therefore used rather large diameter propellers accommodated in part tunnels. Some idea of the effect of these on trim and drag was sought. The tank figures worked out well in practice in spite of the model not being self-propelled.
(iii) A twin hull craft was required to operate special apparatus. The design was checked for drag, trim and spray control.
(iv) An unusually beamy ferry required to satisfy various operating rules was checked for drag and trim.
(v) A craft was required to regularly navigate heavy confused seas at the entrance to a harbour. A self-propelled model was studied manoeuvring in steep regular seas.
(vi) A large barge was to be towed on long voyages by a cable. A study was made to estimate the minimum skegs required for course stability and the associated drag penalty.
(vii) A proposal for a pusher tug and barge system to negotiate a mild seaway was investigated. The tug was notched into the stern of the barge but otherwise the restraints were fairly flexible.
(viii) A design for a light amphibious aircraft was checked for its spray characteristics.

Other jobs come up as operational problems develop. Two examples are given:

(i) The bad trim and spray characteristics of a launch were all too well represented in the tank. Planing wedges were required to correct the excessive trim.
(ii) Some puzzling reports on the loss of a ship in heavy seas were cleared up by capsizing a rather crude model in a simulated seaway in the tank. The model predictions on certain times matched the reported times.

There are a few glamour jobs, or so they seem to people not involved in the day to day work. Sailing yacht tests are an example:

(i) Four series of tests were done on challengers for the America's Cup. The tank at Sydney University was as well equipped as any overseas tank likely to be available for this purpose and there was a sporting motive for doing the work in Australia. Access to the tank at all stages was an obvious advantage. Unfortunately the timing usually meant that the work was almost entirely ad hoc comparisons between many modifications of a few alternative original designs. Only a very small amount of more basic research was attempted, this being on added drag due to ship motions in a seaway.
(ii) There have been other jobs where a proposed modification to an existing yacht was checked. Except for major design faults, usually due to attempts to "beat" the rating rule causing a flow spearation, work on sailing yachts is necessarily limited to comparing one hull with another on an arbitrary basis chosen by the designer.

There are some not so glamorous but very valuable routine jobs done by the ship model test tank:

(i) In close co-operation with the New South Wales Water Conservation and Irrigation Commission a current meter rating service is maintained.
(ii) Quite often somewhat similar instruments are calibrated for Univerity departments and government sponsored laboratories interested in tidal flows, marine biology and oceanography.

By way of basic research the Sydney University tank has maintained an interest over the years in several aspects of ship resistance:
(i) The validity of Froude's correction procedure: The wake belt or boundary layer around an 8 metre model of a 300 metre ship is likely to be twice too thick to scale, and around a 1 metre model, is likely to be 4 times too thick to scale. The thickness of the wake belt is of the same order as half the propeller diameter and so this factor is important in self-propulsion tests. However the small tank is concerned with several other effects. The relatively dead fluid in a thick boundary layer responds more readily than fluid with appreciable momentum to vertical and lateral pressure gradients. The water in the excessively thick boundary layer about a small model moves down to drain away some of the wave crests and up to partly fill in the troughs. Thus wavemaking tends to be too small, to scale, on some models. Against this, the bulk of the excessively thick boundary layer on the model adds to the bulk of the hull in generating waves. Also the skewed flow in the boundary layer tends to increase the viscous shear stress on the hull.
(ii) The independent measurement of the ship or model wave field: A number of techniques have been tried in the search for a satisfactory routine procedure applicable to a fairly narrow tank.
(iii) The viscous shear stress on a planing plate: There is some evidence that the shear stress may be governed by the strong lateral pressure gradients rather than by Reynolds Number as usually assumed.

An unusual feature of the tank is a precisely level bottom which enables experiments on "ground effect" to be done in water to represent vehicles moving in air over level ground.
(i) Some work was done on the lift and pitching moment of slender planform aircraft wings.
(ii) A final year student did some interesting work on motor vehicle body shapes.

The teaching aspect, the item of major importance to the University, need hardly be stressed here. Regular classes are run for students in mechanical engineering at the University of Sydney and in naval architecture at the University of New South Wales. Some of these students use the tank for graduation projects which form a susbstantial part of their work in the final year. These cover a very wide range from the hydrodynamics of a surfboard and the performance of a sailing trimaran to very basic research using simple mathematical forms as models.

THE ECONOMICS OF THE "SMALL" TANK

The "small" tank has serious disadvantages as to the reiability of results and the inability to handle self-propulsion tests. However, apart from the purely technical limitations management and staffing are likely to be inadequate. To make a point by looking at contrasting cases, suppose a small country like Australia has decided to set up a national ship model test facility. The crucial point here is staffing and under government service or industrial conditions each relevant trade and profession would necessarily be represented to form a viable unit. An executive group of at least four top level personnel would be needed to cover the scientific and administrative functions with some assurance of continuity. At the professional level naval architecture, mechanical, electrical and electronic engineering must be represented. Draughtsmen, data handlers, clerical staff and archivists are

needed. Then various tradesmen and equipment operators in the mechanical, electrical, electronic and modelmaking fields must be available. Labourers and cleaners will also be needed. Even where one person can cover two or more of these functions the minimum rough estimate of the annual wages bill might be $(4 x 18 000 + 3 x 12 000 + 3 x 10 000 + 6 x 8 000 + 3 x 6 000) = $204 000. Allowing for other annual running costs the probable total is at least $250 000. The vaguest form of optimal matching of capital to labour would suggest equating annual capital charges to other annual costs and spending at least ten times this figure on the tank. (Here the word "tank" is used to denote the whole laboratory complex, which is customary among tank men.) When technical factors are also considered, it would seem to be inexcusable to try matching this annual bill against the limited quality and scope of the output of a small tank. Anything less than a first class facility is unlikely to attract first class top level staff and one without the other is unlikely to do first class work. Therefore the notional cost of a national tank starts at $2 500 000 which would establish a single tank in the medium size range, while a laboratory complex capable of the wide range of work now being done around the world would cost ten to one hendred times this amount. Thus a national tank is only likely to be considered if it is firmly backed by the national government and if all shipping and shipbuilding interests, including the defence forces, can and will make sufficient use of it to achieve a satisfactory use factor, say more than 2000 hours per annum.

The point which the author wishes to make is that the establishment of a national, or even a commercial laboratory, around a small tank is economically untenable.

The "small" ship model tank which is part of a university, technical college or naval college is another matter. The wages bill does not appear among the university or college accounts. Expertise is usually borrowed on a fairly personal and casual basis and the right sort of expertise is usually available within an engineering faculty. The flexible attitudes which make this possible have existed, and seem to exist still among university personnel. The tank itself is often improvised. Both tanks in Australia, at the University of Sydney and at the University of Melbourne, have been set up in return channels for experimental flumes which are part of general purpose hydraulic laboratories. Given the kind of enthusiasm one always hopes to find among academic staff, equipment is begged, borrowed and stolen over a lengthy period without the university administration being fully aware of the large equivalent cost. The time spent by academic staff in research, including setting up equipment to be used in research, is not begrudged by university administrators. In fact universities expect academic staff to be active in research and to involve senior students in this research as part of their training.

