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# THE USE OF WELDING IN MERCHANT SHIP CONSTRUCTION. & NEW MERCHANT SHIP TYPES.

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## INTRODUCTION.

Some 50 years ago welding was to a small degree used in the construction of certain ship components by Shipbuilders in Great Britain . However, it was not until 1918 that a determined effort was made to use welding extensively and History was indeed made by the world famous yard of Cammell Laird & Co. Ltd., when in that year work was commenced on the first all welded ship the "Fullagar".

Although this ship was only 152 ft. long and of 425 gross tons its construction represented an achievement much greater than its modest dimensions suggest when compared with present day projects.

Today in Japan and the U.S.A.,Oil Tankers of 100,000 tons deadweight capacity are being constructed and it is reported that Cammell Laird & Co. Ltd., of Birkenhead, England have embarked on a colossal reconstruction plan to lay out and equip their Shipyard for the construction of large Nuclear Powered Oil Tankers.

These considerable departures from the orthodox, together with numerous other special ship types, have not been a gradual or natural development of the Shipbuilding Industry. On the contrary the demand for such ships in recent years has come as a sudden impact and has necessitated a new approach to the problems confronting Designers, Builders, Classification Societies, Research Bodies and Harbour authorities. Steel Manufacturers are being called upon to produce larger plates and special sections of notch tough steel.

Shipbuilding in most maritime centres of the world is flourishing. The Shipyards of Western Europe are well equipped for expeditiously effecting the most modern construction methods. Welding is to the forefront in Ship Construction and some Shipyards are equipped for welded construction exclusively.

The welded prefabrication methods employed in an Australian Shipyard are as modern as those in other Shipbuilding Centres. It is unfortunate, therefore, that in a time of World Shipbuilding prosperity the instability of the Industry in Australia, with its associated economic handicaps should hamper the progress of the industry and preclude the installation of the most modern equipment.

## THE WELDED SHIP.

Developments in Ship Design usually take their rise from the rules of the Classification Societies who obtain their information from Research Organisations and revise their rules from time to time in the light of the reported behaviour of ships in service the World over.

In 1918 Lloyd's Register of Shipping gave their approval to the use of electric arc welding on main structural members. Where such use of welding was made, however, the notations "Experimental" and "Electrically Welded" appeared in the Register Book.

The notation "Experimental" was removed from Lloyd's Register in 1932 and whilst it was recognised that considerable improvements were still necessary in design, construction techniques and the quality of steel, it could be assumed that the welded ship had proved to be a safe and reliable structure.

Little impetus was given to the development of welding until the last war when the tremendous output of welded ships was undoubtedly one of the greatest contributions to its successful conclusion. This achievement was realised however, irrespective of cost or scientific economic management.

The great boost given to the welding of ships was unfortunately nullified by the reported cracking and foundering of a number of ships.

Of a total of 1220 Liberty Ships constructed during this period, seven have since foundered due to fractures and 88 have suffered cracks in main structural members.

The opponents of welding made great capital out of this and indeed doubts were raised in many peoples minds as to the seaworthiness of welded ships.

An exhaustive enquiry followed and it was disclosed that in view of the adverse conditions under which the ships were built it was considered that the fatalities were small in comparison with the tremendous output achieved and further that all could be traced to very elementary causes.

A lot of the cracking was attributed to "Locked In" stresses caused by welding components together whilst in a condition of high restraint. The terms "Locked In" and "Residual" stresses can be somewhat misleading. "Locked In" stresses contain "Residual" stresses and present no problem while they remain locked in. It is when these stresses are released quite frequently by the failure of a member of seemingly minor importance that the danger period occurs.

Fig (1)

Strains Experienced by Ships

Structural [redacted] Strains

Fig (2)

Equivalent Girder.

Unlike land structures where the acting forces are known and by an estimation of the induced stresses, the scantlings and connections can be apportioned to keep them within safe limits, the forces acting on a ship nearly all depend on the action of the sea and vary continuously. In addition the hull structure is so complex that it is impossible to assign definite stresses to certain parts.

The riveted ship is subjected to the same reversals of stress and the riveted joints which are known to be inferior in strength to the welded joints have in most cases withstood these forces. Many cases have been recorded of cracked bulwark rails and fractures at the corners in superstructure openings in riveted ships without further damage to the ship.

On welded ships cracks originating in similar positions have been known to travel quickly across highly stressed deck and ships side plating.

It became increasingly evident that design had not kept pace with the rapid development and use of welding practice.

Welding in effect was being blamed for a very creditable accomplishment. It not only joined individual plates and sections together as did riveting but it transformed the many components of a ships hull into a completely homogeneous envelope.

When the impact of welding was first felt in the Shipbuilding industry most of the experienced Draughtsmen were of the "Riveting School". For ships of normal dimensions original structural design had been almost eliminated. The scantlings were extracted from the Rule Book of the Competent Classification Society and the drawings were turned out as though by a machine.

From the designers point of view the changes from riveted to welded ship structures were very considerable. His first task was to arrange light scantling superstructures and bulwarks in such a way that they would not be highly stressed and if by some trick of the elements and the conditions of loading a crack did develop in one of these members then the design should be such that it would be arrested before propogating into one of the main strength members.

