THE INSTITUTE OF MARINE ENGINEERS

TRANSACTIONS

1971, Vol. 83

SOME FACTORS IN THE DESIGN OF CELLULAR CONTAINER SHIPS WITH PARTICULAR REFERENCE TO REFRIGERATED CARGO*

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The introduction of a container service between Australia and the U.K./Europe involving the large scale carriage of refrigerated as well as general cargoes involved a number of problems of container ship design in advance of previous experience. In this paper the author examines some of the main design problems involved in the A.C.T. 1 class of container ships and makes some broad comparisons between the solutions reached as against those reached for the Bay Class container ships of O.C.L. designed for the same service.

No attempt is made to give a complete description of the ships but the problems peculiar to container ships referred to, include structural matters, hatch covers, stabilization and mooring and navigational control. Particular attention is given to the arrangements for refrigeration.

The reasons for the choice of steam turbine machinery are dealt with, together with some of the main features of the installation, such as scoop circulation of the main condenser, electric generating plant and the philosophy for control and automation.


Captain Jenks

In almost every aspect of our modern world we are faced with the problem of scale, and the transport of goods, whether by land, sea or air, is no exception. Whenever it is found possible to increase the scale of an operation the prospect is offered of a drastic reduction in costs and in the case of liquid cargoes and bulk cargoes of grain, ore, etc., a dramatic escalation in the size of ships and of the means of handling the loading and discharge of cargoes in the minimum time has been witnessed for a number of years. The field of general cargoes and of refrigerated cargoes was by far the most difficult one in which to apply the economies of scale because of the extraordinary variation in the size, shape, density and fragility of the items concerned, or because of their perishable nature and liability to damage by temperature and humidity variations or taint. The idea of packing such items into standard size boxes is by no means new, and has been used for transport on land on a relatively small scale for many years, but it was only when the employment of such boxes for land transport became really widespread and relatively standardized that the idea of extending their use to long haul sea transport became possible. The important thing to realize is that a container ship is merely one link in an integrated through transport system and its design parameters are determined by the requirements of the whole system and cannot be considered in isolation. The ship has to match the system, the system cannot be designed round the ship.

In the case of the A.C.T. container ships which will be used to illustrate this paper the service was for the carriage of general and refrigerated cargo between Australia, the United Kingdom and Europe, and although initially intended as an independent operation it was later decided that there should be a joint service with O.C.L. operated by nine ships, 6 O.C.L. and 3 A.C.T. (one of these later taken over by Australian National Line), providing weekly sailings in each direction.

The service was in advance of all previous experience in container ship operation in respect of the length of voyage and the carriage of refrigerated cargo in containers on a large scale. It is interesting, therefore, to compare both the similarities and differences of the two classes of ship which were designed quite independently but in the end have to operate with complete interchangeability in an integrated service. The main parameters on which the design was based were:

a) Number, size and weight of general and refrigerated containers to be carried;
b) Service schedule leading to definition of maximum continuous speed at loaded draft and of endurance (fuel) required;
c) Limiting drafts and dimensions imposed by ports to be served;
d) The range of temperatures at which refrigerated cargo would have to be carried and the minimum degree of subdivision of refrigerated cargo for:
    i) Temperature; ii) Taint.
e) The dimensions and characteristics of the container cranes to be used at the container berths. Originally these were to be single lift cranes, but a decision to use twin lift cranes (fortunately taken at a reasonably early stage in the design of the ships) had quite far reaching implications.

Serious work on the A.C.T. ship design started in January 1967 and was carried out by joint teams consisting of the technical staffs of the three owners concerned (Blue Star Line, Ellerman Line and Port Line) assisted by consultants from the shipbuilding, refrigeration and insulation industries. Invitations to tender were issued in April 1967, an order was placed in June 1967 and the first ship was delivered in February 1969 after extensive trials. These dates are mentioned because a committee structure is not normally considered ideal for dealing with complex and urgent design problems, but it can be claimed that this project has shown that such a system can be made to work.

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* Paper read at a joint meeting with R.I.N.A.

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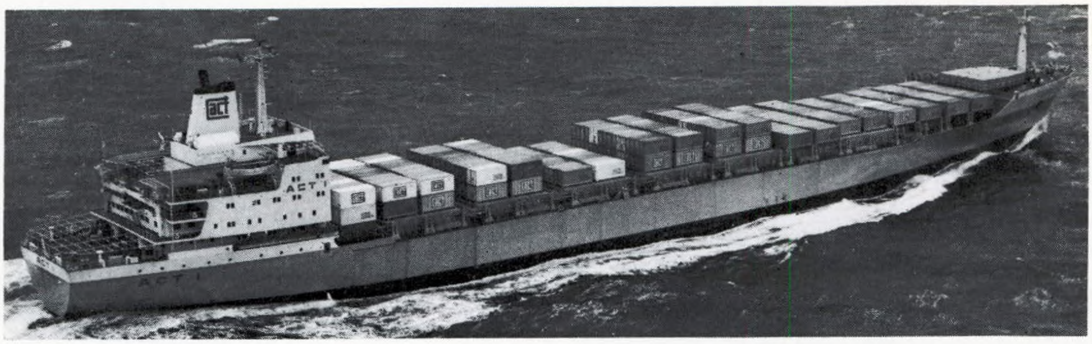


FIG. 1—*General impression of the A.C.T. ships*

Space does not permit a full description of these ships and it is only intended to highlight certain features of the design which may be of interest.

GENERAL ARRANGEMENTS

A general impression of the ships is given in Figs 1 and 2 and it will be noted that an all aft configuration is used to give an uninterrupted area of operation for the container crane while storing and other ship operations can be carried out using the ship's cranes clear of the container operating area.

FIG. 2—*General impression of an A.C.T. ship*

The leading particulars are given in Table I and the corresponding particulars for the O.C.L. Bay class ships have been added for comparison. It will be noted that the beam and length of the A.C.T. ships are somewhat smaller than the O.C.L. design but that the number of under-deck containers carried is practically the same. Above the deck the O.C.L. ships carried initially 71 more containers and it has now been found possible in both classes of ship to carry considerably more deck containers than was allowed for in the original designs.

TABLE I—LEADING PARTICULARS OF A.C.T. CONTAINER SHIPS

	A.C.T. 1 and A.C.T. 2 (as designed)	O.C.L. Bay Class Ships as published by Meeks(1)
Length, b.p.	675 ft 0 in	700 ft 0 in
Length, o.a.	712 ft 8⅞ in	745 ft 9 in
Breadth, moulded	95 ft 0 in	100 ft 0 in
Depth, moulded	52 ft 2⅞ in	54 ft 0 in
Design service draught	32 ft 0 in	30 ft 0 in
Design deadweight	22 980 tons	21 750 tons
Block coefficient at design draught	0·61	0·60
Displacement at design draught	35 938 tons	35 950 tons
Scantling draught	34 ft 6 in	35 ft 0 in
Maximum deadweight	26 376 tons	29 100 tons
Design speed	22 knots	22 knots
Design horsepower (British)	30 000	32 000
Shaft rev/min	137	140
Class	Lloyds + 100 A.I.	Lloyds + 100 A.I.
Gross tonnage	24 820 tons	27 000 tons
20 ft × 8 ft × 8 ft I.S.O. containers:		
General below deck	442	470
Refrigerated below deck	326	304
On deck 3 tiers holds 7–10* 2 tiers holds 2–6	455	526
(O.C.L. 3 tiers throughout)		
Initial total*	1223	1300

* Note. Container capacity on deck is subsequently being increased in both classes of ship, the latest A.C.T. total is 1334 and the O.C.L. total is understood to be considerably greater still.

Some Factors in the Design of Cellular Container Ships with Particular Reference to Refrigerated Cargo

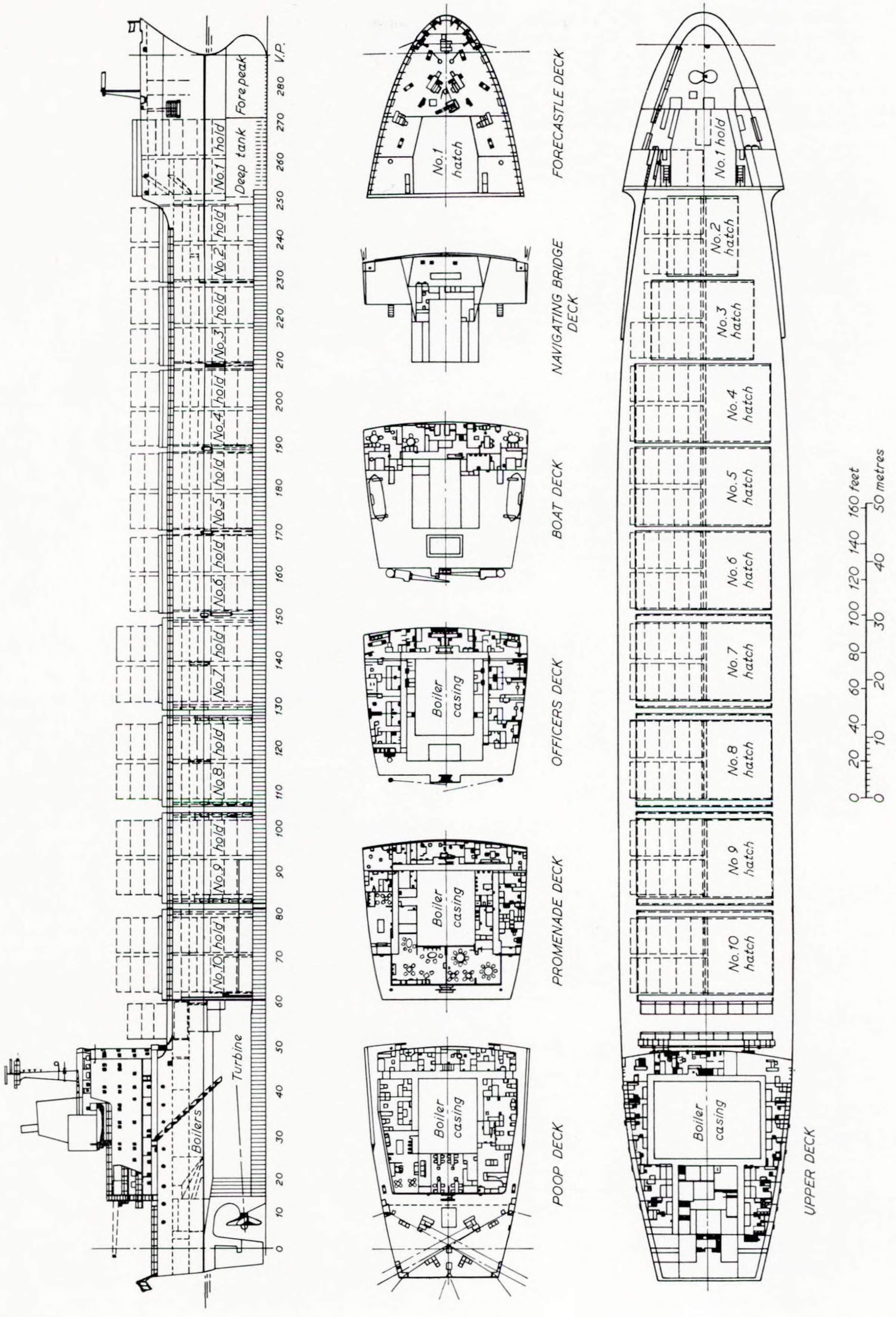


FIG. 3—*Layout of the ship*

The layouts of the ship are shown in Fig. 3. It will be noted that the four aftermost holds are provided for refrigerated cargo, the remainder general. During construction the requirement for refrigerated cargo was reduced and half of no. 7 hold was left uninsulated and allocated to general cargo containers, but can be readily adapted to refrigeration if so required at a later date. The containers are carried eight abreast and this has permitted the longitudinal bulkheads and hatch coamings to be set some 10 ft 6 in from the ship's side which has not only helped the problem of longitudinal strength and torsional stiffness but has also enabled the coolers to be placed at the sides of the refrigerated holds with resultant saving in length. This feature represents one of the main differences from the O.C.L. ships where the containers are stowed nine abreast involving coolers at the ends of the holds and somewhat narrower structure outside the longitudinal bulkheads. Also in order to accommodate the containers within a reasonable beam O.C.L. have had to pitch their containers as closely as possible and this has involved using a 'flip flop' mechanism at the lead in to the container guides as described by Meek(1). A.C.T. have been able to avoid the complication of this device due to greater latitude in lateral spacing. The main problem in the A.C.T. arrangement has been to make the very large twin hatchcovers strong enough to support the weight of deck containers to be stowed on them while keeping their weight within the limit of 26 tons imposed by the container cranes when using one 20 ft spreader. This was particularly difficult in the case of the general container holds since provision had to be made for the possibility of carrying 40 ft containers below decks at some future date thus preventing the fitting of any central supports for the hatches such as are provided in the insulated holds. However, by careful design and the use of a proportion of high tensile quality steel the requirements were met.