This sort of thing appears to be a way in which a valuable facility can be obtained cheaply. What is the catch? Well first of all it is likely to be a small tank with all the limitations already discussed in this paper. A few very strong schools of naval architecture have useful facilities in the intermediate range, for example Michigan, Glasgow, Tokyo, Delft and some others, but to the author's knowledge, none have large tanks. The next most serious limitation, from the point of view of providing a service to naval architects, is that running the tank is usually a spare time job, almost a serious hobby. It may be run by a member of the academic staff who, by some accident of history, is a jack of all trades, and who tries to perform as a "one man band". It is too much to expect such a tank to be run on a sensible, businesslike basis and it becomes a matter of muddling along. Another limitation is lack of capital backing. Often a client is asked to fund a project in advance with less than satisfactory assurance that the results will be handed over on time or the job completed at all. In fact the client is often left guessing as to whether he is dealing with the university as a body

corporate, or an individual member of the academic staff, who, himself being unsure of his position in law, seeks to contract out of all liability. Where there is sufficient volume of business a university may set up an institute, properly incorporated under company law and having a permanent, salaried, full time administrative staff. The Stevens Institue of Technology has the Davidson Laboratory and nearer home the University of New South Wales has set up Unisearch, but there has never been enough demand for the use of the ship model test tank at the University of Sydney to make such an organisation financially feasible. A less important limitation of a university tank is its "open" operation. The university's function is to disseminate knowledge, not to conceal it. This tends to discourage some commercial and defence organisations who demand absolute secrecy.

While the foregoing is written in a rather negative mood, three positive points should be firmly made. Firstly the University of Sydney runs regular classes in model tank technique and conducts these in a business-like manner. Opportunities for research are offered to staff and senior students. Over the years 1958 to 1975 tank running time has exceeded 11 000 hours, which is a fairly good record for part time operation. The real overall cost is quite moderate when compared with other university costs. Secondly the existence of a tank in Australia ensures the existence of local knowledge of tank technique. This can help when planning model work to be done overseas for Australian clients and in assessing the results. Thirdly the interest shown in the local tank and the demand for the use of it are quite valuable when examining the case for a research institute to be set up within the university or for a national laboratory.

CONCLUSION

A small tank which is part of a teaching institution is a very useful facility and its output represents good value for the money invested. Where it is incorporated into a research institute it can offer a useful, but strictly limited service to naval architects and shipbuilders. A co-operative effort by all parties would be required to set up the institute and ensure continuity of work.

A small tank which is built as a cheap substitute for a large tank is an expensive toy. If the demand is such that the tank would be operating on a full time basis with a permanent staff, then the saving in capital charges plus a relatively small saving in running costs would be unlikely to exceed 50 percent of the total equivalent cost of running a medium to large tank. When the reduced accuracy and limited scope of the work are related to the cost of building ships, then a small tank is a very poor bargain.

SOURCES OF INFORMATION

The material in this paper is drawn from the author's own experience in setting up and running the very small tank at the University of Sydney. The opinions expressed are those of the author himself and do not necessarily represent the views of the Department of Mechanical Engineering or of the University. The author is grateful to delegates to International Towing Tank Conferences who have kindly shown him over many of the tanks overseas, both large and small, and discussed the work being done in them. The proceedings of these conferences are among the best references on the art and science of model testing. There have not been many full size epxeriments in which a ship without its propeller has been towed and the measurements compared with the results of corresponding model tests, and it is, therefore, appropriate to mention a recent paper which gives data from a number of comparisons

between sailing yachts and models around one metre water line length tested in small tanks.

Kirkman, K.L. and Pedrick, D.R. (1974), "Scale Effects in Sailing Yacht Hydrodynamic Testing", Annual Meeting, New York, November 14-16, 1974, The Society of Naval Architects and Marine Engineers.

AN ACKNOWLEDGEMENT

The Hydrodynamics Laboratory was built around 1939 being financed by a grant from the Government of New South Wales. The fitting out of one of the channels as a Ship Model Test Tank was mainly due to the interest of the late Professor George Gilmour McDonald and to many of his friends in industry who assisted with gifts of money and equipment. Development continued under Professor P.T. Fink who was responsible for linking Australia with the International Towing Tank Conference.

THE NEED FOR RESEARCH ON FISHING VESSELS IN AUSTRALIA

by

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SUMMARY

The viability of the Australian fishing industry with respect to demand and supply is studied. Important technical and non-technical facilities required in Australia for the continued economic success of the industry are briefly discussed. The need for fishing vessel research is identified and some recommendations are made for its implementation.

INTRODUCTION

In Australia, where over 20,000 people are dependent on the fishing industry for their livelihood, continued economic success is important on a personal, local and national level. Over the last decade there has been a relatively steady increase in the growth of this industry. Further growth, however, depends on the industry remaining profitable for the investor. The measure of profitability is different for different investors. For example, consider the fishermen, the entrepreneurs and the government who are typical investors in the fishing industry. Each invests one or more commodities with the expectation that the rewards justify their investments. The entrepreneurs invest money, the fishermen time, expertise and maybe some money, and the government a combination of money, regulatory expertise and planning. The expected return and hence the profitability for each investor is tempered by the degree of risk involved. For the entrepreneurs it is the risk involved in losing the invested capital, for the fishermen it may be the risk of losing a limb, and for the government the risk of losing the goodwill of the people in the next election.

In general, all investors are interested in reducing the risks affecting their investment thereby increasing the return or profitability. The profitability of any investment is also enhanced by increasing the economic and technical efficiencies of the venture. In the past, most strategies for improving the efficiency of ventures could be quite effectively devised on the basis of the past experience of one or more individuals. Very little attention, if any at all, was paid to the factors which adversely affected the environment and the people involved. As a result of the increasing value of investments, government legislation, pressure groups and an awakening of social consciousness, answers are now being required for very complex problems. Such problems are invariably interdisciplinary in nature and answers to them are arrived at through research. However, money available for conducting such research is limited. It has therefore become necessary for funding agencies to set priorities for research and also to have some say in defining the objectives of the projects they support. The fishing industry is no exception. Some money for conducting research in topics related to the fishing industry is available. However, no money is spent, at present, on fishing vessel research. The main aim of this paper is to stimulate discussion on whether the time has arrived to start some fishing vessel research in Australia.

The question of whether there should be fishing vessel research in Australia arises only if the Australian fishing industry is a viable proposition. This is briefly discussed and is followed by a short discussion of some technical and non-technical facilities necessary for the continued economic success of the industry. Finally some recommendations pertaining to fishing vessel research in Australia are presented.

VIABILITY OF THE AUSTRALIAN FISHING INDUSTRY

An industry is considered viable if it continues to attract resources in the form of capital, labour and expertise. Investing in the Australian fishing industry will continue to be attractive if fish continue to be marketable. This implies that there is an adequate supply to satisfy an established demand at a price acceptable to both the consumer and the investor. In this section the viability of the Australian fishing industry is discussed, rather simply, within the context of an established demand and the supply of fish.

The Demand

The established demand consists of the demand for fish for domestic and overseas consumption. In Table 1 some figures related to the export and import of fish, crustaceans and molluscs are presented for the period 1969 to 1972. Whereas the quantity of fish exported increased from 658 tonnes in 1969/70 to 3,427 tonnes in 1971/72, the value per tonne dropped by 21 percent from 644 to 533 $A/tonne. In the same period however, the value per tonne of imported fish increased by 18 percent. This indicates that any catch increment resulting from the growth of the fishing industry should probably be sold on the domestic market, thereby reducing the amount of fish imported.

The quantities of crustaceans and molluscs exported and imported have also increased. The value per tonne exported, however, has increased by 24.3 percent, whereas the value of that imported has decreased marginally. In this case, it appears promising to market the catch increment overseas. The continued success of such exports, however, is largely dependent on the economic well-being of the trading partners involved. This consideration must be reflected in any plans devised for increasing the production of crustaceans and molluscs.

The favourable trend of the period 1969/72 did not continue into the period 1972/74. The author was unable to get detailed figures for this period, but in Table 2, the total value of exports and imports are shown for the period 1969/74. The value of imports in relation to exports decreased from 85 percent in 1969/70 to 56.5 percent in 1971/72 and then rapidly increased: the value of fish, crustaceans and molluscs imported in 1973/74 exceeded the value of those exported by 3.1 percent.