Fig (3)

MACHINERY & CARGO WEIGHT DISTRIBUTION.

Coincident with the introduction of welding on a large scale, changes took place in the general design of cargo ships. Speeds increased, accompanied by finer block coefficients, raked stems, cargo forecastles and poops, and lighter machinery, all tending to increase the hogging moment in the fully-laden condition. This has resulted in a greater number of ships leaving port on an ocean voyage with a substantial still-water bending moment and, although strengthening of the hull can be introduced to ensure reasonably low calculated stresses, it is considered good design to have the still-water bending moment as small as possible and this applies whether the ship is to be welded or riveted.

In "A" shows a profile of a common type of present day cargo ship. The still-water bending moment in the homogeneously loaded condition is quite substantial, particularly when the midship deep tank is empty. With this arrangement, little can be done to reduce the longitudinal bending moment without reducing the cargo capacity. "B" is ship "A", but with the machinery placed at an intermediate position aft, and "C" is the same ship with machinery space right aft. The calculated bending moment in the homogeneously loaded condition in ship "B" is less than half of that of ship "A", and that of ship "C" is about one-eighth. The still-water bending moment in the ballast condition is least in ship "A", but even in the greatest, that is in ship "C", the resultant stress is quite small.

rticular attention was given to the elimination of abrupt changes in shape or section, sharp corners in way of openings and notching effects of any kind.

As the designs improved there was a noticeable reduction in the number of reported fractures.

A number of all welded Oil Tankers built during and immediately after the war had cracked arrestors fitted in the main deck and shell.

The Classification Societies completely recast their rules, longitudinally framed ships were favoured and it was recommended that the main deck stringer bars, sheer strake and bilge strake should be riveted.

Cracks had been known to occur in ships whilst berthed in calm waters. Investigation revealed that this was due to the steel becoming "Notch Brittle" at low temperatures. Notch Brittleness was particularly acute in thick plating and by virtue of the fact that Ship Owners were requiring new ship types such as large bulk carriers with wide hatchways and main deck plating of necessity to maintain the required sectional area became thicker and thicker.

The Classification Societies therefore amended their rules to provide for the use of special notch tough steel in certain structural members. In some countries which experience low temperatures, steel for all structural purposes is now produced to this formula by the steel Manufacturers. Little is heard these days of "Locked In" stresses, it being generally contended that the working of the ship relieves these stresses after a short time in service. It is however considered that no restraint other than its own weight should be placed upon a component and that it should be allowed free lateral movement during welding. From a practical point of view it is also of great importance that particular care be exercised in burning processes that the joint preparation be such as to minimise the stress in the joint and that a correct selection of electrodes be made for the joining of various components.

Fig. (4)

Assembly of Prefabricated Sections.

In countries where very low temperatures are experienced several instances are on record of extensive cracking during the welding of heavy plates in the shipyard. In most of them, the welding was carried out while the atmospheric temperature was very low. A contributory cause of this cracking is undoubtedly the heat gradient between the hot metal of the weld deposit and the comparatively large mass of cold parent material, resulting in a high rate of cooling in the welds and in the plates in their vicinity. Pre-warming to a temperature of not less than 50 deg. F in way of the joint is all that would normally be required to remove this risk of fracture.

Fig. (5)

1.1/4" Thick Deck Plating Being Automatically Welded.

Wherever possible butt welding should be performed using machine welding or heavy gauge electrodes with high currents producing a single deep penetrating run from each side of the plating with a square edge preparation. Apart from the marked economy in welding production, optimum weld quality is obtained by using the maximum practicable current. Good workmanship is of paramount importance. Shoddy workmanship is not economical. Efficiency is the primary consideration and in welded ship construction efficiency and economy are synonymous.

Today for various reasons Shipbuilders the World over are introducing more and more electric welding into the construction of ships and their machinery. In some countries the all welded ship is quite commonplace.

Fig. (6)

Fabricated Stern Frame.

In some cases Shipbuilders have been compelled to adopt welding as the main joining medium because of the rapidly diminishing number of riveters available to the industry. The depleted ranks of moulders in the Foundries resulting in protracted deliveries of castings has necessitated the introduction of a considerable volume of steel fabrication by Ship and Engine Builders.

The development of welded prefabrication techniques is largely a problem of economics whilst the physical problems and those related to prejudice are also formidable.

Fig. (7)

Prefabrication in Shipyard Shop

Units up to 25 tons weight constructed.

Fig. (8) Fig. (9)

Prefabrication of Units adjacent to 40 tons capacity Travelling Crane.

In laying out a modern shipyard the provision of large areas both under cover and adjacent to the Building Berths for the pre-assembly of units and the servicing of these areas with adequate cranage is of primary importance.

The forced introduction of welding into some of the very old Shipyards in the U.K. has adversely affected production costs as they have neither the room nor the crane power to cater for large scale prefabrication and assembly. The piecemeal welding together of plates and sections on the building berth is not economical.

A typical example of the importance of these facilities is provided in the actual experience of one of the older yards in the U.K. building medium sized Cargo Ships. This yard had three building berths and delivered three to four ships per year. The introduction of a considerable amount of welding did not increase the output. Faced with increasing Continental competition urgent steps had to be taken to improve production output. The immediate action taken was to devote one entire building berth to the prefabrication and assembly of units and to provide increased cranage capacity on the Berths and assembly areas. In the ensuing twelve months, six (6) ships were delivered from the two berths and an average annual output of six (6) to seven (7) ships has been maintained ever since.