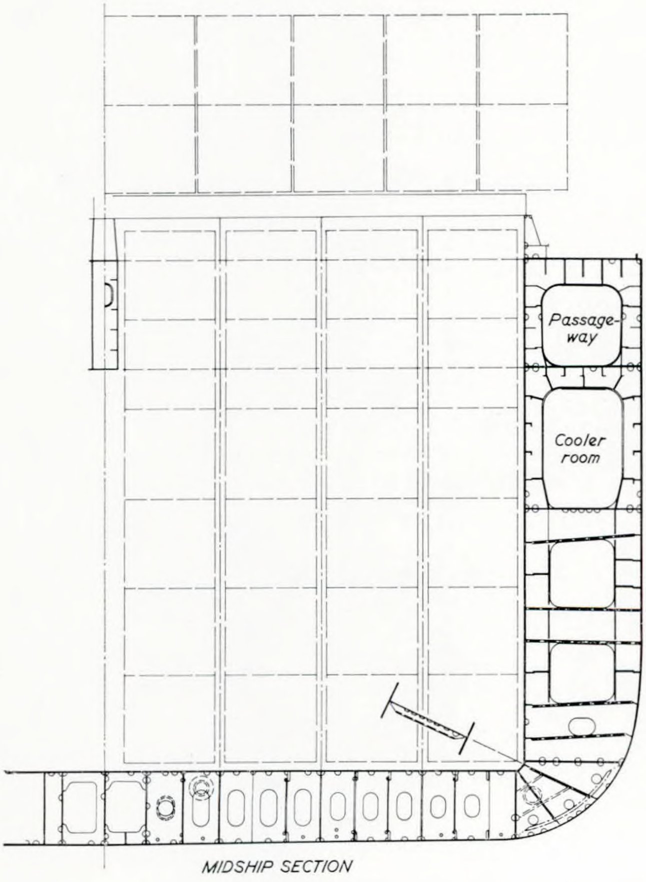


FIG. 4—*Midship section*

STRUCTURAL FEATURES

Referring to the midships section in Fig. 4 the vital importance of the 'box' section girder which encloses the side passages running the whole length of the holds both for longitudinal strength and in relation to torsional stiffness will be noted. It was decided to avoid the use of high tensile steel due to practical problems in shipyard welding, and with the "D" and "E" quality steel used the scantlings are very heavy, the sheer strake and longitudinal stiffeners all being of 40 mm thickness.

In the next generation of container ships it has been decided in consultation with Lloyds to increase the strength and stiffness of the longitudinal girder while maintaining reasonable scantlings by incorporating the sides of the hatch coamings into a continuous longitudinal girder continued over the whole length of the holds and of the accommodation. A portion of the midship section incorporating this feature is shown in Fig. 5.

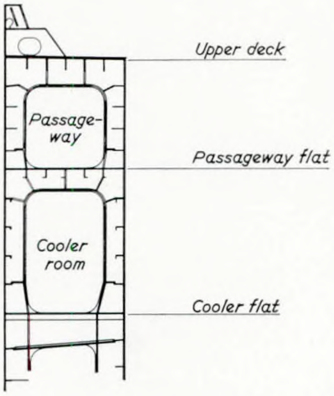


FIG. 5—*Midship section incorporating future developments*

The most important consideration in the structural design of these open deck ships was that of torsional stress and the early design work owed much to the theoretical work carried out by De Wilde and the guidance of Lloyd's Register of Shipping. Reference has already been made to the importance of the longitudinal bulkheads and side box girders in this connexion and so far as possible these were scarphed into the forward and aft ends of the ship beyond the hatches to provide continuity of longitudinal strength and to assist in providing restraint against warping. The effect of torsion is to give very high stresses in the deck plating at the hatch corners and the parabolic shape is of particular importance but the extent is limited by the need to fit the container guides as close to the corners as possible so as to minimize the total extent of the deck opening required. The parabolic and elliptical profiles adopted are shown in Fig. 6. In order to obtain as much information as possible on this problem a static torsional test was arranged shortly before completion of the first ship. Ballast tanks abreast nos 4 and 9 hatches were loaded on alternate diagonals (no. 4 port and no. 9 starboard, then no. 4 starboard and no. 9 port) to give a total difference of torsional moment of 7000 tonne metre and stresses were measured at two cross sections of the ship at forward end of hatch 5 and aft end of hatch 8 by using strain gauges at a total of 45 different positions in the side structure and hatch corner. In addition the distortion of the hatch openings was measured using special equipment to measure the lengths of the diagonals. Under these conditions the highest measured stress was $4\cdot1$ ton/in^2 in the after corner of no. 8 hatch and the greatest variation in the diagonal dimensions of an individual hatch (also at no. 8) was $+3\cdot72$ mm to $-3\cdot60$ mm. It is of interest to note that with the hatch cover in place and undistorted, the above figures would mean a relative movement between hatch and coaming at each corner of the hatch of approximately $\pm1\cdot3$ mm in directions parallel to the sides of the coaming and that on trials in fine weather with minimum swell relative movements of this order

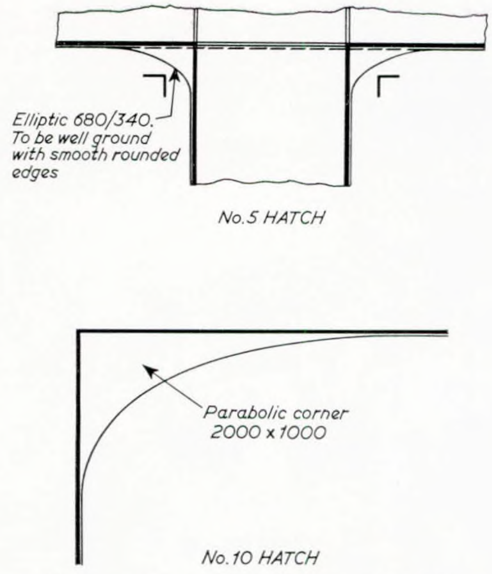


FIG. 6—*Parabolic and elliptical profiles*

were observed. It was because of the anticipated sliding motion between hatches and coamings that it was decided at the design stage to fit stainless steel compression bars to maintain a smooth jointing surface and prolong the life of the neoprene jointing material. In addition to these static tests, arrangements were made with the University of Hamburg for stress measurements to be taken under seagoing conditions during voyage 1 of *A.C.T.1.* A total of 27 strain gauges were fitted at various positions along the side girder, the lower part of the longitudinal bulkheads and on three of the hatch corners (aft end no. 10 and at the corners of the transverse box girder between nos 4 and 5 hatches). Unfortunately the sea conditions during this voyage were not particularly severe and when fairly strong winds (Force 8) were experienced the waves were of a short crested type and did not produce the worst conditions. However, the records obtained were of considerable value and did not indicate that any dangerously high stresses were to be anticipated. So far these ships have not experienced any structural cracking or failures due to stress effects.

In a cellular container ship the container guides and the supporting structure are features of the greatest importance. With containers stowed six high the total load transmitted to the ship's structure by the four corner castings of the bottom containers will be a maximum of 120 tons, or 30 tons at each point. At the point where the corners of four adjoining containers meet there will be a maximum total local load of 120 tons. The supporting structure must therefore be designed to accept this loading and the floors and longitudinals positioned accordingly. An additional complication arises in the general holds which are designed initially to carry two rows of 20 ft containers in the length of the hold but which may, at some later date, have to be modified to take one row of 40 ft containers; this will require the removal of the mid length pairs of guides and repositioning the forward guides to suit the 40 ft containers. Additional floors have therefore been incorporated from the outset under the loading points at the forward end of 40 ft containers.

The loads referred to above are static loads due to the weights of the loaded containers but allowance has to be made for the dynamic loading due to the accelerations caused by the motions of the ship, chiefly roll and pitch. When this design was made it was assumed that the maximum accelerations would correspond to the assumptions made by Henry and Karsch(2).

The most significant accelerations are the vertical ones due to pitch and roll at the ends of the ship and the horizontal and vertical ones due to roll, these affecting the wing containers to the greatest extent. These dynamic conditions are most severe in the case of the deck stow of containers, and taking the conditions assumed by J. J. Henry, of a roll of 30 degrees each side of the vertical in a total period of 13 seconds and pitch angle of 6 degrees either side of the horizontal in a period of 8 seconds, the maximum resultant vertical force at the forward outboard second tier due to rolling, pitching and heave acceleration plus the container's own weight were calculated at 1·59 × container weight and the maximum horizontal force 0·565 × container weight. The corresponding acceleration forces for containers stowed below decks were of course all lower than these figures. The manufacture and fitting of container guides presents quite a problem. In order to ensure that the containers will slide in and out freely without danger of jamming, clearances between containers and guides must exceed a certain minimum, but at the same time the clearances must be small enough to limit the possible amount of eccentricity of the containers stacked on each other since the main container strength only exists directly in line with the corner castings. Allowance then has to be made for the manufacturing tolerances of the containers both in length and breadth and along diagonals and it is found that the guides have to be positioned with extreme accuracy and also have to be held straight to within a very small tolerance. The guide angles are of 6 in × 6 in × 0·55 in section and are approximately 50 ft total length. They are supported by fabricated vertical columns which are braced transversely at each container level and are braced longitudinally at the ship's centre line and by the longitudinal bulkheads at the sides of the holds. The guides are connected to their supporting structure by flat gusset plates at approximately 4 ft spacing welded *in situ.* The method of achieving the required accuracy was to manufacture a number of dummy container jigs made to very fine tolerances, all accurately measured, complete with dowels for accurately locating one above the other and retractable distance pieces representing the designed guide clearances. The supporting pads at the tank top were first accurately levelled for all the container stacks in one hold and then the container jigs were stacked on each support position in turn. The guide angles were clamped to the stack of container jigs and were thus accurately positioned while being welded to the supporting structure. This procedure proved very satisfactory in practice but clearly very considerable effort and time is involved in producing such an extensive steelwork system at this level of accuracy.

Figs 7 and 8 give an impression of the container guides and structure.

HATCH COVERS AND CONTAINER LASHINGS

Reference has already been made to the problem of hatch cover design and of achieving the necessary strength without exceeding the limiting weight. These covers are, of course, of the pontoon type and lifted by the container crane, when removed they are normally placed on top of the hatch cover of the adjacent hold, though in some cases when only a few containers are to be moved they may be placed on the apron ashore. Special support pedestals are built into the underside of the hatch covers to permit them being landed on any horizontal plane surface. Fittings have to be provided on the top of the covers to provide the landing and securing points for the deck stow of containers and also to accept either 20 ft or 40 ft spreaders for lifting the covers. Additionally it must be possible to stow single rows of 40 ft containers or double rows of 20 ft containers on each cover, and finally lashing points must be provided for either arrangement. Fig. 9 shows a picture of the upper surface of a hatch cover on which all these fittings can be identified.

Fig. 10 shows the steel rod lashing system which was adopted and which was based on the design developed by O.C.L. with the modification that integral twist lock fittings were welded to the tops of the lashing rods thus avoiding loose fittings and enabling all lashing work to be carried out from hatch cover level for a container stow up to three containers high with resultant saving of time, and improved safety.

VIBRATION

Vibration represents a serious problem for fast ships with an all aft installation developing 30 000 shp on a single shaft.

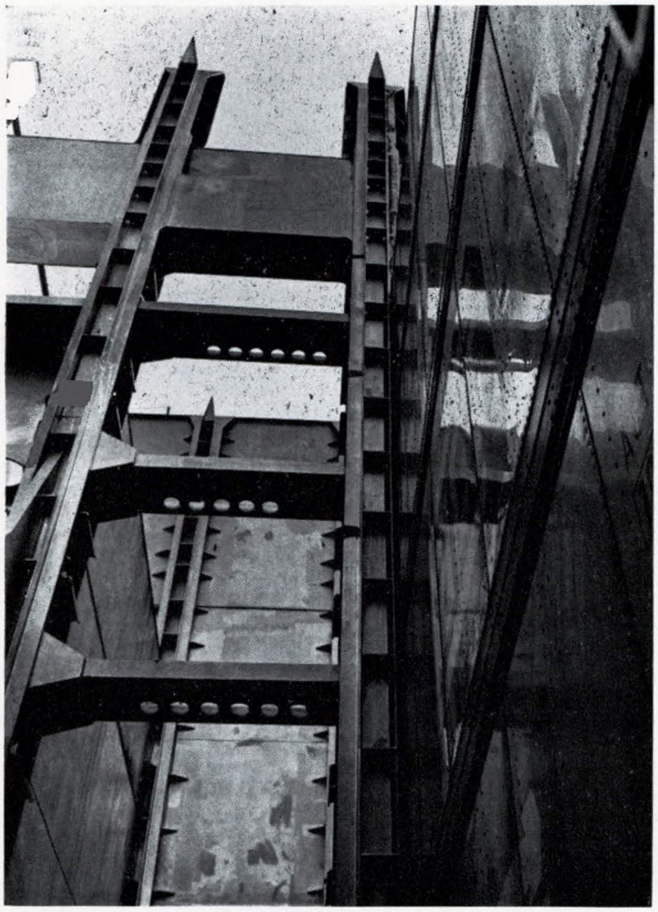


FIG. 7—*Impression of container guides and structure*

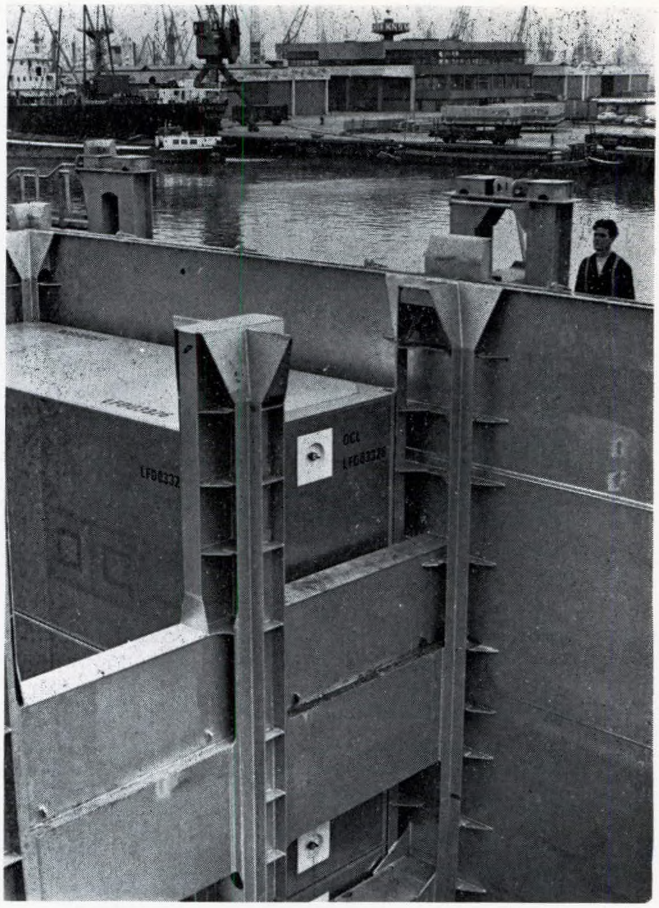


FIG. 8—*Impression of container guides and structure*

Space does not permit this subject to be covered in this paper except to say that design work was concentrated on getting as good a wake distribution as possible, providing maximum propeller clearances and also a continuous web frame structure from tank top to deck houses. Also, of course, care was taken to avoid resonant torsional or axial machinery/shafting/propeller system vibrations near the higher running speeds. Despite these precautions there was initially significant vibration at propeller speeds of 130 rev/min and upwards. Happily, it has been found possible to overcome this problem by fitting some additional vertical stiffening just aft of the main boilers.