For the six year period ending 1971/72 the domestic consumption of fish varied between 4.3 and 5.1 kilograms per capita (Table 3). This indicates that if the eating habits of Australians remain unchanged, then at the very least, the quantity of fish required by the domestic market would increase in proportion. In the same period the domestic fishing fleet supplied between 40 and 49 percent of the fish consumed in Australia. This augers well for the Australian fishing industry since its growth does not appear to be limited by demand.

	Quantity (tonnes)			Value ($A f.o.b)/Quantity (tonnes)		
	1969/70	1970/71	1971/72	1969/70	1970/71	1971/72
EXPORTS: Fish						
Fresh, chilled or frozen	440	1,632	3,113			
Prepared and preserved	218	550	314			
TOTAL: Exports of fish	658	2,182	3,427	644	616	533
IMPORTS: Fish						
Fresh, chilled, frozen or boiled	22,802	30,216	23,296			
Prepared and preserved	3,249	3,903	3,904			
Canned	10,475	10,173	11,469			
TOTAL: Imports of fish	36,526	44,292	38,669	782	832	923
EXPORTS: Crustaceans and molluscs						
Fresh, chilled or frozen	10,463	13,293	14,769			
Boiled, prepared and preserved	2,048	2,623	2,880			
TOTAL: Exports	12,511	15,916	17,649	3,059	3,404	4,042
IMPORTS: Crustaceans and molluscs						
Prepared and preserved (a)	1,820	2,162	2,377			
Canned	854	867	979			
TOTAL: Imports	2,674	3,029	3,356	1,704	1,605	1,667

(a) Includes some other fish

Source: Official Year Book of the Commonwealth of Australia, No.59, 1973, pp. 895-909.

TABLE 1: OVERSEAS TRADE IN EDIBLE FISHERIES PRODUCTS AUSTRALIA 1969 TO 1972

	Value ($A'000 f.o.b)				
	1969/70[a]	1970/71[a]	1971/72[a]	1972/73[b]	1973/74[c]
Imports	33,131	41,694	41,352	47,657	68,633
Exports	38,976	55,615	73,228	73,605	66,575
Imports/Exports (percent)	85.0	76.6	56.5	65.8	103.1

Source: (a) Official Year Book of the Commonwealth of Australia, No.59, pp. 895-909, 1973.

(b) Quarterly Summary of Australian Statistics, No.291, March 1974.

(c) Quarterly Summary of Australian Statistics, No.294, December 1974.

TABLE 2: VALUE OF OVERSEAS TRADE IN EDIBLE FISHERIES PRODUCTS, AUSTRALIA 1969 TO 1974

	1967/68	1968/69	1969/70	1970/71	1971/72
	(Kg. of edible weight per head per annum)				
Australian Origin	1.7	2.1	2.4	2.1	2.1
Imported	2.6	2.7	2.5	3.0	2.4
TOTAL	4.3	4.8	4.9	5.1	4.6
Aust. Org./Imported (percent)	40	44	49	41	47

Source: Official Year Book of the Commonwealth of Australia, No.59, pp.895-909, 1973.

TABLE 3: ESTIMATED CONSUMPTION OF EDIBLE FISH, AUSTRALIA 1967 TO 1972

The Supply

The Australian fishermen do not have to go far to catch fish. Australia is blessed with an extensive coastline and therefore a vast expanse of territorial waters in which it has exclusive fishing rights. Australian fishing has in general been confined to these coastal waters. Waters relatively close to Australia are being fished effectively by fleets from distant lands, thereby beckoning Australian competition. The Australian Government is seeking to obtain fishing management rights which extend 200 miles from the coastline. This would allow Australian fishermen to fish in these waters relatively free from external competition. However, an abundance of supply today cannot guarantee an economic catch rate in the future. The catch rate depends on a combination of factors. These include biological and physical conditions prevalent in the ocean environment, the efficiency of the fishing operation and, of course, over-exploitation as a result of over-capitalization of the industry. It is therefore speculated that with proper management and protection of fish resources, planned growth of the Australian fishing industry will not be hampered as a result of a lack of supply.

LABOUR AND FACILITIES

A course of action can be determined by comparing what facilities are needed and what facilities are available to support the growth of the Australian fishing industry. Many recommendations could be made by people attending this conference. All recommendations other than those which deal with training of personnel and fishing vessel research are not considered in this paper. In order to provide some background, facilities which are essential to the growth of the Australian fishing industry are briefly discussed.

Non-Technical Facilities

A regulatory body is required to legislate on matters affecting the safety of the crew, consumer health, pollution, conservation and the like. The Australian and State Governments together would satisfy this requirement.

Management expertise is required to formulate policies which maximize profitability and to lobby for progressive legislation. The Australian Fisheries Council makes recommendations to the Government on matters affecting fisheries policy on a national basis.

Facilities are necessary for marketing and promoting the sale of fish in Australia and overseas. Most fish caught for the domestic market are auctioned under the control of various State authorities. This system on its own, without adequate facilities to freeze and store the catch and/or long term contracts, leaves a lot to be desired. Since the annual consumption of seafood was a very low 5 kg. per head in 1971/72, there appears to be tremendous scope for promoting seafood in Australia.

Technical Facilities

The aim of fisheries research in Australia is to provide a background of biological, technical and economic information which provides guidance for the efficient and rational exploitation of fisheries resources. Organizations in Australia engaged in research topics related to fisheries are *:

*Source: Official Year Book of the Commonwealth of Australia, No. 59, 1973.

(i) C.S.I.R.O. Division of Fisheries and Oceanography, with its headquarters and main laboratory at Cronulla, N.S.W. (fisheries science and oceanography);

(ii) C.S.I.R.O. Division of Food Research; main laboratories located at Ryde, N.S.W. (handling, storage, processing and transportation of fish);

(iii) State fisheries departments (fisheries laboratories have been established in Perth, Hobart, Melbourne, Sydney and Brisbane; research vessels are operated by New South Wales, Victoria, Western Australia and Tasmania; the Department of the Northern Territory conducts a Prawn Research Unit in Darwin);

(iv) Fisheries Division, Department of Primary Industry, Canberra (economic and management research, gear technology, extension and education service); and

(v) private fishing companies (surveys of fisheries resources, research into handling and processing).

The fishing vessel is a complex engineering system which has very far-reaching effects on different aspects of the fishing industry. Probably the least understood aspect of fishing vessels is the interaction between the dimensions, coefficients of form, speed, fish-carrying capacity and engine power on the economic efficiency. Such information, which indicates the sensitivity of return to different design parameters, is of crucial importance in putting together the specifications of the vessel. Unfortunately, however, at this time there is no organization in Australia which can provide this information. The computer offers considerable scope for the numerical computation of such information. Fortunately, computers appear to be easily accessible to the scientific and academic communities of Australia. Hence, research in this area can be conducted in Australia and is strongly recommended.

The lead time involved in developing programs for teaching and training professionals for employment in the fishing industry could be substantial. In order to effectively satisfy the requirements of the fishing industry, these programs would have to be multidisciplinary in nature. Any such program would include topics drawn from the fields of naval architecture, management and biological sciences, operations research, oceanography, mechanical and electrical engineering, seamanship and the like.

An initial step in setting up any teaching or training program would be to acquire the staff to do this. The number of teaching staff in Australia interested in, or having any expertise in maritime research is miniscule. Of course, teaching staff could be imported from overseas when the need finally arose. Since there is some time available, it may be quite economical and effective to attract the interest of specialists in appropriate disciplines at various places of learning in Australia. This interest could be aroused quite easily by providing some funds for researching topics related to the fishing industry.