Economies can emanate from the Design Office by the production of a simpler hull form. Deck sheer may be eliminated over the mid ship body, orthodox deck camber could be replaced by straight camber with a knuckle at the hatch sides. An increase in Bilge radius would provide greater length of parallel body. All of these items would facilitate prefabricated panel construction and assist in the reduction of production costs.

The Ship Draughtsman of today is required to think in terms of welding and to familiarise himself with the practice obtaining in the Shipyard, the facilities available and the disposition and capacity of Shipyard Cranes.

Fig. (10)

35 Tons Bow Section Being Erected.

Working drawings for Shipyard use embody a great deal more information than was the case with the orthodox built riveted ship. The drawings clearly indicate the limits of the sections to be prefabricated, the weights and in cases of irregular sections the position of the centre of gravity for lifting purposes.

The automatic repetition of the dictates of welding codes relative to joint preparation, electrode size and number of runs etc., can have adverse effects on production costs so the draughtsman should simply specify on the drawings the fillet size and spacing if intermittent required by the Classification Society Rules. The choice of Automatic or Manual welding and the electrodes to be used is a matter for determination by the Production Department.

In embarking upon a programme of welded ship construction Managements are faced with considerable risks. The expected saving in costs has to be balanced with the capital outlayed in welding the burning plant, jigs, fixtures and lifting facilities.

Most other countries have a distinct advantage over Australia in this regard. The large volume of orders placed overseas enables many Shipbuilders to concentrate their efforts on specific ship types and thus benefit greatly in so far as several ships are often built of the same scrieve. Rolled steel sections specially designed for welded ship structures and plates up to 12'0" in width are available to the industry. These sections are unobtainable in Australia and Shipbuilders are faced with costly improvisation or have to resort to riveting of bulb angles or channels in order to obtain the required section modulus.

Inverted angle stiffeners, because of their large surface area have been found to be in need of renewal earlier in the life of a ship than stiffeners of bulb plate section. The latter is unobtainable in Australia.

Whilst some form of jig is necessary in the prefabrication of panels the cost of producing one for every shaped unit such as for shell plating would be prohibitive if it could not be spread over a number of sister ships.

Fig. (11)

Fairing a Shell Panel Prior to Welding.

At the State Dockyard a simple method for obtaining the shape and checking the fairness of a panel during welding has been evolved without the use of complicated jigs. When the shell plating is temporarily fastened to the frames it naturally assumes the frame contour and is roughly the required shape. The unit is turned with the frames downward onto the welding table and , waterline battens, the dimensions of which are obtained from the Mould Loft by measuring from a vertical or buttock line into the shell plating at the various frames, are erected vertically from the shell plating. The unit is then jacked or wedged up until the tops of all the battens are in the one horizontal plane.

Due to the rapid advances being made in burning, welding and prefabrication techniques and the introduction of modern automatic equipment demarcation codes and agreements between unions of some years standing are no longer of much assistance to Managements in the allocation of work. The craft of Shipbuilding is centuries old and established construction methods have been handed down from generation to generation. The prejudices against the introduction of modern methods and machinery whilst understandable to a degree have to be firmly broken down. Some tradesmen erroneously believe that their craft is being belittled, that they are becoming mere robots that press buttons.

On the contrary the shipbuilders job in this modern age is becoming more and more scientific.

It is true there is little difficulty in learning how to deposit weld metal and indeed only a few years ago little more was required of a welder. This practice resulting in some serious fractures earned for the welding industry a very bad reputation which has taken some breaking down.

Today the welder must apply scientific knowledge to his job. Firstly there is the selection of the correct type and gauge of electrode and welding current. Other aspects to be considered by the welder are "Fit up", joint preparation and above all sequence to avoid "Locked In" stresses and to minimise distortion.

Each welder engaged in the construction of a ship should realize that the success of the welding ultimately depends on his skill and integrity. A ship may be in the middle of the ocean when his particular contribution to the welding is by virtue of conditions of loading and the elements put to the test. When he makes a weld he should be sure it will withstand this test as faulty workmanship could result in the ship foundering with the loss of hundreds of lives and hundreds of thousands of pounds worth of valuable equipment.

It has been said that the Managing Director of a Shipyard who secures the contracts, and directs the large scale operations of the establishment is dependent for the success or failure of his efforts on the welder whose job it is to join two pieces of metal together. These is a lot of truth in this when it is considered that the welder by the simple process of selecting the correct electrode size and using the right amperage can, without working any harder or longer hours, quadruple his output.

Is this not more scientific than the old days when a riveter was responsible only for filling up holes with rivets? Can the Managing Director quadruple his output without extra effort? This comparison is not made with the intention of belittling the work of the Managing Director whose business acumen undoubtedly provides the welder with his livlihood but it serves to show how much the economical production of ships today is dependent upon the application of scientific knowledge by individual welders.

It is doubtful whether the costs incurred in any other manufacturing process can be so vitally affected by Horsepower as can welding.