STABILIZATION

Reference has already been made to the limiting ship motions which have been assumed when calculating the forces which may have to be carried by the guides and structure supporting the containers and by the lashings which hold the deck container in place. It is, however, important to restrict these motions as much as possible not only to safeguard the containers as a whole but also the container contents which may not always have been packed in the ideal manner. The condition most likely to cause concern is that in which the ship may be only partly loaded and have a high G.M. giving a roll of short duration with corresponding high accelerations. Calculations by the N.P.L. showed that such conditions would be significantly ameliorated by a suitable passive tank stabilization system. Two tanks were accordingly fitted at the forward engine room bulkhead below the brine room without sacrifice of container stowage. The ability to use one or two tanks and to vary the height of water in each tank gives a reasonable range of stabilization for differing conditions of loading of the ship. Service experience has so far shown the system to be satisfactory though, unfortunately, it is difficult to obtain a reliable comparison of ships' behaviour with and without the tanks in use under identical sea conditions.

MOORING

The container ship provides some special problems in the fields of mooring and of the rapid control of heel during cargo

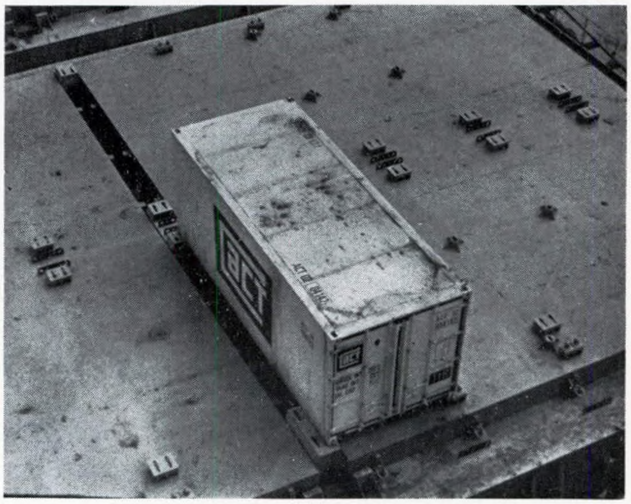


FIG. 9—*Upper surface of a hatch cover*

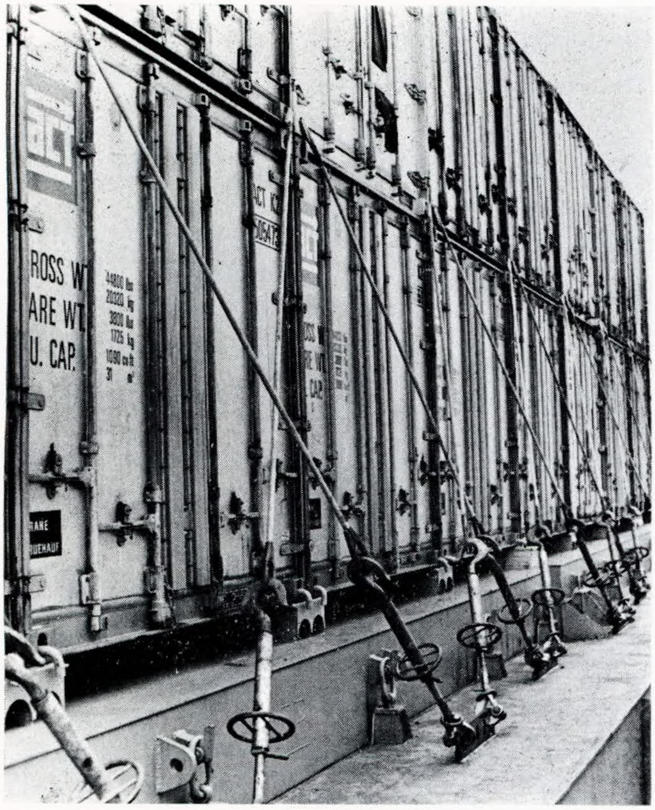


FIG. 10—*The steel rod lashing system*

handling. The designed system of container handling with a twin lift crane is first to remove a complete twin stack of containers from one side of the ship, and thereafter to load two containers and remove two containers alternately, working across the ship to the other side when a complete twin stack would again have to be removed. Assuming the containers concerned were at their full loaded weight of 20 tons each this would mean initially removing 240 tons at the extreme heeling arm, then gradually transferring this moment across the ship, and finally have a corresponding heeling moment in the opposite direction. If no corrective action were taken, and depending on the G.M. at the time, this could mean a very considerable degree of heel occurring during a period of less than 20 minutes. In order to avoid difficulties in shipping and unshipping containers the heel should be limited to a maximum of 3 degrees either way and to ensure this condition is met a ballast pumping capacity of about 500 ton/h was provided and means fitted to enable ballast water to be transferred automatically between selected wing tanks. The system incorporates a sensitive inclinometer which, using relays, starts and stops either or both the ballast pumps and simultaneously opens or closes four valves which determine the direction of pumping port/starboard or starboard/port, from the ballast main. Any of the ballast tanks can be pre-selected by remote manual control for use with this system, but normally two tanks with the greatest righting arm would be used. The arrangement has given very satisfactory results in service.

So far as mooring is concerned, the requirement is to keep the ship as closely constrained as possible to prevent movement along the quay, but at the same time to allow any lengthening or shortening of the bow and stern lines that is necessary on account of the listing of the ship due to cargo operations or any tidal effects where relevant. The system adopted, which was designed in relation to the work of the Chamber of Shipping Mooring Panel, is one providing complete restraint by three self tensioning winches at each end of the ship, two each end providing lateral restraint by bow and stern lines angled where possible at about 45 degrees to the ship's centre line, and one at each end dealing with the springs. Since the springs act in opposition, one of the winches is fixed while the other is in the auto-tension condition. 4¼ in wires are used on all winches. 7 in polypropylene ropes are used for first lines and for backing up the wires if necessary in very severe weather, they are handled by warping ends on the two windlasses and on the winches and are secured to bitts in the ordinary way. This system has so far proved satisfactory in service and capable of operation with minimum manpower.

NAVIGATIONAL CONTROL

The wheelhouse is the central control position of a ship and its equipment and layout demands the utmost care in choice and design. It is regrettable how little attention sometimes appears to have been given to this vital area in the past (the author has seen some wheelhouses in large and important ships with free-standing binnacles, telegraphs and other impedimenta scattered around like the pins on a bagatelle board), and even in modern designs one sometimes sees large consoles extending the whole width of the wheelhouse which seem difficult to relate to the control function required. In the A.C.T. ships the wheelhouse layout represents a logical development of arrangements with which the author had been concerned in several previous designs. The essential requirements are:

1) A control position right forward against the wheelhouse front giving only the essential information and facilities required for conning and controlling the ship in close water or in traffic, and providing maximum visibility;
2) A space behind the control position giving ample unimpeded passage for the whole width of the wheelhouse and out to the bridge wings;
3) Facilities on both bridge wings either for direct control of the ship (steering and engines) or for direct transmission of orders to the central control in the wheelhouse;
4) Maximum all round visibility, including if possible visibility right astern;
5) A chart table within the wheelhouse at which all the information required for navigating the ship is concentrated (Decca navigator, log, echo sounder, direction finder, navigational radar, master compass, chronometers, etc.). There should also be good visibility from the chart table position at least from right ahead to either beam so that the navigator is at all times in close touch with the actual situation.

Fig. 11 gives a general impression of the wheelhouse in A.C.T. showing the forward console incorporating main engine control, non follow-up electric steering control and auto-pilot, with compass repeater, rudder and helm indicator, revolution and direction indicator, echo sounder repeat, whistle control

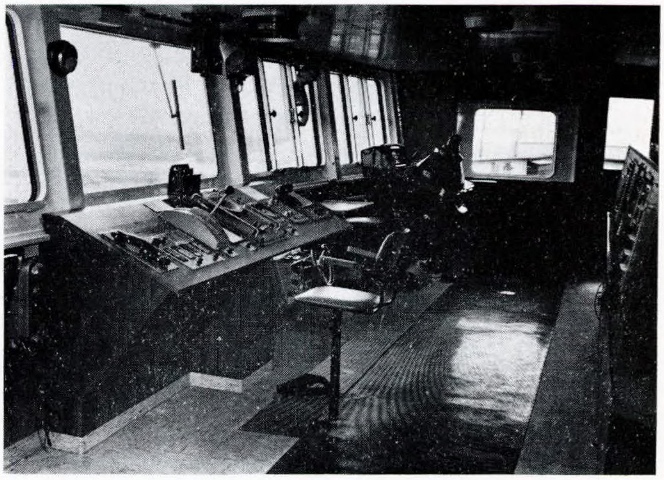


FIG. 11—*General impression of the wheelhouse in A.C.T.*

and vhf telephone, and on the starboard side the conning radar and semi-automatic plotter. The arrangement is such that one man can and does physically control the ship in close waters, both operating the main engine control and steering the ship with non follow-up steering control.

FIG. 12—*General impression of the wheelhouse for an earlier twin screw ship*

Fig. 12 shows a similar layout for an earlier twin screw ship also arranged for one man to control both engines and steering, in this case the steering being by foot pedal, with an alternative hand control. In both cases the information for conning and the size of console has been kept as small as possible, redundant information or excessive size in this position merely serves to confuse and mask the really important things and renders control less effective.

REFRIGERATION

There are several ways in which refrigerated cargo might be carried in containers in ships:

i) Each container to be self contained with its own refrigerating plant which would be connected to ship's power supplies;
ii) Insulated containers to be connected to individual 'clip on' refrigerated units;
iii) Insulated containers to be stowed within a refrigerated hold with arrangements for circulating air through the containers;
iv) Insulated containers to be stowed in non-refrigerated and lightly insulated holds and connected to a closed system of cold air circulation through permanently installed trunks and coolers served by the ship's main refrigeration plant.

For relatively small numbers of containers methods i) and ii) are practical and were used on the earlier container services operating from the U.S.A., but for really large quantities of refrigerated cargo such as are transported from Australia and New Zealand this arrangement would be hopelessly uneconomic, and would involve serious practical difficulties. If carried on deck and subject to ambient tropical temperatures and direct sun's rays the total refrigerating power required would be very large, the condition of the cargo in each container would depend on the reliability of its individual unit, and to duplicate the units would be very expensive, all containers would need to be centrally monitored, and arrangements for access to the refrigerated units would have to be provided. Repairs at sea would be difficult or impossible in adverse conditions, and these conditions would in themselves tend to reduce the reliability of the units. If containers were carried under deck, provision would have to be made to absorb the considerable amount of heat involved either by forced ventilation on a considerable scale or by water cooling of the refrigerating unit condensers, and the dangers of the latter course are obvious.

If, therefore, cellular container ships are required to carry regularly large quantities of refrigerated cargo the use of a centralized refrigerating plant permanently installed in the ship represents the most economical and reliable system to adopt. While method iii) would be a possible solution it would involve the expense, weight and space of heavy insulation of the holds, similar to that in conventional refrigerated ships, and would subject all the exposed steelwork of guides and supporting structure as well as the container corner castings and strength members to very low temperatures. This would be highly undesirable, involving use of special steels and danger of ice formation during discharge with its attendant difficulties. Also, there would still be the need to arrange for a definite air circulation through each container to ensure even cooling and proper control of temperatures.

Consideration of the above factors led inevitably to the decision by both O.C.L. and A.C.T. to use method iv) for the cellular refrigerated container ships designed for the Australia/U.K. service, and a similar system will be employed for the cellular container ships at present on order by these two consortia for various trades serving Australia and New Zealand. The details of this system will now be more closely examined.

The first main problem that had to be considered was that of arrangement of coolers and air ducting in relation to the massive stiffening required on the transverse hold bulkheads. The objects were to keep the holds as short as possible, while maintaining good access to all containers, and to confine insulation so far as possible to plain surfaces. The arrangement of coolers and ducting for the A.C.T. ships is shown diagrammatically in Fig. 13 and it will be seen that coolers are accommodated in wing compartments immediately beneath the side passages, and air is distributed by main vertical supply and return trunks to each level of containers, and by horizontal trunks to the different containers at each level. The bulkhead stiffeners are contained between twin bulkheads (one of which is watertight) forming cofferdams extending the full height of the holds, and in this way only plain steel surfaces are presented within the hold itself. The cofferdam spaces are used for hold access.