Since a major portion of fishing hardware is imported, the involvement of the engineering industry at present is limited to maintenance. This is not likely to change in the near future as the appropriate expertise is currently unavailable in this country. An expansion of the Australian fishing industry will undoubtedly create a demand for trained people. On-the-job training in most cases will probably not be possible or economic because

of the increased complexity of the systems and the large initial outlays. The Australian Maritime College, some Institutes of Technology and Universities would probably have to assume the major responsibility for providing people trained in maritime, engineering and management sciences. Initially, this will include people trained to fish, to maintain and service equipment, to manage different aspects of the industry and to train and teach others. In time, it is expected that there will be a demand for Australian designed and built fishing vessels; with the equipment still being imported. This undoubtedly would generate the need for naval architects with a background in the design of small craft.

At present the only University offering a course in naval architecture is the University of New South Wales. More practically oriented courses are offered at the Royal Melbourne Institute of Technology and the New South Wales Institute of Technology. These organizations would need to modify their syllabi in order to train people in the design of small craft.

The fishing vessel represents the single most important piece of hardware in the fishing industry. Researchers often face the problem of over-specialization in a particularly small field at the expense of future employability. Fishing vessel research provides ample scope for the researchers to continue developing and diversifying their skills. Fishing vessel research can undoubtedly be used to bring people from different disciplines together and aid the growth of the fishing industry in general. In this context fishing vessel research is a viable proposition.

RECOMMENDATIONS

In order to make good use of the money available for research, some goals for the industry need to be identified and some guidelines for research need to be established. A council with membership from different sectors of the industry and the academic and scientific communities is required for this purpose. This council would be in a position to identify and recommend problems to be researched in Australia. Fink (1973) proposed the formation of an Australian Ship Industry Research Council (A.S.I.R.C.) in 1973. Unfortunately, the proposal has not been acted upon. Had the A.S.I.R.C. been established, the goals for fishing vessel research would probably already have been defined and the guidelines available. On a smaller scale, it is in the interest of the Australian Fishing Industry Council and the Australian Fishing Council to sponsor a committee which would identify and promote research relevant to the fishing industry.

For the purpose of stimulating discussion, some guidelines applicable to fishing vessel research in Australia are presented. In the initial stages the principal aims of funding research would be to encourage teaching staff and scientists to enter the field and to identify future research which should be carried out in Australia. At a later stage, the aims would correctly emphasise improvement of the technical and economic efficiencies in the industry. In setting priorities for projects to be funded, the following questions may provide some help. To what extent would the proposed project:

1. contribute to bringing information from overseas to Australia?

2. aid in the understanding of the phenomenon under investigation?

3. aid in the development of methods for the design of different components of a fishing vessel?

4. aid in the development of methods for evaluating the merits of new developments and proposals?

5. increase the capability to perform feasibility and trade-off studies?

6. improve the quality and relevance of the subject matter to be taught to the budding engineers and managers?

7. increase the safety of the operation?

8. increase the profitability of the venture?

Many more questions could of course be added to the above list.

Once the results of research start becoming available, it would become necessary to establish a system for making available such information to interested parties. Valuable data could be computerized and computer packages used for the design and the sensitivity analysis of engineering systems could be made available through, say, the C.S.I.R.O. computer network. This would enable practicing naval architects, engineers and managers to have easy access to these developments. Many other exciting possibilities could be enumerated - but one must be realistic!

CONCLUSION

Resonable growth of the Australian fishing industry does not appear to be limited by lack of demand or supply. Major non-technical facilities required to sustain growth of the industry exist in Australia. The technical facilities need to be extended. Specifically, this involves establishing training programs for those planning a career in the fishing industry. There is a shortage of teaching and research staff working in areas related to fishing technology. In order to increase this number it is proposed that some research should be funded. In this context the fishing vessel provides one of the most promising areas of research.

ACKNOWLEDGEMENT

Very helpful discussions with Professor J.R. Paulling of the Department of Naval Architecture, University of California, Berkeley, U.S.A., are gratefully acknowledged.

REFERENCE

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SOME ASPECTS OF PATROL CRAFT DEVELOPMENT IN AUSTRALIA

by

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I. INTRODUCTION

Whilst the title of this session contains the word "Research" - perhaps this word is too pretentious to cover the activities described below.

A better term might be "Development", or, what is now commonly used in US Aerospace, "R.D.T. & E", which means Research, Development, Test and Evaluation and where in our case the "R" has less emphasis than the "D.T. and E."

This paper will describe two aspects of work conducted at Hawker de Havilland:

- Development of the Patrol Boat concept.
- Development of the open water Hydrodynamic Test Facility.

In my text I shall be drawing upon aerospace background and analogy, not only due to historical reasons, both Company and personal, but also because I feel that marine developments have a lot to learn from aerospace approach and methods and especially from the System Approach. A recent typical example is that described in Ref. 9 in which a troublesome hull and flow interface problem was solved by using an aerodynamic approach and wind tunnel tests.

II. THE DEVELOPMENT OF THE PATROL BOAT CONCEPT

In discussing the development of this concept a certain perspective of the background is required, against which the activities described should be viewed. I would like therefore to review very briefly the technological background between, say, 1950 and 1970 because in this period various new methods, technologies and products became available. These products, initially developed mostly by and for aerospace, became gradually available for other industries, enabling considerable savings in weight and size of their products.

These developments related to:-

- Large scale availability of marine quality aluminium alloy sheet and plate,
- Methods of joining aluminium/alloy by inert gas-shielded welding,

- Lighter, smaller and more efficient power plants,
- Miniaturised electronic components and sub-systems for communications, navigation, sensing and auto-steering,
- Improved hydraulic sub-systems,
- Lighter and more compact armaments,
- Computer-aided design methods,
- CPM and PERT methods for progressing and controlling complex developmental activities.

But it was the gradual development and use of the SYSTEMS APPROACH which became the unifying factor which enabled the benefits of all these developments to be translated into more efficient and cost-effective products.

It is against this background that I shall view the development of the Patrol Boat Concept at Hawker de Havilland. Details of construction of the craft are given in another paper and I shall concentrate here on the systems considerations.

The Marine Division of Hawker de Havilland was started in 1958 in order to exploit the advantages of aluminium in the small boat field. The know-how and capability of the Division grew over the years until, in 1971, it obtained a contract to design and manufacture 6 off 46 ft. Patrol Boats for the Royal Malaysian Police.

This contract marked a watershed in the Division's history.

At that stage of development we had solved the problem of providing adequate light weight welded structures with good corrosion resistance and satisfactory strength characteristics. We have investigated the vibration problems of shafts and propellers (Refs. 10 & 11) and evolved certain criteria regarding the orientation of flexible couplings, universal joints and the interaction of propeller, engine and flow-induced modes.

It was realised for some time however, that the design and manufacture of high performance boats of some 12m and above in length involves systems considerations, not only in relation to the design of the sub-systems in the boat itself (i.e. the micro-system) but also

in relation to the role performed by the boat in the coastal surveillance-reaction scenario. (the macro-system).

The design of this boat provided an opportunity to incorporate some of this thinking into practice.

It may be appropriate, at this stage, to re-state some of the basic considerations of the systems approach:

- none of the sub-systems of a system exists in isolation and each of them interfaces with other sub-systems.

- a good design is always a compromise, not only between the various sub-systems, but also between performance in any given area and the cost required to obtain high performance.

- by using the systems approach it is often possible to compensate the shortcoming of one sub-system by improvements in another, in order to obtain a more cost-effective overall solution. A typical example for a search and intercept boat would be to compensate the need for extreme high speed, which is always expensive, by providing longer range radar and armament.