The prefabrication of ships requires a completely different organisation than construction by orthodox methods. The working drawings show the split up of units whether they be panels or blocks and the material is listed and ordered accordingly.

Templates made in the Mould Loft which are less in number for this type of construction are racked in units as are the steel plates and sections when received from the Steelworks.

It used to be the practice for a Boilermaker Marker-Off to be given a whole plan, e.g. a Deck plan to mark off and he would progressively obtain all the templates and all the steel for that deck and by applying the templates to the steel, mark the whole deck off. This often led to serious delays in having the various components fabricated. Today several Boilermakers may be assigned to work on marking off a deck, each having an individual unit. For example Boilermaker "A" obtains the templates and steel for unit "P2" and Boilermaker "B" does likewise for unit "S5".

Fig. (12)

Manually Tracing Around Scrieve Lines.

Another development is the scrieving of all floor plates, bilge brackets, etc., onto sheets of masonite for attachment to a large oxy-acetylene Profiling Machine in the Platers shop. The old method was to template every floor or make a cumbersome "Banjo" template giving the shape of several floors and in each case these templates were applied to the steel and the relative information transferred.

Fig. (13)

Two Floor Plates Being Cut Simultaneously.

With the profiling method no markings other than identification and erection aids are required, the port and stbd. floors being cut to shape simultaneously by tracing around the scrieve lines on the masonite. Intercostals, Beam Knees, and brackets of which considerable numbers of the same dimensions are required are automatically cut to shape on the same machine using a steel template and a magnetic tracing head.

Fig. (14)

Optical Drafting of Templates.

On the Continent and in the United States of America a further advancement has been made in the Marking and Burning fields. These processes are known as "Visual" or "Optical Marking" and "Monopol" cutting. These two methods are identical up to a point. Most of the Establishments using these methods have eliminated Loft work and templating entirely. A new works drawing office has been set up and personnel trained in the craft of lofting now draw to a one tenth scale on preshrunk plastic cloth or white painted aluminium or light steel plating all of the information previously produced full size on the loft floor.

The greatest accuracy is required in producing these drawings and to achieve this magnifying glasses with a 10/1 magnification are fastened to the drawing pens and pencils and focused onto their points.

The drawings are then accurately photographed so that the negative produced is exactly one tenth the size of the drawing i.e. one hundredth full size. The two processes differ from here on.

For "Optical Marking" the negative is placed in a projector in a tower some 60 ft. above the plating to be marked which is carried on a conveyor in a semi dark room. By remote control the marker off adjusts the focus so that the projected check marks are correctly spaced when measured with a steel tape. He then proceeds to mark over the top of the light projected onto the dark plating.

The "Monopol" gas cutting machine has a central control carriage with an arm projecting from either side carrying the blow-pipes. The one hundredth scale negative is placed in an electronic head in the control carriage. When the mechanism is set in motion the pantograph action is automatically enlarged one hundred times so that the plating is cut to the required size and shape.

It is regrettable that the demand for ships in this country is so small that the capital expenditure involved in acquiring such modern aids to economic production would be unwarranted.

Fig. (15)

Bulkhead Being Turned in Mid Air using Main & Auxiliary Crane Hooks.

Extensive use is made of Automatic and Semi-Automatic welding at the State Dockyard and as much as possible of the handwelding in the assembly of the various units is executed in the down hand position which is known to be most conducive to economy and efficiency.

Considerable experimental work has been performed with Automatic Welding and for the past seven years plating 1.1/4" in thickness has been welded with a square edge gap at the butt. In the past six months a technique has been perfected whereby two inch thick plating has been satisfactorily welded using the same process. This type of joint whilst undoubtedly the most economical is also favoured because of the resulting low average stress in the joint and the control of distortion.

There is little doubt that few countries could claim equality with Australia in the progress made in the field of welding.

Fig. (16)

Completed Shell Panels Erected after being painted, & Fitted with Spar Ceilings, Air Escapes, Etc.

The size of units constructed is limited only by the crane power available and the practibility of erection. The aim being to attain an irreducible minimum of welds made in situ on the building berth. Before erecting all pipes, bollards, fairleads, ceilings, rigging fittings and the like are fitted to the relevant units and where possible the units are painted.

In joining together units of considerable weight or in welding "Insert Plates" where "Locked In Stresses" may be involved, considerable use is made of low Hydrogen electrodes.

Fig. (17)

Studs Being Fired to Fasten Timber Grounds.

Stud welding has replaced drilling and tapping for studs, or bolt fastening the many thousands of electrical fittings, wooden grounds, wood decking and sundry joinery and metal fixtures.

Fig. (18)

Progressive Erection of Units for Bass Strait Ferry.

Fig. (19)

A Ship Almost Complete on the Building Berth
On an adjacent Berth Prefabricated Sections for a Sister Ship.

Welded ships are appreciable lighter than riveted ships by virtue of the fact that connecting flanges, angles, and laps are eliminated and the section modulus of the various components is utilised to the fullest extent.

This difference in weight between riveted and welded ships of the same dimensions represents the additional weight of cargo that may be carried and over the life of the ship the revenue obtained by the ship owner from this source alone is considerable.

Damage to cargo due to sprung rivets and leaky seams is now not experienced and the accumulation of rust in way of faying surfaces resulting in high maintenance cost has been considerably reduced in the welded ship.