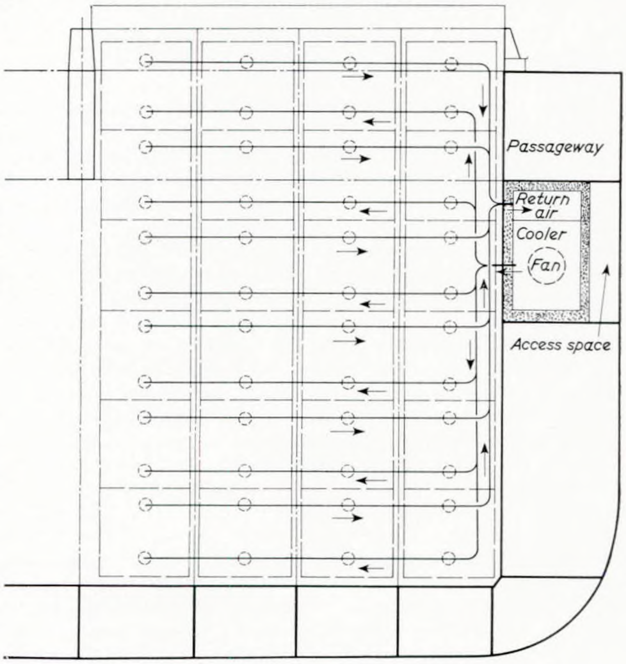


FIG. 13—*Diagram of air trunk layout*

With this system each main hold is served by four coolers, each cooler therefore supplies one quarter of the number of containers in the hold, i.e. 24 in the largest holds. It is clearly essential with the number of circuits in parallel, to ensure approximately equal air flow through each container, the designed flow being 40 air changes/h.

It is not possible without very expensive instrumentation to monitor the air flow to individual containers when connected and therefore the flows were balanced when discharging to an open hold; the errors involved in this are less than might be supposed since experiments with containers carried out by S.R.C.R.A. showed that the total air pressure drop within the container with the internal air distribution arrangements as finally fitted amounted to only about 0·6 inches of water against the total air pressure drop across the fan in the ship system of 3·0/3·5 in. Any imbalance of air distribution within the ship system as found initially was corrected by insertion of deflector plates into the main branches of the air trunks as required and the final air quantities as tested in the open hold were correct to within small limits.

It cannot, of course, be guaranteed that a full outfit of refrigerated containers will be connected to each air cooler during any homeward voyage and it was therefore a requirement that the system should be operable and stable with as few as three containers out of 24 connected and the remainder blanked. This imposed a considerable problem of fan design since the reduced flow had to be accommodated without the fan stalling and without excessive air pressure being produced which would impose undue cost of air trunking. The requirements were met by using a mixed flow (combination of axial/centrifugal) type of fan and by fitting a flap relief valve between supply and delivery trunking design to limit the maximum discharge pressure.

The next major problem is that of coupling the two openings arranged in one end of each container to supply and return trunking installed in the ship. With a loading/discharge cycle of three minutes for every two containers out and two containers in, and a total of 660 connexions involved (much larger numbers in later ships) it was obvious that it would not be practical or economic to do the job manually and that some form of automatic coupling would be required. In the first instance separate ideas for coupling design were being developed by O.C.L. and A.C.T., but, as it was essential that the containers should be standard, it was decided to develop common design for both consortia, and the Shipowners' Refrigerated Cargo Research Association was entrusted with this task, working in collaboration with owners and contractors and basing the design on the O.C.L. proposals which appeared the more promising.

Fig. 14 shows the couplings as finally installed, and Fig. 15 shows a sectional view. A double lip seal operating against a flat facing on the end of the container forms the actual joint, which is maintained by the pressure of two springs, the coupling is retracted pneumatically and a separate pneumatically operated device will latch it in the retracted position. The twelve couplings for each vertical row of six containers are operated simultaneously by a single three-way cock from the mid level platform in the hold. In order to deal with part refrigerated container cargoes it is necessary to be able to shut off air circulation from complete vertical stacks of containers or even individual containers and in the A.C.T. ships this is done by interposing horizontally sliding steel plate shutters between the containers and the retracted couplings (see Fig. 14) and then releasing the couplings on to the shutters when they have been slid into place. These shutters also provide an additional safety feature in that no container movement into or out of the hold is permitted unless the shutters are in place, and any danger of coupling damage during container movement is positively prevented. Each vertical stack of sliding shutters is operated simultaneously by a continuous wire system, but individual shutters can be disconnected and operated separately if required.

It may be thought that the coupling mechanism described is reasonably straightforward but when it is appreciated that the containers can move up to 44 mm fore and aft and 28 mm athwartships in the guide clearances—and do in fact move in a

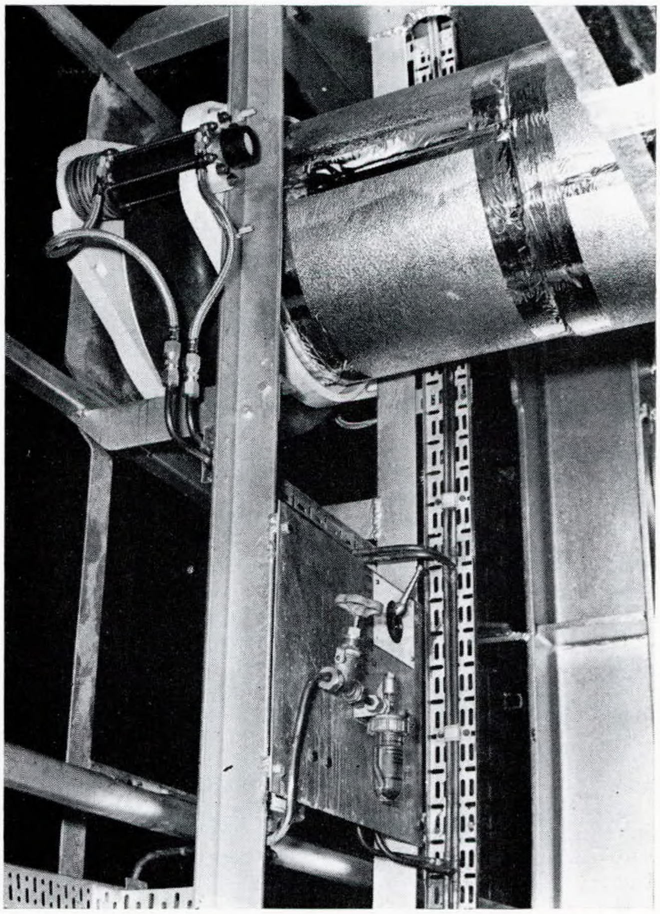


FIG. 14—*The couplings as finally installed*

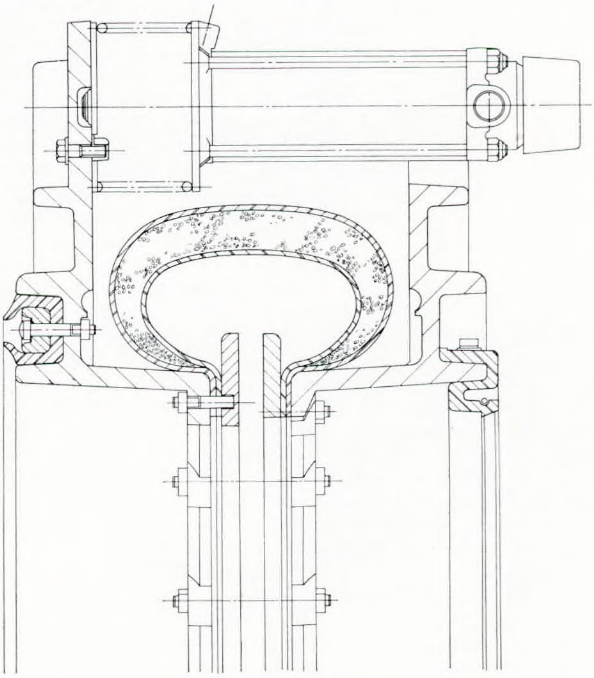


FIG. 15—*A sectional view*

seaway, that leakage of cold air past the seal would give severe icing problems, that the operating mechanism needs to be insulated from low temperatures to avoid icing, and that absolute reliability of operation is essential, the problem will be seen to be less simple. A special rig was set up by S.R.C.R.A. simulating the possible container movement and with cold air circulating to prove the tightness of the seal, and the durability and insulating properties of the flexible element using Neoprene and E.P.D.M. diaphragms with polythene foam insulant. The couplings (and the container closures referred to later) were also subjected to rigorous environmental tests covering vibration and corrosion.

The next problem is that of insulation of the holds. One of the features of carrying refrigerated cargo in the relatively small spaces represented by individual containers is that the ratio of surface area to volume is much greater than in the large holds of conventional refrigerated ships. If therefore the container ship holds were uninsulated the heat leakage would be relatively large and an expensive refrigerating plant would be necessary. If, on the other hand, the holds were heavily insulated the temperature in the holds would approach more closely that of the cargo and would certainly lie below freezing point with low temperature cargoes, with the disadvantages referred to earlier. The requirement, therefore, is a compromise whereby the hold insulation is sufficient in series with the container insulation, to cut down the overall heat leakage to a reasonable figure while leaving the temperature in the hold itself normally above freezing point. However, the cargo may have to be carried at −10°F (−23°C) and the ambient temperature will vary between 95°F (35°C) and 32°/40°F (0°/4°C) and it is obvious that we cannot maintain the hold temperature above 32°F (0°C) in all circumstances unless subsidiary arrangements are provided. In the A.C.T. ships this was done by providing 'hold conditioners' in the form of heat exchangers, fans and trunking to circulate air within the hold, and which could be used as heaters, with hot brine, or subsidiary coolers as required. These hold conditioners are used as required to maintain an optimum hold temperature of 35°/40°F (2°/4°C). One of the uncertain factors, when introducing this system of container refrigeration, was the extent to which cargo temperatures would vary according to the position of the container in the hold and whether it would be necessary to provide positive circulation of air round the containers to minimize any differences. The whole question of heat transfer in the hold/container system was investigated by S.R.C.R.A. using an analogue computer simulation, which provided data in relation to hold insulation thickness and also indicated that while variations would not be unduly large it would be prudent to provide some means of air circulation, and the hold conditioners fulfil this role.

It was calculated that in order to produce optimum temperature conditions in the holds for as wide a range of circumstances as possible an overall heat transfer coefficient of 0·25 to 0·30 Btu/h °F ft^2 of exposed surface area was required and this would be met by the use of 2 in thickness of polyurethane slab material faced with aluminium foil glued and pinned to the plain surfaces of the bulkheads. The air trunks were insulated with 4 in thickness of polyurethane slab, aluminium foil covered. In this application the low conductivity and light weight of polyurethane together with ease of application showed to definite advantage, weight and space being particularly important in these container ships.

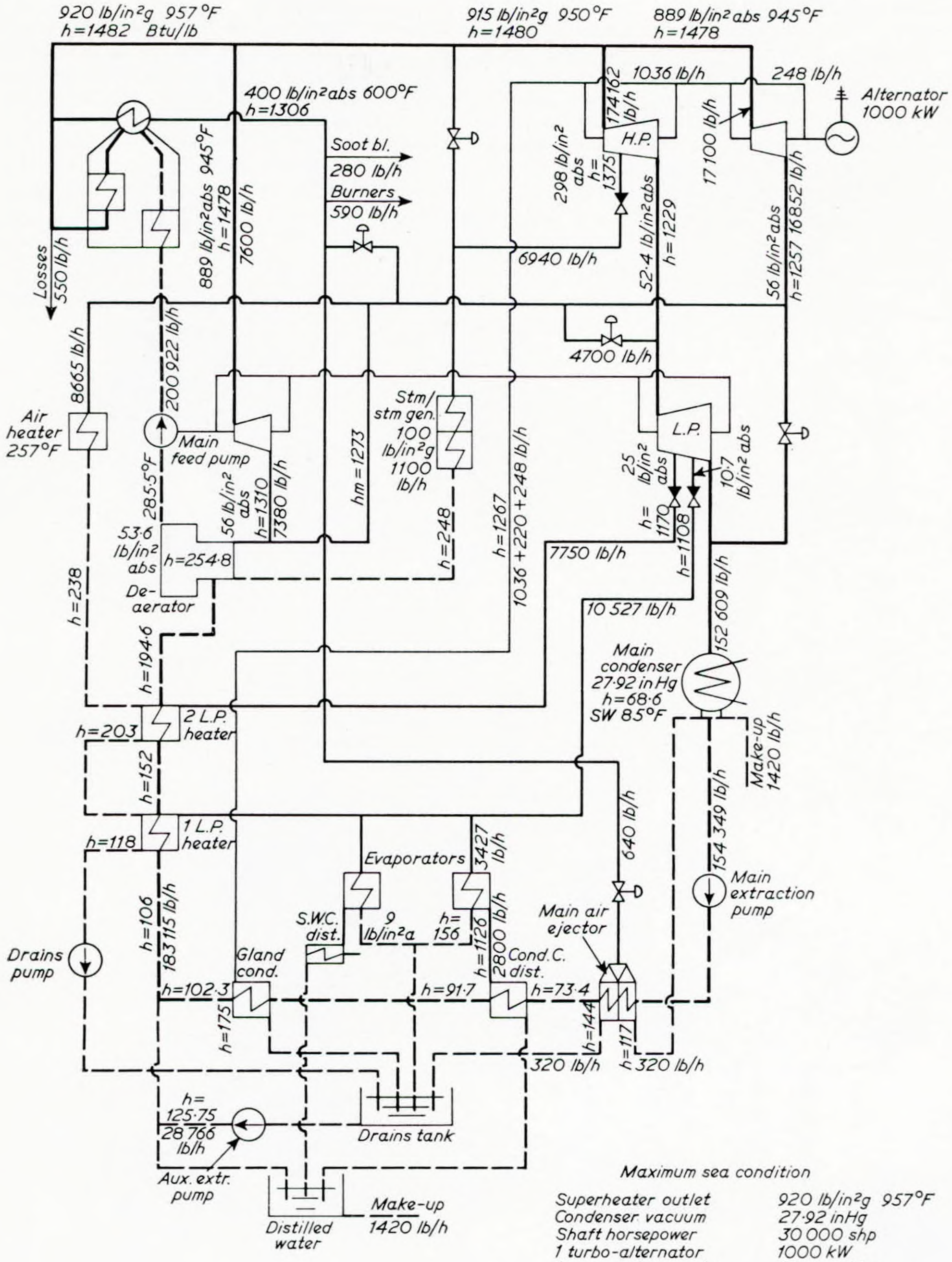
So far no mention has been made of the arrangements within the containers themselves to ensure proper distribution of air flow through the cargo with a minimum air pressure drop. Extensive full scale experimental work was carried out by S.R.C.R.A. on this problem and the final arrangement provided 10 in diameter air supply and return holes on the centre line of the container at the end opposite the doors with a divided internal air screen covering the whole end of the container and 5 in from the inside of the insulation supported by splitters giving air distribution across the width of the container, the air then flows along the container between slotted 'T' bar aluminium dunnage and finds its way up through the cargo to a plenum space at the top whence it finds its way back to the return opening. Various forms of construction and materials have been used for insulated container manufacture, but the internal arrangements have been standardized in the manner described. Whenever containers are being transported and are disconnected from a refrigerating plant the air supply and return openings must be sealed to prevent undue rise of temperature and damage to the contents. Special spring loaded valves operable from outside the container and capable of being positively secured in the closed position and spring loaded for the open position have therefore been fitted as an integral part of all insulated containers.