Returning th the Development of the Patrol Craft Concept, the analysis of the macro-system, i.e. the scenario in which our Patrol Boats were to operate, yielded the following considerations which influenced our thinking:

- the areas of operation were the coastal waters of the Australian mainland, of South East Asia and the island archipelagoes of the Pacific,

- the patrol boat use was appropriate to the peace-time surveillance-reaction operations. An important corollary of this is that the boat does not have to be at sea in all conditions of sea-state and weather. It is interesting to note in this context that, in the Indian Ocean, sea states 4 and above occur only on 4% of all occasions and on 71% of all occasions the sea state is 2 or below (ref 12),

- there is an inverse corelation between the size of craft and the number of mooring and fuelling facilities available. In other words, smaller craft can use existing facilities, spread at least every 400 miles around the Australian coast. It follows that extreme range is not required for such craft in peace-time.

Following this approach the basic design of the 46ft 9200 Series Patrol Boat was gradually refined and the 9208 series (Patrol Boats for the Philippine Navy) (Fig. 1) had the following

characteristics:

Top Speed: 27 knots

Range at 12 knots: 1000 miles

Length: 45ft. 10 ins.

Draft: 3ft. 3 ins.

Full load displacement: 18 tons

Armament: 2 x 0.5 inch M.G., capability of using 20mm guns.

This can be compared with an earlier generation patrol boat of the Attack class:

Top Speed: 21 to 24 knots

Range at 13 knots: classified, thought to be below 1000 miles.

Length: 107 ft. 6 ins.

Draft: 7ft. 4 ins.

Full Load displacement: 146 tons

Armament: 1 x 40mm

2 x 0.5 inch M.G.

Since the cost of a boat is roughly proportional to the ratio of its length cubed, or to its displacement, there is no question which of the two boats is more cost effective, with the lighter boat having equal or superior performance in virtually all areas.

I say virtually because the important subject of sea keeping and habitability must be mentioned at this stage. It looms very large in our systems considerations since the ability of the crew to remain alert and effective is a primary ingredient in ensuring success of a mission which requires a prolonged period at sea.

Traditional thinking is that the sea keeping capabilities of a given craft are mainly related to its size.

We queried this simplistic approach. It is already acknowledged that certain hulls possess better sea qualities than others. Significantly, the quality of sea keeping itself is not very well defined.

Using the systems approach it should be possible to analyse the problem, define and determine the main parameters involved and investigate and propose artificial means of increasing the habitability and sea keeping qualities of small craft. Finally, compare the cost effectiveness of these solutions with the brute force approach of size increase alone.

One such device, sprung and damped seats, has been installed on the 9208 series of Patrol Boats and produced a noticeable reduction of crew discomfort in high sea states.

In order to fully investigate the problem we have proposed a study into the various aspects of sea keeping of small boats, (Ref. 13), and it is gratifying to record that we are being commissioned by the Dept. of Transport to conduct such a study.

We are confident that the resulting findings will provide another step in increasing the overall capabilities of our Patrol Boat Concept and of small craft in general.

III. THE HYDRODYNAMIC TEST FACILITY.

De Havilland Marine, whilst involved in the design of the first 46ft Patrol Boat, sought in 1971 the assistance of Hawker Siddeley Research (HSR) (now called Hawker de Havilland Research), in the development of new planing hull shapes and in the resolution of various powering problems.

This request involved a search of published data and the determination of means by which information could be acquired on the design, behavious and powering of various high speed planing hulls.

The search proved negative and the investigation of local towed tank facilities revealed that these facilities were limited in nature and used essentially for student's experiments. (ref. 1) They were not suitable for testing planing hulls at representative Froude Numbers.

It was further determined that the Shipbuilding Division of the Transport Department provided consulting services to the industry but they, in turn, relied on the NPL in the U.K. to undertake model testing. BHP requirements for model testing and General Design data were sought from Japan and consulting naval architects relied on model testing data from the U.K., Denmark and Holland. It became therefore apparent that we had to look to our own resources to provide the required assistance to the Marine Division. (ref. 2)

The aim was to have a low cost local facility, capable of ad-hoc support to an on-going design project and of on-the-spot evaluation of any changes; and it was decided to look into the concept of an Open water facility using towed and self-propelled models.

I would like to mention at this stage that the idea, development and initial usage of the facility, as described below, was purely our own idea and did not follow any overseas examples. In fact, we were asked by many officials in various Departments - 'if this is such a good idea, why is it not used elsewhere?.'

It was only two years after inception that we received from Prof. P.T. Fink, a report (ref. 3), describing a very large and comprehensive open water facility in Poland, on the Lake Jeziorak. It appears from this publication that the above facility was initiated in 1956 and, in 1960, 'resistance and propulsion tests corresponding to model tests in towing tanks' were started. Of the seven open water facilities existing in the world, the Polish one appears the most comprehensive, the others being mainly devoted to turning characteristics and are adjuncts of conventional towing tanks.

Our background of missile work and familiarity with trials which involved missiles fitted with instrumentation and telemetry, transmitting often on some 50 data channels, immediately brought to mind a similar approach, using free models, powered and instrumented. This was, in the initial stage, rather an ambitious approach. To be on the safe side, the initial version involved a model, towed abeam of a tender craft, which was to be sufficiently instrumented to provide the relevant quantitative data and to record photographically the dynamic behaviour and the flow pattern on the model under test.

The development of the HTF took place in three phases:-

(i) proving the feasibility of the concept,

(ii) equipment selection and design,

(iii) proving the concept by testing a model of an existing craft and comparing the scaled results with test results of a full size craft.

The proving of the feasibility of the concept was undertaken in May, 1971 using a De Havilland Marine 21ft Trojan as a tender boat and a 9ft Cub boat as a model. A 12ft aluminium towing frame was designed and fitted to the tender boat. The original instrumentation was simple: a 0 - 200 lb spring balance for drag measurement and a commercial pitot-type speedometer for velocity measurement.

The aim of the trials were to:-

(i) Assess the dynamics and interaction of the craft and the model,

(ii) Determine the resolution and the usefulness of a spring balance for drag measurement and photography for behaviour determination,

(iii) Develop experimental techniques,

(iv) Provide design information for future development.

The initial results were encouraging and the curves of resistance versus speed obtained corresponded to analythical laws for planing hulls having the b/1 of the model used. As a result of the early trials the towing boom structure was extended and a better method of trim measurement appeared necessary. A further series of trials were conducted in August 1971 to confirm the modifications. (Ref. 4)

After the proof of the concept was completed, the Marine Division of Hawker de Havilland commissioned HSR (now HDHR) to conduct model tests of the 46ft type 9201 Patrol Craft with a view to suggesting improvements in its performance.

It was apparent at this stage that meaningful results could be expected, provided adequate instrumentation was available. The basic philosophy for instrumentation and support equipment was that it should be relatively inexpensive and simple, yet capable of an accuracy of at least 1%. The variables to be measured in the un-powered and powered trials were:-

* Model drag
* Model Speed
* Sea water temperature
  density
  viscosity
* Ambient air temperature
* Wind speed and direction
* Local water velocities around the model
* Model propeller shaft
  thrust
  torque

In addition, the support equipment was required to:

* Measure model trim
* Determine flow patterns around the model
* Record dynamic behaviour
* Determine model wetted surface.

Time and space prevent me from going into detail of how the above requirements were met in practice. On several occasions we had to develop our own equipment to ensure the necessary accuracy. In particular we had to develop our own viscometer and our own fine speed measuring device which consisted of a pitot-static tube connected to a manometer filled with bromoform (S.G. 2.9). We had, also to develop our own torque and thrust transducers. (ref.5)

It was decided to use as large a model as the current power of facilities allowed - which meant a 1/5th size, 9ft. long model.