There have been numerous instances of welded ships suffering underwater damage and it is reliably reported that the welding has held and that the damage has been less than would have been expected with a riveted ship.

INSPECTION & TESTS.

Radiographic inspection of ship welds is being extensively practiced by the Admiralty.

There is no doubt that Radiography is beneficial in the training of welders and controlling the quality of workmanship. In Commercial Shipbuilding however caution should be exercised in the use of Radiography because of the high cost involved and the very doubtful advantages.

In a 10,000 ton cargo vessel there are some 13,500 individual plates and sections to be joined and the length of main structural welds excluding bulkheads, floors, beam knees, girder butts, etc., is in the vicinity of 26,000 ft. It is doubtful therefore that an accurate selection of sections to be radiographed could be made.

Even if the welds in the half length amidships known to be subject to normal Hogging and Sagging stresses were radiographed, a length of weld approximately 1700 ft., would be involved.

In such cases where a faulty weld is discovered by radiography very thorough investigation of its effect on the ship, considered as a whole should be made before cutting it out as the re-welding process, carried out under conditions of high restraint may produce stresses far more dangerous than the original weld.

Tests of welded joints and electrodes should be in some way related to service requirements.

The testing of deposited metal is futile unless considered in conjunction with parent metal, and the quenching of welded test pieces as required by some codes could never be carried out in actual shipbuilding practice

Fig. (20)

M.V. "KOOJARRA" returns to Port after Undergoing sea trials.

With sound practical design, good steel and faithfull workmanship welded prefabrication methods enable the shipbuilders to effect greater turnover with efficiency and economy and to provide ship owners with cheaper and stronger ships with a greater pay load capacity.

NEW SHIP TYPES.

Vehicular Passenger Ferries.

Vehicular Passenger Ferries which have in recent years been operating between the British Isles, from U.K. to the Continent, within the Continents sea ways and in the United States and Canada are becoming more and more popular. These ships if properly designed to attract tourists with a studied balance of accommodation for passengers and vehicles and operating on a "Ferry" timetable are proving to be a sound financial investment to the Shipping Companies by which they are operated as well as providing a convenient intercontinental highway for the motoring public.

In most cases particularly in the tourist season a continous service is operated and the maximum time spent at the terminal points for unloading, loading, fueling and victualling is one hour.

The following statistics published by the Danish Government serve to illustrate the popularity and usage of this type of transport on the Great Belt. A daily average of about 1,000 Railway Carriages, 1,600 autocars, motor cycles, etc., 400 bicycles and motor-assisted cycles and 13,000 passengers are ferried across the Great Belt between Korsør and Nyborg. Every year the ferries of the Great Belt sail a distance corresponding to round the earth twenty times.

An error in the estimation of numbers of non vehicle passengers has in the past proved costly to some Shipping Companies operating Ferries. Some Ferries with capacity for 120 vehicles have provided elaborate accommodation for 1000 passengers when service records have shown that they transport very few passengers other than the occupants of the vehicles. Apart from the high initial cost of providing the accommodation for the passengers and sufficient crew to cater for them the maintenance costs and loss of revenue from space which could have been profitably employed is considerable.

People who do not wish to travel by car have a number of convenient avenues open to them to cross the water, namely by air, regular passenger ship services or by boat train.

Ships fitted to carry trains usually run on the same route or a route parallel to the car ferries. Some ferries carry both cars and trains.

Two kinds of train ferries operate on overnight journeys. Some are fitted with sewerage disposal units between the tracks on the train deck and in these cases the passengers do not leave the train. On other services the passengers disembark from the train and are accommodated aboard the ship during the crossing.

The average motorist, be he touring or on a business trip desires the cheapest means of transporting his car, his passengers and himself across the sea. The most successful ferries are designed on this basis. By day the ship is a Restaurant, a Lounge and a Bar, by night it is a "Motel". A small number of luxurious suites are usually provided for those who desire them and can afford them.

The loading arrangements for Vehicular Ferries vary considerably. Some load through the Bow, others through ships side doors but the most modern trend is through the stern. In all cases provision has to be made at the terminal points for loading ramps which may be readily adjusted to take care of the rise and fall of tide, the trim and restricted list of the ship whilst loading.

Apart from the detailed attention which must be given to the accommodation and catering requisites for passengers and crew the Naval Architect is confronted with some unusual problems associated with stability, trim, displacement, drainage, ventilation and Fire extinguishing.

These problems may best be briefly illustrated by reference to a Vehicular Passenger Ferry at present under construction at the State Dockyard. This vessel when completed will operate on a service between Melbourne, Victoria and Devonport, Tasmania a distance of some 240 miles.

It is understood that this will be the longest regular service of its kind in the world. This coupled with the fact that there will be no other regular passenger ship service constitutes a major economic handicap. Whilst it is considered that there will be a constant demand for car and commercial vehicle transport, the tourist passenger traffic without vehicles based on past records will be seasonal.