The refrigerating plant itself follows conventional lines and in this case consists of five eight-cylinder reciprocating compressors using Freon R.22 as refrigerant, two of the machines for single stage operation, two, two speed machines for compound or single stage operation, and one single speed machine for compound or single stage operation. Automatic unloading gear is fitted on one of the single stage and two of the compound machines. The plant is designed to maintain approximately one quarter of the containers at −10°F (−23°C) and the remainder at 0°F (18°C) when the ambient air temperature is 95°F (35°C) and sea temperature 90°F (33°C). Four brine mains (low temperature, frozen, chilled and heating) are fitted and provided with automatically controlled injection from lower to higher temperature mains. Automatic control of air temperatures is effected by pneumatically operated modulating valves in the brine returns from the coolers. The set points for air and brine temperatures are all remotely controlled from the refrigerating control station. A data logging system for temperatures only is provided covering brine mains, individual brine returns from each cooler, delivery and return air temperatures at each cooler, individual air outlet temperatures from each container, evaporator inlet and outlet temperatures, air temperatures, ambient and sea water temperatures. All this represents conventional modern practice but the requirement for monitoring and logging the return air temperature from each container means a large data logging installation.

Consideration was given to the use of screw compressors in lieu of reciprocating ones but these show to greater advantage for larger installations and would have resulted in significantly greater cost in this case. In future ships with much greater refrigerated capacity screw compressors will be used.

MACHINERY INSTALLATION

The choice of a machinery installation depends not only on the power required and the type of ship in which it has to be fitted but essentially on the service on which the ship is to be employed. In the case of the A.C.T. container ships the defined service required operation on an exact time schedule between one port in the U.K. and three ports in Australia, with turn round times not exceeding 48 hours in Australia and four to five days in the U.K. This schedule was to be maintained throughout the year except for 14 days per year for docking, repairs and outstanding surveys. 30 000 shp was required to ensure the continuous seagoing speed of 22 knots, and an aft end position for machinery was desirable to achieve maximum container stowage in a given size of ship and to provide uninterrupted space for container handling. The only possible systems which could be considered at the time were the geared steam turbine and the direct drive Diesel. The power required was at the extreme range of powers of the Diesels then available, and in fact was beyond what could be achieved with the customary prudent reduction of engine manufacturers' ratings, and even then would have involved either a sacrifice of some 70 containers or at least 25 ft increase in the overall length of the ship. Added to this the shaft speed would have had to be limited to 119 rev/min which, it was considered, would have introduced propeller design problems due to the restriction on diameter imposed by depth of immersion and propeller tip clearances. Finally, it was considered that with the rigid scheduling required for this service the maintenance problem for a twelve cylinder main engine and for the considerable Diesel alternator capacity required would be greater than for a steam installation. The above considerations led to a decision in favour of geared steam turbines and after careful consideration of alternative types available the Stal-Laval A.P. type was adopted. The emphasis on the need for maximum



Maximum sea condition

Superheater outlet	920 lb/in²g 957 °F
Condenser vacuum	27·92 inHg
Shaft horsepower	30 000 shp
1 turbo-alternator	1000 kW
1 evaporator cond. c.	30 tons/day
Steam/steam generator	7100 lb/h
Fuel gross calorific value	18 500 Btu/lb
Preheated air	257 °F
Heat content air	608 Btu/lb
Boiler efficiency	0·883
Fuel consumption	14 595 lb/h
Fuel rate	0·486 lb/shp h

FIG. 16—*The heat balance for maximum service power*

reliability, not just of one ship but of a whole service, precluded anything experimental and steam conditions were limited to the latest accepted practice, namely 900 lb/in² 950°F (515°C). Similarly it was desired to keep the steam and feed cycle as simple as possible, compatible with a good steam rate while avoiding the excessive complication which would be involved in securing the highest possible efficiency.

The heat balance for maximum service power is shown in Fig. 16. It will be seen that back pressure turbo alternators are employed and these, together with the turbo feed pumps, provide all the steam required for the de-aerator and steam air heaters with a significant surplus which is passed in to the L.P. turbine. The overall fuel rate at the normal service power of 28 000 shp with 28·5 in vacuum, one evaporator at 30 ton/day and 1050 kW of electric load is approximately 0·48 lb/shp h which can be considered satisfactory.

While the plant is of relatively conventional type certain features may be worth individual mention:

a) *Scoop Circulation of Main Condenser*

The rival merits of scoop circulation against circulating pumps are very difficult to determine, since the additional propulsion resistance offered by the scoop cannot be very accurately assessed. The use of the scoop does, however, avoid the need for continuous operation of a main circulating pump at sea and reduces the total electric load. The auxiliary pump, which must be used below a certain speed, can be designed for reduced water flow and only needs to be run for limited periods while raising steam, standing by and entering and leaving harbour. On the other hand the pump should be arranged to cut in automatically below certain shaft rev/min and interlocks must be arranged to prevent speed being increased above these rev/min, again until circulation has been changed over to the scoop.

Careful tests were carried out at the Berlin and Hamburg tanks to determine the optimum positions for scoop entry and overboard discharge, based on measured water pressure distribution round the hull sections at service speed, and the optimum scoop profile and effect of discharge lip. As a result of these tests the scoop entry and overboard discharge were placed at the positions shown on Fig. 17. In view of the importance of discharge lip height on the water flow it was decided to provide on the first ship a variable height lip operated by screw mechanism from within the ship to obtain measurements during trials which could be related to the results of model tests. The results of the full scale tests indicated that if the lip was entirely omitted the circulating water requirement for full power tropical conditions would only marginally be met and it was therefore decided to fit a permanent lip 4 in deep on the discharge.

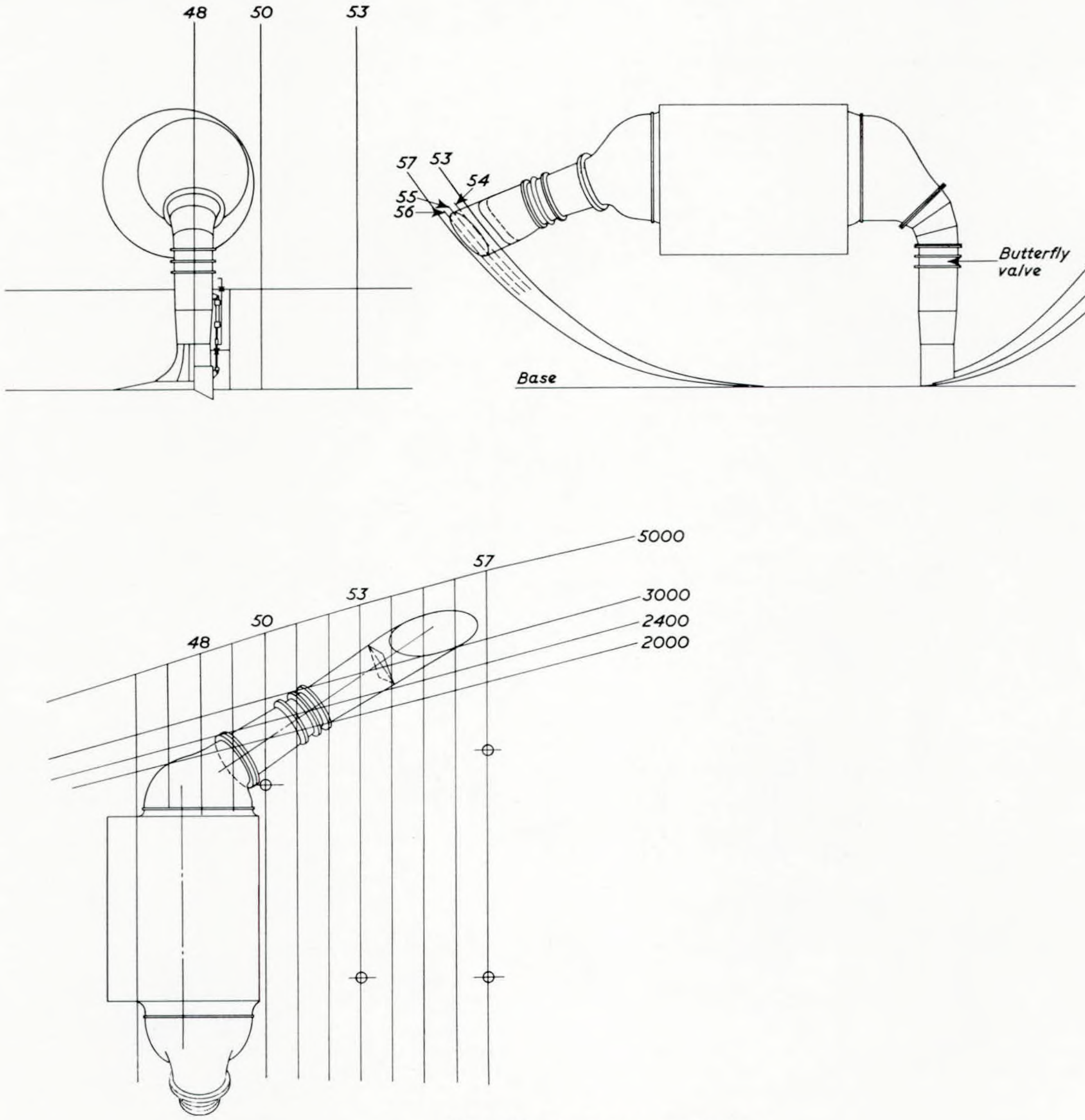


FIG. 17—*Arrangement of scoop*

b) *Electric Generating Plant*

In any refrigerated ship the possible maximum load imposed by the refrigerating plant under extreme conditions represents a high proportion of the total ship's load, but in general refrigerated cargo is carried in one direction only. Also there will be a wide variation in the refrigerated load from cooling down of a full cargo which is embarked under conditions of high ambient temperature, and is to be carried at minimum temperature, to the holding load under temperate conditions for a part cargo which is being carried well above the minimum temperature. The electric generating plant must be capable of meeting the worst possible conditions, but if, say, a 50 per cent margin of capacity were provided above such conditions the result would be great excess of capacity over that which was likely to be required during the normal service of the ship. Because of the operating schedule for these ships, it was considered that the steam plant would normally be kept in operation at all times except during the four to five days turn round at the home terminal when the plant might be shut down for repair or maintenance work after the discharge of refrigerated cargo. The main generating plant would therefore be steam turbo alternators with Diesel alternators in a supporting and emergency role.

The maximum total load while cooling down a full refrigerated cargo at sea was estimated to be just under 1600 kW (including 800 kW refrigerated). The maximum tropical load at sea when holding the temperature of a full refrigerated cargo was estimated at about 1300 kW (including 550 kW refrigerated). It was decided that one turbo alternator (of 1360 kW capacity) would normally be able to carry the sea refrigerated tropical load, and that there should be two identical machines thus providing 100 per cent standby under these conditions without using the Diesel alternators. If the maximum possible load was required at any time then it would be necessary either to run both turbo alternators or to supplement one turbo alternator with a Diesel alternator; it was, however, expected that such occasions would be infrequent and of relatively short duration. The Diesel alternators serve several purposes:

1) To provide sufficient capacity to run the whole ship's load, excluding refrigeration, in port whenever it was decided to shut down both main boilers;
2) To provide sufficient power immediately available in emergency, in the event of a blackout, to run all essential engine room auxiliaries and ship services and enable the situation to be brought under control pending restoration of the steam plant. In the author's experience there is no greater comfort to the chief engineer of a steam ship than to know that he has adequate Diesel generator capacity always immediately available, there is nothing worse than to have only steam plant—and no steam !
3) To provide supplementary power to the main turbo alternator if the load is only marginally greater than can be carried by one machine.