Two models were made, one of metal (fig. 2) fitted with a power unit and propellers, the other wooden, to enable easy and rapid change in hull lines.

Whilst it was apparent that the greatest flexibility and ease of instrumentation would be obtained from a power plant based on a DC motor with a Ward-Leonard control system, the availability and cost precluded such an approach and a Honda 4.5 BHP single cylinder 4 stroke engine was adopted. It had adequate growth potential over the current requirement of 1.07 H.P per shaft. A gearing and drive assembly was developed to gear up from the rated RPM of 3600 to the 4,470 RPM on two outward turning propellers.

Fig. 3 shows a close-up of the power plant, transmition and shafts.

Available facilities precluded the use of strain gauges for torque and thrust measurements and mechanical/hydraulic transducers were designed to measure thrust on one shaft and torque on the other.

The metal model was also fitted with perspex panels on and around the tunnels in order to enable flow visualisation by means of tufting. The tufts were visible from the tender boat and good results were obtained by photographic recording.

Calibration of equipment and final development of techniques commenced early in April, 1972.

A view of the model under test is shown in Fig. 4.

At that stage the full scale trials of the 9201 Patrol Craft conducted between August 1971 and February 1972, were completed (ref. 6) and the purpose of model testing was to:

- investigate regions of the hull developing high resistance,
- determine possible means of modifying the hull shape to improve its performance, and
- determine hull and propulsion characteristics parameters.

Three series of trials were conducted:-

The first consisted of trials of the unmodified 1/5 scale metal model of the 9201 series Patrol Craft and involved trials of the bare hull with and without tunnels, with tunnels and appendages and of powered trials.

The second series consisted of trials of a wooden model, with and without tunnels (to establish a comparative datum) and two trials of modified hull, with the aft bottom surface cut away and with rounded chines.

The third series consisted of trials of the metal model with rounded chines.

The results obtained enabled a very much better understanding of the hull problems of the 9201 series of Patrol Craft and most of our recommendations were incorporated in the 9208 series (6 Boats for the Philippines Navy), with the results that the top speed was increased from 23.5 knots to over 27 using the same engines. The model-derived and full scale trials results for power, torque and RPM indicated a correlation factor of close to one. (ref. 7) The results are shown in Figs. 5, 6 and 7.

After the completion of these trials an overall review of the facility and methods used was made and covered in ref. 8 (Apr. 1973). Its conclusions were that the HTF "has been developed for the purpose of testing planing hulls and, with the improvements mentioned above, should become a very capable facility. However, much of the potential work available for such a facility will involve testing of displacement hulls. It is therefore recommended that a feasibility study be considered to investigate the possibility of extending the current HTF into the domain of displacement hull testing."

Finally, in an unpublished report, we looked into the minimum size and manning of an independent self-contained facility, based on a waterfront and utilising the open water testing principle. In relation to its potential, the costs are very modest, especially in comparison with standard towing tank facilities.

IV. CONCLUDING REMARKS

What was the result of our efforts?

We were very close to obtaining a contract for testing hulls of the projected 40 ft Workboats for the RAN - but this project somehow evaporated.

We have publicised our facility by writing directly to all the active dockyards in Australia and to most practicing Naval architects. There were a few encouraging noises, but no contracts.

The final outcome is that, after spending a considerable amount of company funds and proving the usefulness of the HTF, it is now mothballed and its staff disbanded.

I end this paper with the usual statement that the views expressed are my own and do not necessarily reflect those of my Company, Hawker de Havilland Australia Pty. Ltd.