PRINCIPAL PARTICULARS OF BASS STRAIT FERRY.

| | |
|---|---|
| Length on L.W.L. | 356'0" |
| Length Overall | 370'0" |
| Breadth Moulded at Vehicle Deck | 58'0" |
| Breadth on Waterline | 58'0" |
| Depth Moulded to Vehicle Deck | 20'9" |
| Depth Moulded to Upper Deck | 36'3" |
| Draught moulded | 15'0" |
| Service speed | about $17\frac{3}{4}$ knots. |
| Cargo in Trailers and Motor Cars | 550 tons |
| General Cargo in Hold | 100 tons |
| Passengers | 400 |

This ship will be fitted with 2 direct drive "Nohab" Polar main propulsion engines each capable of developing 4,670 B.H.P. at 250 R.P.M.

For manoeuvring and berthing purposes a "Voith-Schnieder" bow propeller will be installed and for the comfort of the passengers and the safety of the vehicles the ship will be fitted with "Denny Brown" stabilisers.

Stability, trim and displacement are to a great extent interdependent on one another and to illustrate the problems encountered in this particular design brief reference will be made first principles and comparisons made with a bulk cargo ship of similar overall dimensions.

STATICAL STABILITY.

Stability is a special problem since too much stability will result in quick jerky rolling which does not make for comfort and too little stability may be dangerous. The provision of a happy medium between what is necessary for safety and what is desirable for comfort is a major problem for the designer.

A competent authority on passenger ship design states that the G.M. should not exceed 5% of the beam for vessels of 50 ft. beam and 6% for about 100 ft. beam.

Although the G.M. cannot be determined until a vessel is inclined, an early accurate assessment has to be made in ships such as this which are to be equipped with stabilisers.

Having determined the vertical position of the centre of gravity in the inclined position it is a comparatively simple process to calculate its position for various conditions of loading.

If at this stage it is found that in a certain condition of loading the ship will be unstable action myst be taken to remedy the fault.

It is quite often erroneously believed that in all cases a positive G.M. may be restored by the addition of permanent ballast low down in a ships structure. In some cases this is true, in many instances the stabilising effect is negligible and in a few cases the addition of ballast has made the condition worse.

Dependent upon the positioning of the ballast and the consequent trim of the ship, the moment of inertia of waterplane may slightly increase, remain the same or slightly decrease.

Within the practical and economic limits of adding ballast it may be assumed that the moment of inertia of waterplane on most vessels will remain about the same. Therefore, although the vessels centre of gravity is lowered the B.M. is also reduced because the volume of displacement has been increased.

The "Freeboard" of a vessel, having been determined by the competent authority the ship owner is naturally desirous of filling the gap between light displacement and permissable full load displacement with the maximum possible cargo pay load.

Permanent ballast would therefore deprive the Shipowner of the revenue accrueing from an equivalent weight of cargo carried throughout the life of the ship.

Attention should rather be given to ways of reducing top weight. It is not unusual these days to find extensive use being made of aluminium alloys in the superstructures of passenger and cargo ships.

In choosing the dimensions, designing the lines and arranging the superstructures of the Bass Strait Ferry, to effectively cater for its specialised service, and to obtain economic powering for the required speed left little margin for error in the preliminary stability calculations.

The light ship displacement is designed at 3,590 tons when floating at a mean draught of 12'6". When loaded to the maximum mean draught of 15'6" the displacement will be 4,590 tons.

Most of the total deadweight of 1,000 tons will be made up of vehicles and passengers which will increase the height of the centre of gravity and decrease the G.M.

A bulk cargo ship recently completed had the following dimensions:

| | |
|---|---|
| Length between perpendiculars | 365 ft. |
| Breadth Moulded | 52 ft. |
| Depth Moulded | 28 ft. |

This is a single screw vessel fitted with a Doxford Diesel Engine of 2,800 B.H.P. giving a service speed of 12.1/2 knots.

The light ship displacement of 2,530 tons on a mean draught of 7' 1.1/8" and the loaded displacement is 9,680 tons on a mean draught is 23' 10.3/4". The total deadweight in this instance is therefore 7,150 tons.

The G.M. in the light condition is 11.12 ft. and when loaded to the maximum draught with a homogeneous cargo the G.M. would be 2.33 ft. If a concentrated cargo of, say iron ore were carried then the G.M. in the loaded condition would be considerably higher.

It will be appreciated therefore that although the overall dimensions of the two vessels are similar the basic designs are radically different.

Fig. (21)

The Fine Lines of the Bass Strait Ferry.

Fig. (22)

Double Bottom Units for the Bass Strait Ferry.

In order to maintain the maximum possible inertia of load water plane and to arrive at the estimated displacement within the specified dimensions has resulted in the lines of the ferry being fine and yacht like. A full midship section and fine lines forward and aft would result in "hollow" waterlines and considerable "flare" at the ends which is undesirable for economic powering. The fining must therefore originate from the midship section and consequently a very steep rise of floor has been introduced. This item alone leads to complications in the construction of Double Bottom Units.

The vehicle deck is kept as low as possible for stability reasons and consequently the main propelling machinery must be of a type which requires a minimum of head room.

DRAINAGE.

Adequate drainage is required on the vehicle deck as there is no watertight subdivision throughout its length and the stability could be endangered by the incidence of free water over such a large area. Some vessels of this type operating in sheltered waters have freeing ports, others have scuppers discharging overboard through screw down valves operated from above the Upper Deck by extended spindles.