A high speed type of Diesel generator is ideally suited to the above requirements since it is cheap in first cost, its total running hours should be relatively small, it can be kept ready for immediate use, remotely started and connected to the board in a minimum of time and without warming or special preparation and it takes up the minimum of engine room space. Two generators of 410 kW capacity running at 1800 rev/min were installed and have proved invaluable for the purposes intended particularly during the early running of the ships when there have been above normal requirements for shutting down the steam plant for examinations and making good of the inevitable 'teething trouble' defects.

c) *Control and Automation*

From the onset these ships were designed for a manned engine room with one officer and one rating on watch. No watch is kept on the refrigerating plant but master refrigerated plant alarms are repeated at the main control room. The control philosophy was that all main systems would be self-operating under full automatic control both under steady state and manoeuvring conditions, with the main engines under bridge control. Vital auxiliaries such as feed pumps, lubricating pumps and extraction pumps have a standby fitted with auto self start, while other units including the Diesel generators are provided with manual remote control. Intermittent operations such as fuel transfer, pumping bilges, etc., are carried out manually by the watchkeepers. The main machinery systems and units such as evaporators are brought into operation manually but once connected and in use, function automatically. Bunkering and ballast systems are operated manually using centralized remote control. There is a comprehensive monitoring and alarm system centralized in the control room with master alarm repeats at strategic positions in the engine room and steering gear compartment, so that when the watchkeeper is absent from the control room on his routine inspection of machinery, or for other reasons, he will know immediately if a fault condition arises and will return to the control room to deal with it. It is *not* intended that the watchkeeper should spend all his watch in the control room. The control room itself, although enclosed, sound insulated and air conditioned, is regarded essentially as part of the engine room and is situated as centrally as possible and close to the steam driven units which have to be manually restarted in event of failure, i.e. turbo alternators and evaporators. The arrangement of the control console is shown on Fig. 18 and shows that it has been kept as short as possible and in three distinct sections, main engine control and systems central section, boiler control and instrumentation port section and auxiliary machinery starboard section. The switchboard faces the control console and subsidiary functions such as the bunkering station are kept well clear at one side of the control room. This arrangement gives maximum control ability and the greatest amount of logically arranged information to the watchkeeper from a central position.

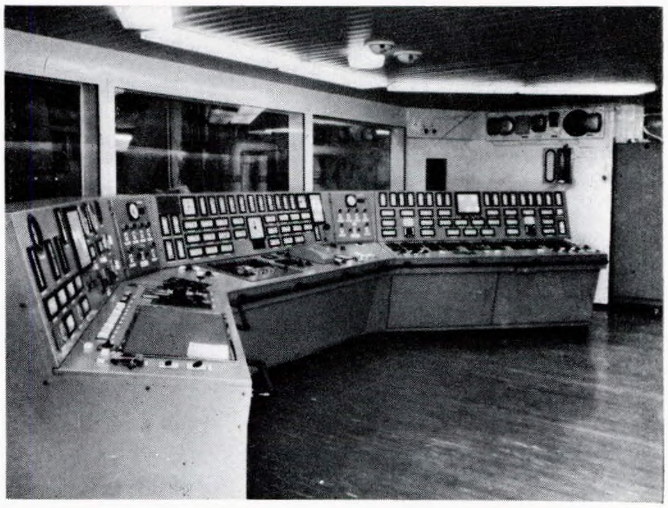


FIG. 18—*Arrangement of the control console*

The refrigerating machinery control station, together with its group switchboard, remote controls, instrumentation and data logger are all situated on the flat above immediately adjacent to the refrigerating machinery. This plant is under the control of the daywork refrigerating engineer but as previously stated a refrigerator master alarm is incorporated in the main control room alarm panel to alert the main watchkeeper in the event of a fault.

The bridge control system is an electronic one coupled to the turbine designer's standard electro hydraulic control of the main manoeuvring valves. The system is necessarily much more elaborate than that required for Diesel machinery, incorporating as it does programmed rates of increase and decrease of power, provision for movement of the engines ahead and astern automatically every two minutes to prevent rotor distortion when stopped or standing by, provision for overriding action in emergency, etc. The boiler controls and the automatic controls in the steam, back pressure and feed systems are pneumatically operated, and a pneumatic system is used for remote controlled valves on the oil fuel and ballast systems.

OPERATIONAL EXPERIENCE

Generally speaking it can be said that these ships have fulfilled all the design intentions, and in particular the novel features of container stowage and handling, and the refrigeration arrangements have been extremely successful. There have, of course, been various operational problems during early service and reference has already been made to vibration. There have also been machinery problems but these have mostly been in the nature of teething troubles and have not been such as to have any significant effect on the operating schedules of the ship. They included one case of L.P. turbine blade failure, due to a nozzle excited resonant vibration, which fortunately involved no consequential damage, and was capable of fairly simple rectification by replacement of one diaphragm by a new one with a different number of nozzles. Disposal of back pressure steam under standby manoeuvring or slow speed conditions has also posed something of a problem since there was a tendency to erode main condenser tubes and to overheat the L.P. eduction pipe with possible effect on turbine clearances. At the same time the auxiliary condenser was not entirely adequate, but design modifications have now been made to overcome this problem.

CONCLUSION

This paper has been written from the point of view of one who has to take an overall view of ship design as well as dealing in some detail with the particular problems arising in widely different design areas. The aim has been to place on record some of the particular problems and features in the design of cellular container ships in the hope that they may prove of some interest, not only to other designers, but also to those whose duty is to operate and maintain the ships. The author apologises for lack of reference to the extensive and important electrical installation, this omission is not due to any lack of material but simply because to include it in any worthwhile fashion would exceed the permitted length of the paper.

ACKNOWLEDGEMENTS

The author wishes to thank the Cunard Steam-Ship Co. Ltd. and Associated Container Transportation Ltd. for their permission to publish this paper, and also to thank his colleagues in Blue Star and Ellerman Lines, and Cunard International Technical Services, the Directors of Bremer Vulkan Ltd., and the Technical Director of the Shipowners' Refrigerated Cargo Research Association for their help and advice in the preparation of the paper. The opinions expressed are however attributable solely to the author.

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Discussion

MR. M. D. PENNEY A.M. of Council R.I.N.A. said Table I compared A.C.T. and O.C.L. Bay Class designs and showed the principal differences between the ships. In the footnote the author mentioned that the O.C.L. total container capacity was being increased; this would stand at 1522 when modifications to carry 12 across on deck were complete. The O.C.L. ships carried containers four high in the 11 after sections, visibility preventing them from carrying four high further forward. The carriage of containers this high presented no difficulties *vis a vis* the stability and was a justification for the 5 ft extra beam of the O.C.L. Bay Class ships.

The author referred to the flip-flop mechanism at the lead in to the container guides. Prior to the ships entering service there was some apprehension amongst ship operators and managers about the practicability of such a device. Certainly the first prototype produced well before the commissioning of the first ship, was not strong enough to stand up to the normal working of containers, but a subsequent stronger design had proved very satisfactory in service and given no trouble. The simple hydraulic machinery for moving flip-flops had proved satisfactory.

Vibration had been a continuing problem in the Bay Class ships and various steps were now under way to reduce it. What had been the reduction of the vibration in the A.C.T. ships resulting from the modifications mentioned?

Regarding mooring arrangements, both O.C.L. and A.C.T. ships were similar, and apart from the very early days when ships' companies were not fully aware of the characteristics of the mooring equipment, in O.C.L. ships the winches have proved very satisfactory. The cable lifters were incorporated into the self-tensioning winches, thus saving motors and machinery and providing four 4 in multi-directional wires at each end. The first line capability—using nylon bar rope—was also incorporated in a tensioning winch at both ends; the ships were worked satisfactorily with an officer and four seamen at each end.

With reference to the comments on structural features, D, E and EH grade steels were used successfully in O.C.L. ships following a schedule of welding procedures tightly controlled by the staff of Ocean Fleets Ltd. Problems in handling these steels might be more acute if repairs—particularly large repairs—had to be carried out at minor repair yards.

The author gave an interesting account of the strain gauge experiments; a large number of these had been carried out in O.C.L. vessels on a continuous basis. Could the author explain why experiments were discontinued before the worst conditions had been experienced? Might there be a case in ships of this type for permanent strain gauges to be fitted with indication on the bridge when nearing the limits of stress?

It was thought that at present, there was insufficient experience with refrigerated containers to know with certainty whether the system adopted in both O.C.L. and A.C.T. ships was the best expedient, or whether the degree of flexibility of temperature control per container and taint proof subdivision was the best possible. O.C.L. and A.C.T. ships varied slightly in this respect, and a little more experience was necessary before a full appraisal could be made.

DIPL. ING. H. H. ERLENWEIN disagreed with the author on the arrangements intended for the A.C.T. ships now under construction, regarding the incorporation of the sides of the hatch coamings into a continuous longitudinal girder continued over the whole length of the holds and accommodation.

MR. A. PAXTON M.R.I.N.A. asked the author to comment on the difficulties so far experienced in loading the containers on the fastenings on the hatch covers.

Regarding vibration, what was the number of blades eventually selected for the propeller, and what precautions were taken to ensure that the number so chosen avoided resonances of the natural vibration?

Much had been said about the various types of stabilizers. What correction would it be possible to make in the stabilization system to allow for variation in the G.M. of the vessel? What was the effectiveness of the stabilization system when the ship met heavy seas on one of her stern quarters? It was presumed that a loading plan was prepared to indicate the way containers were to be loaded on board to ensure they were in the right position for discharge, as well as to show the effect on the G.M. of the ship.

The author claimed that the system was designed to be capable of carrying a variety of refrigerated cargoes. How many types of cargo could be carried in any one vessel and at what variation of temperatures?

Reference was made to the electrical loading considered in conjunction with the refrigeration. In this connexion, did the cooling down of the cargo to its carrying temperature take place before the container was received on board? If the cargo had to be cooled down from atmospheric temperature after loading in the ship, what period of time was envisaged for this operation?

With reference to taint, it would be interesting to know how this was controlled between containers carrying different cargoes, and how the containers themselves were cleared of taint between unloading and loading operations.

Were ozone generators fitted to the ship in the air cooling system?

In the conventional type of refrigerated ship on the Australian trade, arrangements were made for the carriage of chilled meat. Were such provisions now made in containers? If so, was the meat hung, and what steps were taken for the sampling of the CO_2 content and for the injection of that gas when required?

Certain fruit required continuous monitoring of temperatures to ensure only a small variation plus or minus; what steps were taken to achieve this? It seemed impossible to monitor exactly the amount of fruit carried in each individual container and it would be valuable to know how this difficulty was overcome. With the carriage of fruit, the problem of CO_2 sampling arose. Was the CO_2 content ascertained from the return air duct or from some other means of monitoring each container? Was there any method of varying the number of air changes to suit different cargoes? The minimum temperature of cargo being specified, was there a maximum for the carriage of certain fruits?

On a recent American ship, a flush deck configuration had been designed without hatch coamings for the whole length of the ship. Had this configuration been considered at an early stage of the design of these vessels? Did the author envisage that the advent of containers would eventually preclude the use of conventional refrigerated vessels on Australian service?

Has the author considered the carriage of bananas in containers?

Mr. J. R. Stott, M.I.Mar.E., noted the similarity between O.C.L. and A.C.T. ships regarding refrigeration design.

The author had stated that the coolers were placed at the sides of the refrigerated holds with a resultant saving in length. Comparing the drawing by Meeks(1) there would appear to be little saving in length in the refrigerated holds but what did emerge was the tremendous difference in length of the engine rooms. The coolers were not placed in the wings on the O.C.L. ships because that space was required for tanks. Although the author had pointed out this difference in cooler position as being a main one between the two classes of ships, it was only a matter of layout and of no fundamental significance.

He thought the use of the word optimum, where the author had claimed that the insulation fitted to the holds gave optimum temperatures, should be qualified by the statement that this was the optimum temperature for a ship built largely of ordinary mild steel. In the early stages of the design of O.C.L. ships it was considered imprudent to have a ship with insulated holds of ordinary mild steel, as the safety of the ship would at times depend on the correct functioning of heaters fitted in the insulated holds. Accordingly, it was decided on these vessels to use special quality steel suitable for low temperatures in way of the insulated holds. This obviated the requirement of the A.C.T. ships to maintain hold temperatures above freezing point at all times, and it became feasible to insulate the holds to a higher standard. This was carried out on O.C.L. ships so that the heat leakage into a hold was about 55 per cent of that into a corresponding hold on A.C.T. ships.

With forced air cooling of refrigerated cargoes, as used in these vessels, there was a relationship between heat leakage and weight loss of cargo: the lower the heat leakage the lower the weight loss. In assessing optimum insulation weight loss considerations could not be ignored. Although the insulation standard of the A.C.T. ships was a reasonable compromise, it should not be unquestionably accepted as the optimum for future ships.

The author had said that screw compressors would have been more expensive if provided for A.C.T. ships. One was confronted with the problem of intrinsic cost as compared to the buying price. Screw compressors were used on O.C.L. vessels and a manufacturer was able to provide them at the same price as the conventional reciprocating compressors.

Regarding electrical capacity, it was stated that the estimated load was 800 kW for cooling down cargo at sea and 550 kW for cooling refrigerated cargo through the tropics. On O.C.L. ships an estimated load for cargo in the tropics was about 450 kW and this was the maximum provided for the refrigerated installation. The higher figure of 800 kW (putting all the refrigeration plant on together), which endeavoured to cool down the ship and all containers simultaneously, was not considered, as this was a condition not met in practice.