FIGURE 1 TYPE 9208 PATROL BOAT

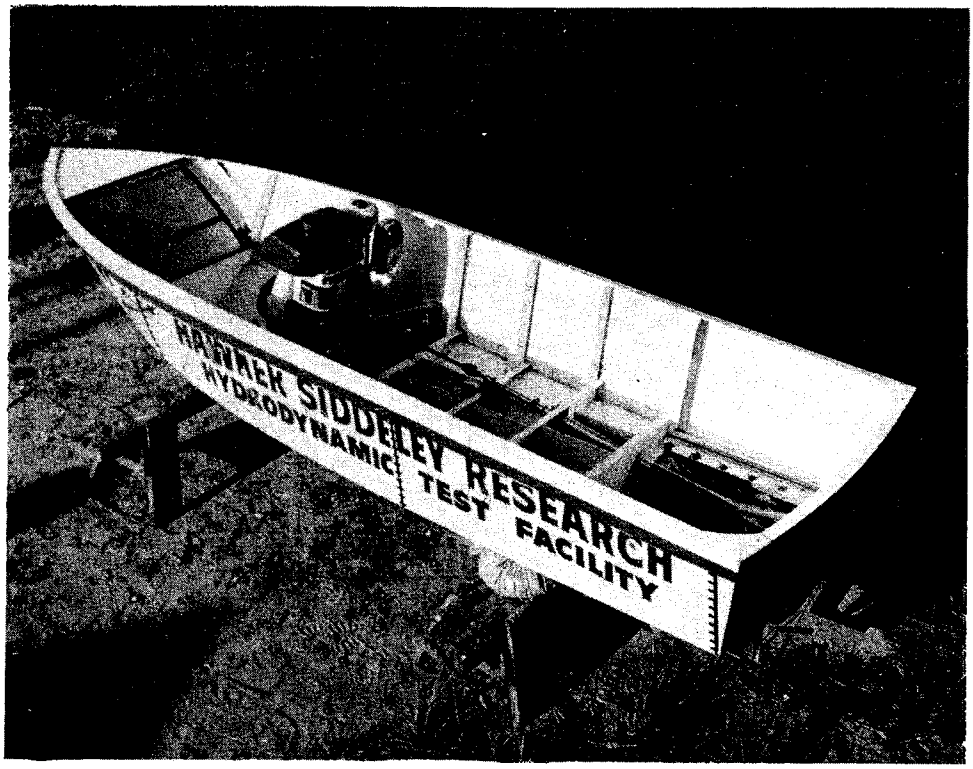

FIGURE 2 POWERED 1/5TH SCALE MODEL
OF THE 9200 SERIES PATROL BOAT

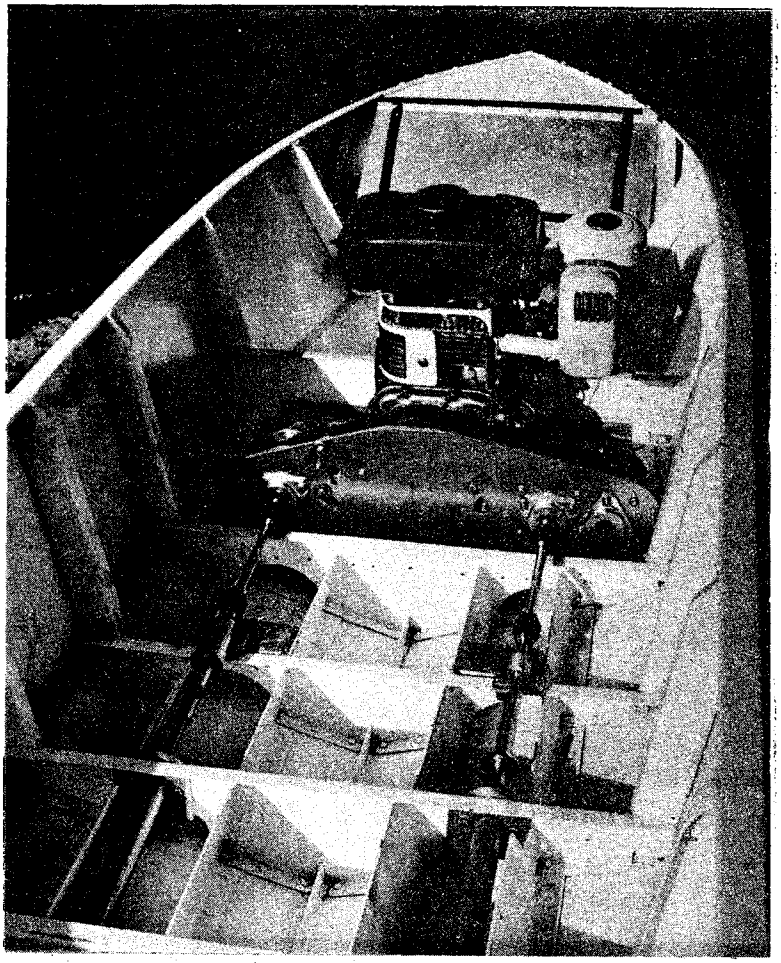

FIGURE 3 DETAILS OF POWER PLANT, TRANSMISSION AND SHAFTING

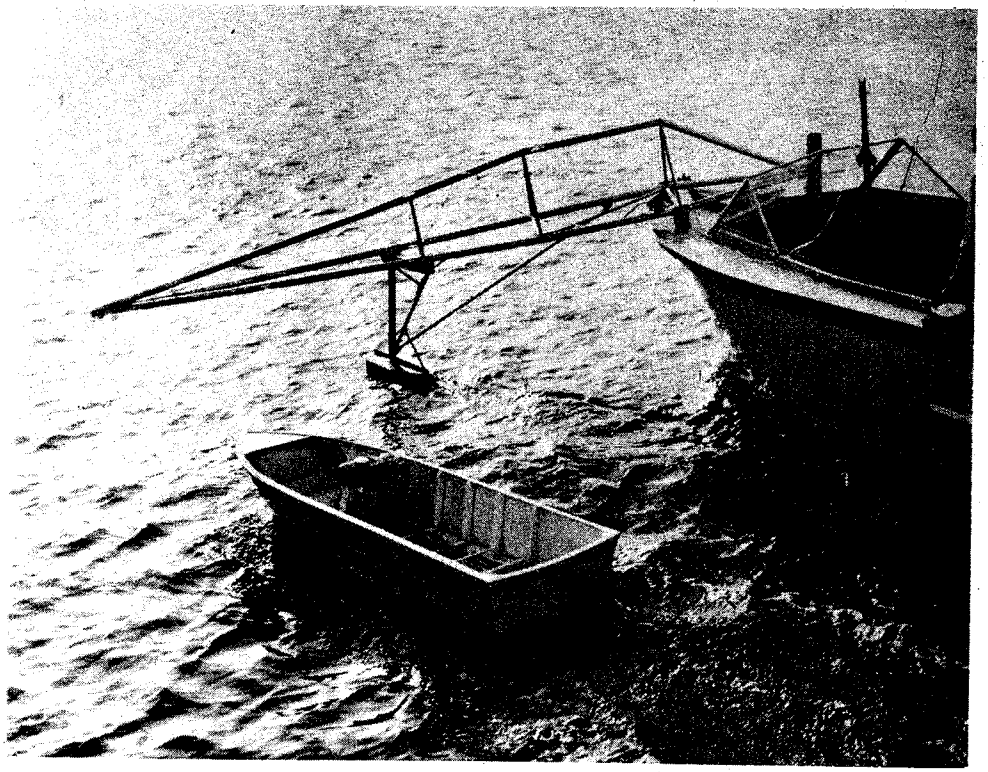

FIGURE 4 MODEL UNDER TEST

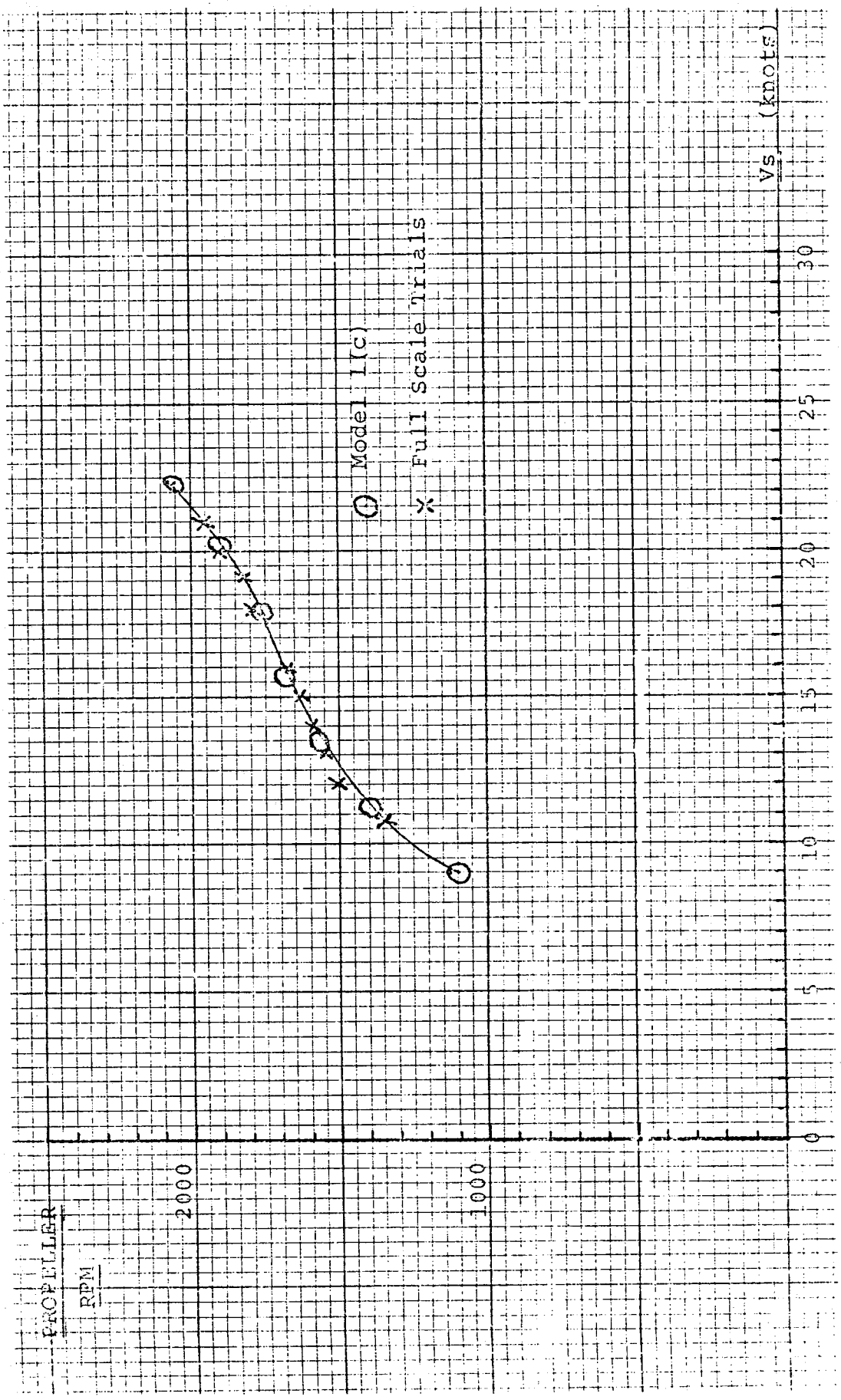