Neither of these methods is considered satisfactory for vessels operating in open sea. There being little freeboard to the vehicle deck, a list in the vessel caused by bilging could render impossible the discharge of water through freeing ports or ship side valves. Drainage to pumps situated in seperate watertight compartments below the vehicle deck and discharging overboard is a positive way of dealing with the problem of flooding.

VENTILATION.

As the vehicles are driven on to this class of vessel and contain petrol in their tanks throughout the voyage it is of paramount importance that adequate provision be made for the disposal of exhaust gases and petrol fumes. The vent ducts leading to and from the vehicle compartment must be fitted with quick closing valves which may be operated from outside the compartment should a fire break out.

FIRE EXTINGUISHING ARRANGEMENTS.

It is essential that facilities be availabe for quickly limiting the spread of a fire once started and then extinguishing it. Opinions vary considerably as to the most practical method of dealing with this problem. Most Government Authorities specify some means of zoning the fire. This requirement can be met by the installation of asbestos curtains, insulated doors or spray curtains to be operated transversely at intervals along the lenght of the vehicle deck. Asbestos curtains and insulated doors are required by regulation to be closed during a crossing and this considerably complicates the loading and parking of vehicles and restricts the number that may be carried. Spray curtains should be operated at least once a day to prove their efficiency.

Although each of these methods satisfy the requirements of the regulations by theoretically dividing the vehicle compartment into zones, where a fire once started may be extinguished by a sprinkler system it is doubtful whether any one of them would be very effective in practice. In fact it is felt that the spray curtain which is gaining in favour because it causes the least obstacles to the expeditious loading of the vessel could well be responsible for spreading a petrol fire instead of zoning it as intended.

At least one continental shipbuilder has been successful in gaining the necessary approval to dispense with the zones and to provide in liew a foam extinguisher installation to cover the entire vehicle deck.

TRAILER SHIPS.

Trailer ships more commonly known as "Roll on Roll off" ships are becoming very popular particularly in America. Designed similarly to Vehicle and Train Ferries the Trailer Ship is distinctive from the Vehicular Ferry in so far as the trailers are rolled on and off without prime movers instead of being driven on and off.

The success of these ferries depends largely on standardization and the control by one authority of the ships and the road transport. Standard trailers carrying various cargoes are hauled to the terminal points by prime movers which are then disconnected and the trailers rolled on to the ship. At the end of the journey the trailers are rolled off the ship connected to other prime movers and driven to the consumers.

Most trailer ships are equipped with a heavy lift radial or gantry crane so that trailers may be loaded and discharged at ports where loading ramps are not availabe. This method of loading and unloading is slower than the ramp method but still considerably faster than convential methods.

Trailer ships have similar drawbacks to the vehiclur and train ferries particularly in that a high percentage of cubic and deadweight is wasted; there are however, many advantages which make this form of transport one of the most efficient and economical methods of carrying cargo:-

(1) A large variety of goods can be handled in the Standard trailers and in the case of refrigerated cargo, without the special

reefer boxes and elaborate dunnaging which would be required on a conventional ship.

(2) Carrying cargo in trailers eliminates some of the cargo handling at both ends where the roll on roll off method is employed there is no handling at all.

(3) Goods carried in trailers because they are not handled are delivered in good condition; this is especially desirable when the cargo can be spoiled by handling as in the case with fruit.

(4) The highways are relieved of a considerable volume of heavy transport. In Australia where the highways are not constrcted to cater for the huge number of trailers using them, a reduction in this traffic would reduce the high annual road maintenance bill and make the highways safer for motorists.

An analysis of the cargo handling costs of the T.M.T. Trailer Ferry Inc., in the United States of America reveals that the basic costs using the "Roll on Roll off" method are about two (2) dollars per ton whereas the basic costs of cargo handling under convential methods were twelve (12) dollers per ton.

As pioneers in the operation that has contributed most to the transportation industry in recent years and for its success in developing fast and efficient "roll on roll off" methods, T.M.T. received the National Academy of Science award for 1955.

CONTAINER & PALLET SHIPS.

Ships for the carriage of Containers and Pallets should be specially designed for the purpose and there is an even greater necessity for standardisation than with trailer ships for the scheme to be a success.

In some cases cargoes for shipment are delivered to the wharf in the normal manner and then loaded into containers before placing aboard ship. Alternatively the containers are packed by the manufacturers and the contents are not handled until they are received by the consumer.

By this method losses through pilferage of small valuable items such as drugs, cosmetics, cigarettes, radios, watches, jewelery etc., are almost eliminated and insurance rates on the cargo are consequently reduced.

The containers or pallets are as a rule taken aboard ship by fork lift trucks or tractors driven up ramps through ship side doors. Unloading is similarly carried out.

A shipping company on the Great Lakes in Canada is operating a regular service from Manufacturer to consumer using Pallet ships. The average loading and unloading rate is 450 tons per hour. These ships have flush deck with no hatches or cargo handling gear and these are utilised for the carriage of vehicles which are driven up ramps at the same time as the Pallets are being loaded.

Although there are certain disadvantages such as the limitations on the type of cargo suitable for stowage in containers and the loat deadweight of the containers themselves, (standard container used in the United States takes up about 15 per cent of the deadweight) the case for the unit package ship is becoming stronger due to the increasing costs of handling cargo by convential methods.