Mr. T. Kameen, M.I.Mar.E., had been associated with a fleet of Ro/Ro container ships and met many similar problems. Inevitably solutions had been different. He asked the following questions on the author's paper:

a) had the design speed been achieved in service, and if so, had this proved adequate for the schedule?
b) was consideration given to the use of contra-rotating propellers?
c) what was the philosophy behind the choice of back pressure turbo alternators: had this proved to be the right decision or would operation of the ships in service have been more flexible if, say, one self-condensing set had been installed?
d) with regard to the electrical installation what short circuit protection had been installed: were the alternators tested under short circuit conditions and was the effect of a short circuit situation on the gearing and prime mover investigated and due allowance made in the design of the gearing?
e) the emergency generators were arranged for remote manual start up in the event of a main alternator failure. Why was this facility not extended to provide automatic start up on failure?
f) what was the philosophy behind the separation of refrigeration and propulsion machinery controls? A data logger was provided for the refrigeration plant, why was this not extended to include the propulsion machinery?
g) was consideration given to the installation of lateral thrust units—if so why were they not fitted?
h) had the decision to install a tank stabilizer system been shown in service to be correct?
i) had the lashing system adopted for these ships proved successful in service?
j) could the author give further information regarding hull vibration—presumably this was propeller induced but could some more information as to the remedial steps taken be given?

Mr. A. N. S. Burnett, M.I.Mar.E., referred to the delivery dates of the first O.C.L. and A.C.T. ships which, from the design stage were both delivered in under three years. This was a remarkable achievement.

He commented that many were concerned about the amount of damage caused or claimed by vibration.

On the subject of shrouded propellers, Dr. van Manen in Holland had stated that, as a result of experimental work, an increase in power could be installed to a given propeller diameter and also that a vessel fitted with shrouded propellers on two shafts had superior manoeuvring qualities compared to a vessel with a conventional single propeller arrangement.

An authority in Sweden had recently stated that from model experiments it had been found that ten to fifteen per cent increase in propeller efficiency could be obtained with a nozzle, leading to a saving of £12 000 per annum for an initial cost of about £100 000. The weight of the nozzle, which was the largest ever fitted, was 63 tons and it was now being fitted to a 130 000 dwt tanker.

He had been connected with tug operations where shrouded propellers were used and vibration had been eliminated almost entirely. Dr. van Manen and other authorities had shown that vibration could possibly be reduced by the fitting of shrouded propellers. There was abundant evidence that there were benefits to be obtained from the use of shrouded propellers. He wondered whether shrouded propellers were being considered for future ships.

The author had mentioned that his philosophy was that with one officer and rating on watch using the roving engineer concept that there would be bridge control. Constant night watches did not appear to be necessary where bridge control with a roving engineer was operated.

Why was the unmanned engine room concept not adopted, possibly it was due to doubtful reliability of machinery?

Was the control centre mentioned, meant to be integrated with a maintenance centre thus enabling some maintenance to be carried out in the vicinity of the console arrangement?

Mr. A. R. Hinson, M.I.Mar.E., said that in Figs 11 and 12 the control console was placed right forward against the wheelhouse front. If, as sometimes happened, the bridge windows leaked, with the arrangement shown in these figures, it was possible that a trickle of water could enter the back of the console. Were any special precautions taken for window and console sealing?

If the console were placed, say 18 in aft of the wheelhouse front, not only would there be no risk of leakage, but access to the console for maintenance could be improved by fitting doors on the forward side. It would still be possible to have unimpeded passage for the whole width of the bridge and to compensate for the slight restriction in visibility, the console and the seat could be raised.

With regard to the console itself the author stated: "redundant information or excessive size in this position merely serves to confuse and mask the really important things". It would seem that this was self-evident yet it was surprising how often we received plans in Lloyd's Register of bridge controls where there was information displayed which the bridge officer did not need to know and about which he could do nothing.

Mr. Hinson thought the console a model of simplicity and the control of propulsion and steering effected from so compact an arrangement remarkable.

The same simplicity was evident in the machinery control console shown in Fig. 18. The console was in three distinct sections: main engine control, boiler control and auxiliary machinery. Again, this would seem obvious, but at least one accident had occurred which could have been partly attributed to badly laid-out controls.

He thought the windows of the engine room were too large. They should be as small as possible with the glass reinforced with wire netting in order to maintain as much as possible the integrity of the room in cases of fire or explosion.

Correspondence

Mr. K. V. Taylor, M.I.Mar.E., in a written contribution said the author had indicated that the hatch corner shape was limited by the need to fit the container guides as close to the corners as possible in order to minimize the total extent of the deck opening required. Perhaps the reluctance to increase the hatch cover size was why the deck opening was kept to a minimum, and as a result the corner shape was always made of less importance and as sharp a corner as permitted by the classification requirements fitted.

The adoption of elliptical shaped corners was an added advantage since it had been shown that they permitted the guides to be located to better effect so far as the minimum hatch area was concerned. Unfortunately, regarding the stresses induced by torsion, it would be more beneficial for the major axis of the ellipse to be athwartships instead of fore and aft when the stress system resulted from the warping of the two ends of the transverse deck strip. However, since the stresses occurring in the corner were a combination of at least two stress systems which would vary in magnitude under different loading conditions, it would seem logical to fit a circular corner in order to obtain the optimum concentration factor. It should be borne in mind that for the stress concentration for ships of this type, it was not the width of the opening in respect to the breadth of the ship that was important, but the relative width of the deck strip in relation to the corner radius. Obviously, for a given corner radius a thin deck ligament between hatches would be less stressed than a wider strip with the same corner.

On the question of the full-scale measurements obtained from A.C.T. I, it must be pointed out that the chance of meeting the worst conditions on a single specific voyage was very rare. Fortunately for the naval architect the probability of extreme conditions was very low, and because of this the designer was able to think in terms of a 10^{-8} probability of occurrence in respect to a design load. However, this did not mean that a limited full-scale structural investigation at sea was not useful, and providing the right sort of information was collected it was possible to correlate these data with those obtained by a theoretical technique. This could be taken a stage further by extending the theoretical data and building up a behaviour pattern based on long-term weather and route statistics.

Regarding vibration, the main difficulty with these ship types had been the large amount of power required to meet the speed regulations in association with an all-aft accommodation. Good flow conditions into the propeller were of prime importance, but the close proximity of living spaces to the propeller meant that even a small amount of energy could be effective in exciting resonance in local structure particularly in the superstructure. In the second generation of containerships, this should not be a problem although with even higher powers being incorporated in these ships and twin propellers, further new vibration problems might be faced in the future.

Author's Reply

The author in reply to Mr. Penney said he was grateful for the information that the total container capacity of the O.C.L. ships was being increased to 1522 containers. The current capacity for the A.C.T. ships was in excess of 1400 depending on draught and required loading condition.

The flip-flop mechanism was working satisfactorily in O.C.L. ships; nevertheless, he felt it would be advantageous to omit this, because it had to be operated and maintained and could be vulnerable. This was one advantage of having the containers stowed eight abreast below decks in the A.C.T. ships as opposed to nine abreast in the O.C.L. ships.

Regarding vibration, the stiffening mentioned in the paper had reduced the vibration amplitudes by some 60 to 70 per cent. The vibration was related to the number of blades in the propeller; it was not a natural hull vibration but a vibration of the deck house which took the form of a rotation of the entire house about a horizontal athwartships axis through the lowest foremost point of the house. It came to a peak somewhere above the maximum running speed but it was significant from 130 rev/min upwards. Analysis showed that the superstructure vibration was related to the vertical stiffness in the area just abaft the boilers and additional stiffening was fitted at this point. Vibration conditions could now be considered generally satisfactory and acceptable.

On the question of mooring, the arrangements in the two classes of ships followed broadly the same lines and the number of people employed was the same. The differences therefore resolved themselves into a question of first cost balanced against the ease of operation in the two cases.

A.C.T. had avoided using special steels wherever possible, particularly high tensile steel. The repair problem had been very much in mind in this connexion.

Unfortunately there were practical considerations which prevented strain gauge experiments from being further investigated. Mr. Penney referred to the possibility of having permanent strain gauges fitted to ships in order to determine the limit of stress so that the ship's course might be altered or the ship slowed down; this was connected with the idea of having slamming gauges in some ships. This was feasible if the anticipated stress levels were high enough to give possible danger in severe conditions. The criteria which would justify permanent strain gauges would, however, need careful consideration.

He was grateful for Mr. Erlenwein's correction of his statement regarding the continuous girder running into the accommodation. This did not refer to the future construction with which Mr. Erlenwein was concerned but to another class of ship. The reason why fuller details were not included in the paper was that, as had been stated, no attempt had been made to describe all features of the ships but rather to select certain problems. In the case of machinery the arrangements generally conformed with accepted modern design but were not necessarily peculiar to container ships, and therefore he had only highlighted problems which he thought were of particular interest.

In reply to Mr. Paxton's query on the difficulties in landing containers on the fastenings on the hatch covers, so far as he was aware there had been no special difficulties though the operation of stowing deck containers was inevitably slower than that of stowing containers in the guides below decks.

Before fixing the propeller blade number at four, a full theoretical investigation was carried out into the various modes of vibration of the hull and of the torsional and axial vibrations of the propelling machinery/shafting system in order that resonant frequencies would be avoided at the continuous running speed. As previously stated the vibration experienced was local to the superstructure.

Passive tank stabilizers were fitted to deal with conditions where the ship might be lightly loaded with a high G.M., to reduce the violent motion expected. The value of stabilizing tanks varied under different weather conditions and they were likely to be least effective with a quartering sea. Two tanks were fitted and their characteristics could be varied by using one or both tanks and by varying the height of water in these tanks. With a fully loaded ship and low G.M. the tanks were not required and would be left empty.

Containers were loaded strictly to a plan designed to provide the desired stability as well as in relation to the best positions for loading and discharge. With refrigerated cargo temperature and taint must also be taken into account.

There were four coolers for each main refrigerated hold and all the containers connected to any one cooler would be operated at the same temperature. There was a maximum of 24 containers per cooler but in the holds further aft, Nos 9 and 10, the number of containers per cooler was smaller. The design permitted cargo to be carried at temperatures within the range −10°F (−23°C) and 50°F (10°C).

The refrigerating plant was not designed for cooling down cargo from atmospheric temperatures, the cargo must be pre-cooled on delivery, but nevertheless, some variation from the correct carrying temperature might be experienced when the containers were loaded, depending on the time in transit from the freezing works or shore refrigerated stack and the ships plant was of ample capacity to bring the cargo rapidly to the correct temperature.

Steelwork sub-division provided the only effective safeguard against taint; one possibility was that container doors might leak. This meant that there were six sub-divisions of the cargo space subject to taint, two quarter holds and one half hold in No. 10, two whole holds Nos 8 and 9, and one half hold No. 7. All containers carried in each one of these compartments must be compatible from the point of view of taint. Regarding clearing taint from a container, the arrangements used in ordinary refrigerated ships would be used in the containers themselves; this would normally be done ashore.

Provision had been made for fitting ozone generators in each cooling space, and two portable generators were carried in each ship. No provision had been made for carrying chilled meat and there were no arrangements for CO_2 injection. CO_2 sampling arrangements were, however, fitted for each cooler system. It should be noted that provision made for carriage of chilled meat in conventional refrigerated ships on the Australian trade route had been virtually unused over the years.

The temperatures were measured in the return air from each individual container. These temperatures together with the supply and return air temperature at each cooler were automatically recorded on a data logger once a watch or as required. Special arrangements for continuous monitoring of fruit cargoes for North America would be fitted in addition to the above for ships to be employed in that trade, but that did not apply to the A.C.T.I. class of ship. Air changes, as stated in the paper, were 40 per hour and could not be increased above this for a full outfit of containers. The highest temperature allowed for in the design was 50°F (10°C), which would be required for citrus fruits.

Flush hatches had been used on an open deck type container ship. They would not show to advantage in a cellular type container ship where containers were taken out vertically.

The author could not say to what extent container operations would finally encroach on the proportion of the Australian trade carried in conventional ships, but clearly the latter would be drastically reduced. These container ships were only able to serve certain specially equipped ports, and various other smaller ports in the producing countries concerned had to be dealt either by conventional ships or by small feeder container ships.

The vessels in question had not been designed for the carriage of bananas: one reason was the number of air changes would not be adequate.

Captain Jenks agreed with Mr. Stott that the placing of the coolers had no significance in principle regarding refrigeration but had a much more significant effect on the structural arrangements of the ship. There was a reduction in length in the refrigerated holds compared with the O.C.L. ships though again he agreed with Mr. Stott that there was a much greater saving in the engine-room and forecastle.

The standard of insulation and size of the refrigerating plant were inter-related and in all cases of refrigerated ship design a compromise was reached which took account of the weight, space and cost of insulation and the capacity, first cost and running cost of the refrigerating plant. In the case of the container ships the hold insulation was in series with the insulation of the containers and the standard of hold insulation adopted in the A.C.T.I. class gave an overall K value of the same order as that which was customary in conventional refrigerated ships. Irrespective of steel temperatures, therefore, it was considered that a reasoned compromise of the above factors had been adopted.

It was not clear on what grounds Mr. Stott based his statement that the heat leakage in the O.C.L. ships was about 55 per cent of the A.C.T. This could only be determined by accurate heat leakage tests in the two classes of ship and would depend not only on the nominal thickness and specific conductivity of the insulating material but also on its consistency and on the area and configuration of the steelwork. The plain steel surfaces devoid of all exposed stiffeners, which permitted the use of factory made polyurethane slabs, were favourable from the points of view of minimum area to be insulated, consistency of product, low cost of installation and avoidance of certain difficult shipyard problems which were implicit with sprayed *in situ* polyurethane used by O.C.L.