FIG. 5 SHP, DHP AND EHP COMPARISON - SERIES 9201 PATROL BOAT

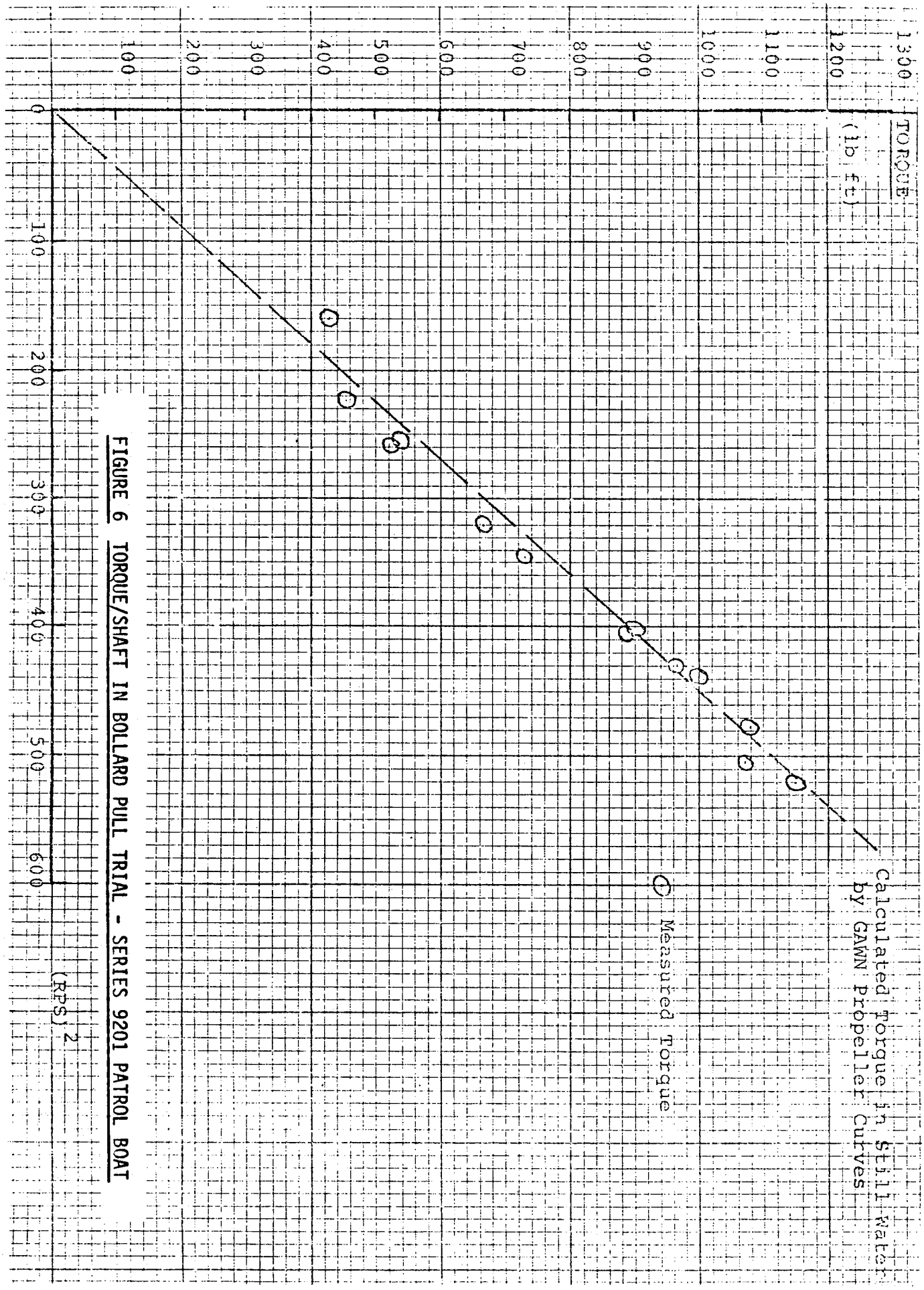

FIGURE 6 TORQUE/SHAFT IN BOLLARD PULL TRIAL - SERIES 9201 PATROL BOAT

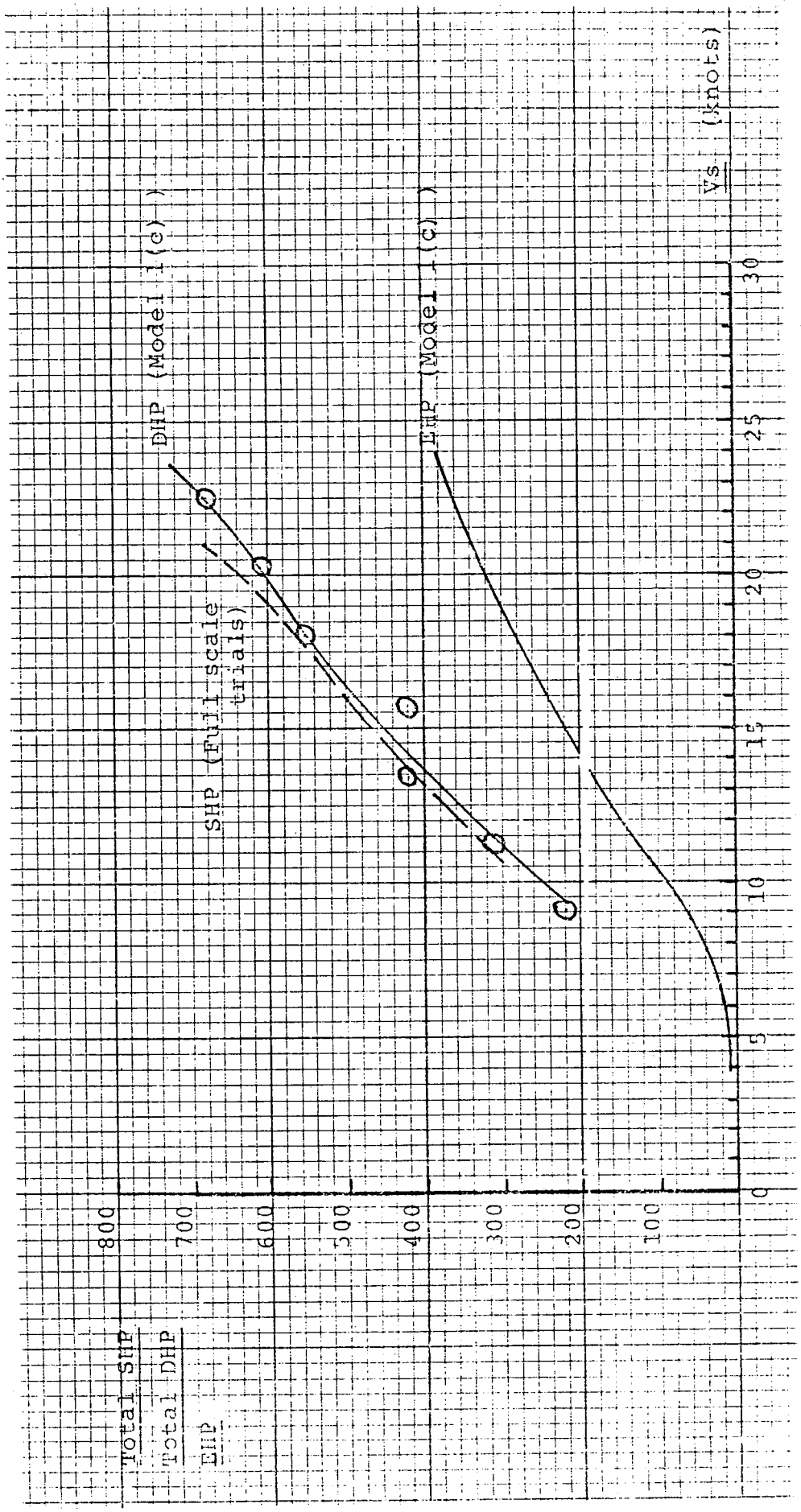

FIG. 7 COMPARISON OF RPM - SERIES 9201 PATROL BOAT

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