## INCREASING DEMANDS ON THE NAVAL ARCHITECT.

From the brief description given of some of the special ship types now in demand it is evident that in most countries a determined effort is being made to reduce sea transportation costs in an endeavour to meet the rising competition of road transportation.

Efficient road transport companies have themselves demonstrated the economies of sea transportation by building and operating their own ferries.

Shipping Companies look to the Naval Architects for the complete answer to their problem. Unfortunately there are a number of factors influencing the design of a ship over which the Naval Architect has no control. These include such items as Port facilities, Rail Gauge, Harbour Depths, etc.

These matters have a vital bearing on economic ship construction and operation and dependent as we are in this country on shipping services their effect on the national economy cannot be too greatly emphasised.

Some figures recently published in the U.S.A. by the Society of Naval Architects and Marine Engineers give interesting comparisons of average loading and unloading times of various ship types and emphasise the importance of adequate port facilities:-

| Ship Type | Loaded by | Loading Tons per hour | Unloaded by | Unloading Tons per hour |
|---|---|---|---|---|
| General Cargo | Burtoning | 120 | Burtoning | 120 |
| Ferry | Roll on | 3,000 | Roll off | 3,000 |
| Ferry | Crane | 1,100 | Crane | 1,100 |
| Ore Carrier | Spouts | 16,000 | Grabs | 1,000 |
| Tanker | Shore Pumps | 3,000 to 5,000 | Ships Pumps | 2,800 |
| Dry Bulk Cargo | Shore Gear | 4,000 to 8,000 | Self unloader Conveyor | 5,600 |

## STATISTICS.

At one stage in the 1890's the United Kingdom with an annual output of nearly one million gross tons was producing 82 per cent of all merchant shipping launched in the World. At the beginning of the 20 th Century, British predominance was challenged by the rapid growth of foreign competition, much of it assisted by state subsidies. In the period 1910 to 1914 United Kingdom output averaged 1.6 million gross tons a year and its share of world output has dropped to 62 per cent.

The output of various shipbuilding countries in more recent years is shown in the table hereunder. At 30th June, 1957, 2 million gross tons of shipping were under construction in the United Kingdom representing 23.5 per cent of world tonnage.

Position of Leading Shipbuilding Countries.

Tonnage Launched.

(Thous. Gross Tons)

| | 1938 | 1949 | 1951 | 1953 | 1954 | 1955 | 1956 | 1957 ~~Approx.~~ |
|---|---|---|---|---|---|---|---|---|
| World[2] | 3,036 | 3,132 | 3,643 | 5,096 | 5,353 | 5,317 | 6,674 | 8,500 |
| U.K. | 1,030 | 1,267 | 1,341 | 1,317 | 1,409 | 1,474 | 1,383 | 1,445 |
| Other British Commonwealth Countries | 30 | 102 | 78 | 126 | 84 | 55 | 55 | |
| Germany | 481 | n.a. | 318 | 818 | 963 | 929 | 1,000 | 1,275 |
| Sweden | 166 | 323 | 404 | 485 | 544 | 526 | 489 | 680 |

| | 1938 | 1949 | 1951 | 1953 | 1954 | 1955 | 1956 | 1957 |
|---|---|---|---|---|---|---|---|---|
| U.S.A. | 201 | 633 | 166 | 528 | 477 | 73 | 169 | 340 |
| Japan | 442 | 148 | 434 | 557 | 414 | 829 | 1,746 | 2,465 |
| Netherlands. | 240 | 169 | 217 | 341 | 411 | 397 | 450 | 510 |
| France | 47 | 155 | 223 | 235 | 267 | 326 | 299 | 425 |
| Italy | 94 | 99 | 112 | 263 | 162 | 167 | 358 | 510 |
| Denmark | 158 | 86 | 115 | 148 | 130 | 154 | 130 | |
| Norway | 55 | 59 | 94 | 118 | 138 | 141 | 172 | |
| Other Countries | | | | | | | | 850 |

Source - Lloyd's Register Shipbuilding Returns.

[1] Vessels of 100 gross tons and over

[2] Excluding countries where figures are not availabe - China, Poland and U.S.S.R.

n.a. Figures are not available.

## FUELING & PROPULSION.

Coal has been largely replaced by oil as a source of power for new ships. Only 7.7 per cent of shipping afloat in the World in 1957 used coal, compared with 51 per cent in 1935 and 96 per cent in 1914. Rather more than half the shipping under construction in United Kingdom yards in June, 1957 consisted of motorships. The steamships now building are mostly being equipped with turbine engines of various kinds.

## NUCLEAR PROPULSION.

As yet no ship fitted with nuclear power and intended for commercial operation has been built anywhere in the world. It is known that plans are underway for the production of nuclear powered tankers and in the United Kingdom several important groups of shipbuilders and marine engine builders have entered into partnerships with a view to pursuing these far-reaching possibilities.

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## REFERENCES.

1. Attwood, E.L. - Theoretical Naval Architecture
2. Lloyds Register - Shipbuilding Returns
3. The Society of Naval Architects and Marine Engineers - Steel Merchant Ships.
4. Turnbull, J. - Hull Structures (Paper before Institution of Engineers and Shipbuilders in Scotland 1956)