Regarding Mr. Stott's implication that the safety of the ship could depend on the correct functioning of the hold conditioner, even if this unit were inoperative it was only the exposed steelwork, or that which, although insulated, lay between hold and cooler or air trunk that could fall below 32°F. The former did not form an essential part of the strength girder of the ship and the latter was made of the appropriate grade of steel.

Mr. Stott's remarks about screw compressors were noted and it was agreed that cost comparisons would often depend on which manufacturer was concerned.

It was also agreed that the theoretical 800 kW cooling down load was unrealistic and it was not taken seriously into consideration when planning the electric generating capacity. The figure of 550 kW holding load quoted, covered the original designed capacity for 374 refrigerated containers and the generating capacity was not reduced when it was decided to reduce the number of refrigerated containers to 326. The maximum tropical refrigerated holding load that had been experienced in service was 410 kW.

The author shared Mr. Kameen's regret that the electrical installation had not been mentioned, but the length of the paper had to be kept within reasonable bounds and it was never intended to provide a complete description of the ships.

Design speed had been attained and it was adequate for the schedule which did not require an overall average of 22 knots to be met.

Contra-rotating propellers were not considered for these ships but had been considered for later ships. It was not possible to embark on such an experimental concept for ships of such importance as these.

Back pressure alternators provided a reasonable compromise between first cost, operating economy and compactness. The flexibility of operation had been quite adequate and there was no reason to doubt the correctness of the decision for these particular ships. The alternators had not been subjected to short circuit tests, but were protected by their breakers in the usual manner. The extra safeguard expected with such tests had to be considered and balanced against the danger that in the process of carrying out these tests some fault might occur in the machinery which might remain undetected until later on.

Remote manual start-up was simple, reliable and inexpensive. It provided a good facility for rapidly restoring the situation in event of main alternator failure, as had been proved by tests at sea. A more complex auto-start and self paralleling arrangement which might be less reliable was not considered necessary or desirable.

Regarding the separation of refrigerating and propelling machinery controls this was a natural and logical process. If there was a fault the refrigerating machinery would shut itself down. Refrigerated cargo was not at risk for some hours and a master alarm for any refrigeration faults would operate at the main control position. From the point of view of periodic operation on the refrigerating plant, carried out by the refrigerating engineer, it was highly desirable to concentrate all his controls and information in the immediate vicinity of the refrigerating machinery and the brine room, which had their own local control panels.

A data logger was essential for refrigerated cargo temperatures, a large number of which had to be recorded at frequent intervals. It was not considered justifiable to log the ordinary machinery quantities, which needed to be checked and assessed by the responsible ships officers at the time. Print out data logs of these quantities tended to produce a mass of information which would never be used.

Lateral thrust units were not considered justified for these ships which served a small fixed number of terminals and where the number of port movements was relatively small. Reference had already been made to the tank stabilizing system. The lashing system had proved satisfactory in service.

The author appreciated Mr. Burnett's remarks regarding the ships' delivery programme, major credit for this must lie with the builders, but the good team work and co-operation between the owners, committees and the builders had a useful part to play. The design of couplings stemmed in the first place from the initiative of Cayzer Irvine and Co. Ltd., acting on behalf of O.C.L. and was developed as described in the paper.

In reply to Mr. Burnett's remarks regarding shrouded propellers, he would prefer not to comment on their possible application in container ships, as this would come more appropriately from specialists in this field.

On the question of an unmanned engine room, he did not consider that at the present juncture this was acceptable in the case of steam machinery; experience indicated that there were many matters which required a watchkeepers attention, and systems and control arrangements were far more complex than in a Diesel ship. Quite apart from this he would challenge the validity of the whole concept at the present time, it did not result in any justifiable reduction in complement and while it was easy to talk glibly about improved maintenance what major maintenance work could occupy the daywork time of three engineer officers at sea in a correctly designed ship? By removing these officers from watchkeeping they were being deprived of that vital experience of being *responsible* for running the machinery; there was no substitute for this experience and no greater incentive to an officer to find out how everything worked when he knew that it would fall to him to take immediate action if a fault occurred.

The author did not agree with the concept of a maintenance centre in the control room. It should be confined to its primary purpose and be laid out with the greatest possible care for maximum effectiveness. The fact that there was an engine room watchkeeper did not imply that he should spend the whole of his watch in the control room, in fact the range of his necessary duties would preclude this, but he would always be relatively close by and repeat master alarm signals in all strategic parts of the machinery space would ensure his recall promptly, in event of any trouble.

With reference to Mr. Hinson's comments, from the point of view of operation, the console should be right against the front of the wheelhouse. The window over the console was fixed and experience with a number of ships in which this design was used had not revealed any problems. The equipment was all designed for easy maintenance from the aft side of the console. The author was pleased that Mr. Hinson supported his ideas in respect of the principles of console design and of restricting the information to that which was essential for operational control. He agreed with Mr. Hinson's view on the size of machinery control room windows, though if the principle were maintained of siting the control room as closely as possible to the machinery most likely to require manual attention, in event of trouble, it would be difficult to provide for the integrity of the room in case of fire or explosion.

Mr. Taylor made an interesting and valuable contribution on the difficult matter of hatch corner shape and he was certainly correct in his view that it was of greater importance to provide a sufficiently large curvature of the hatch corners than to minimize hatch cover size. Nevertheless, it was a fact that the size of hatch covers was a limiting factor for the whole design of the ship and therefore one could not provide too large a safety factor.

It was also agreed that with combinations of longitudinal and torsional stress a circular corner, or an empirical curve as recommended by Det norske Veritas would be more logical than the solution used in these ships, but it must be borne in mind that reliable data on this matter was scanty at the time these ships were designed and that they had been free of all trouble at the hatch corners.

It was not considered that the width of the side structure should be reduced as it was clearly important with respect to torsional rigidity, but the use of narrow transverse box girders between hatches would reduce the corner stresses, and this solution was adopted in these ships.

Mr. Taylor's remarks regarding vibration were endorsed and as experience built up it should be easier to avoid serious vibration problems with future designs of container ships. However, with the large powers transmitted by the propeller and the inevitable variations in structural configuration to meet changing operational requirements it would be foolishly optimistic to think that such problems belonged solely to the past.

Related Abstracts

Trends in Intermodal Refrigerated Container Systems

Two types of refrigerated container are in general use today by shipping companies; the "conventional" type with integral refrigeration machinery, and the "machineless" type which is cooled by an independent external supply. There are three main systems for stowing ship-borne containers:

On-Deck conventional system

This uses conventional-type containers which are stowed on the weather deck to assure dissipation of compressor heat. Disadvantages of the system are the loss of cargo volume compared with a ship with insulated holds, and a further loss of cubic and revenue-earning capacity in the case of a roll-on/roll-off ship due to the space required for trailers, etc. However, this system is extremely flexible and can be used on most types of ship.

The Coldwell system

In this system machineless-type containers are carried in insulated refrigerated holds. Four ships of this type (each with three holds) are at present being built for Farrell Lines, New York, and details of their capacities and refrigerated air-supply system are given.

The Plenum system

This is a below-deck duct system in which refrigeration is supplied to insulated machineless containers by a separate ship-mounted plant incorporating a number of compressors working in conjunction with a circulating brine system. Details of the arrangement are shown in diagrams. The system (which is fully automated) has ample coil surface and standby capacity, and can provide cargo temperatures ranging from −10° to 70°F (−23·3°C to 21·1°C) with controlled air change; it is in use in the Associated Containership *ACT 1*. *—Paper by Sebin, A. B., presented at a meeting of the Northern California Section of the Society of Naval Architects and Marine Engineers. 8 January 1970; Journal of Abstracts, B.S.R.A., August 1970, Vol. 25, Abstract No. 29855.*

Container Feeder Ships

The m.v. *Brage* which left the yard of her builders, N.V. Scheepswerf and Machinefabriek 'De Biesbosch', of Dordrecht recently, is a sistership of *Birka* delivered by the same builders in April.

Both ships have been designed primarily for carrying the maximum number of ISO standard containers and for the rapid loading and discharging of these containers. As a result the cargo spaces are not interrupted by transverse bulkheads, while the access to these holds is through very large hatchways. The deck space available for containers to be carried on deck has been increased to the maximum by reducing as much as possible the length of the deck-house for the accommodation.

The statutory number of crew has been reduced to the optimum by keeping the length of the vessel within the 75 m limit as defined in the Dutch 'Sea Diploma Act' and providing the machinery installation with extensive signalling system and remote control systems.

Principal particulars are:

Length, o.a.	81·60 m
Length, b.p.	74·60 m
Breadth moulded	14·20 m
Depth to maindeck	7·70 m
Depth to tweendeck	5·05 m
Draught (summer)	5·026 m
Deadweight capacity	2530 tons (metric)
Gross tonnage	1130·88 R.T.
Net tonnage	738·37 R.T.
Grain capacity	146·163 ft^3
Container capacity	126 (20 ft ISO standard)
Speed	13·86 knots

The windlass and capstan, which are electrically driven, are of Van der Giessen-Werktuigen maufacture. The steering engine is of the electric-hydraulic Svendborg type, with time-dependent manual control and automatic steering by means of a Decca Arkas installation.

Propulsion is by an MaK Diesel engine type 5 MU 551 AK, developing 2400 bhp at 300 rev/min. The direct reversing engine drives a four-bladed Lips propeller. Three generator sets are mounted on the tweendeck in the engine room. Each of them consists of a Volvo-Penta Diesel engine type TMD-100 A, which is direct coupled to a Heemaf alternator of 145 kVA, 380 V, 50 Hz.

The machinery installation is protected by an extensive alarm system, comprising 16 alarm points on the main engine and its auxiliaries, 6 points for the generating sets and 15 points distributed over the engine room for the control of the tank levels, bearing temperatures, bilge water level, etc. Alarms are given visually on a separate board near the control position of the main engine. In addition, the alarms are passed on to the wheelhouse and the cabins of the chief and second engineers.*—Holland Shipbuilding, July 1970, Vol. 19, pp. 32–33; 36.*

Isofreeze Insulated Containers

ConCargo Ltd. has obtained an order for part of the massive U.K./Australia liner containerization programme which the Associated Container Transport consortium began in 1968.

The containers for the new A.C.T. contract will conform essentially to the basic ConCargo 'Isofreeze' design; the major physical features being the ISO standard length of 20 ft with a tare of 2 ton 10 cwt, giving a capacity of 957 ft^3 and a gross load of up to 20 ton. The insulation performance under refrigeration shows an operation transmittance of

40 Btu/h°F. The container itself will support the weight of 6 fully loaded containers stacked above it and will withstand extremes of temperatures between −40°F and 120°F.—*The Journal of Refrigeration, December 1969, Vol. 12, p 378.*

Determination of the Steel Weight of Bulkcarriers and Containerships

This article describes the determination of steel weights of bulkcarriers and containerships and should serve as a supplement to an article, which described the determination of steel weights of multideck vessels (Hansa 1967/p. 1864, translated by "The British Ship Research Association", Translation No. 2946).

The basic idea of the new method is the calculation of the hull weight on area basis rather than on a volume basis as with the majority of other methods.

The values given in the tables of this article allow to determine steel weights of bulkcarriers resp. containerships (built of normal shipbuilding steel without use of high tensile steel for certain parts of the hull) up to a length b.p. of about 200 m.—*Carstens, H. Hansa, Special Issue, November 1970, Vol. 107, pp. 1945–1948.*

Torsional Strength of Large Container Ships

The torsional strength of a containership was investigated by all available methods. Calculations with theory or torsion and finite element techniques were checked with measurements. The measurements were carried out with a ship model made of Acril and a hatch corner model made of steel. The Acril model was built as similar as possible with details of the full size ship. The results of the calculation and the measurements show good agreement for practical purposes.—*Alte, R., Behr, P., Beuermann, H., Niessen, E., Prange, D., Rose, D, and Schonfeldt, H. Hansa, Special Issue, November 1970, Vol 187, pp. 1879–1894.*

New TMT Roll-on Roll-off Containership and Car Ferry

A combination roll-on/roll-off containership and car ferry is the subject of a recent design by Rudolph F. Matzer and Associates, Inc.

The 360 ft vessel will feature three stern ramps, a 250 hp bow thruster and the facilities for containers, trailers and automobiles.

With a total displacement of 5116 long tons, the vessel will be capable of carrying 2576 long tons of deadweight. Fuel oil carried in the inner bottom tanks accounts for 336 longs tons of deadweight, while 86 long tons of fresh water is carried in the forepeak and after peak tanks. Approximately 5200 shp will be required to sustain a speed of 15 knots while operating at a maximum draft of 15 ft.

Twin 15 ft wide stern ramps, port and straboard, lead to the weather deck. This deck can accommodate 28 trailers or, by special deck fittings, a mixture of containers or trailers. The need for a shore-side or ship-mounted container crane is eliminated by using a special mobile device to carry the container aboard the vessel. The device, called Swinglift, is mounted on a trailer and can unload 40 ft containers to its side and stack them two-high. By using this Swinglift, a total of 40 containers can be stacked on the weather deck. In addition to these containers, eight trailers may be carried on the 53 ft wide super-structure deck. Twenty-five 40 ft trailers and 25 automobiles can be loaded on the main deck over a 21 ft wide ramp, which also serves as a weather-tight closure in the stowed position. Seventy-six cars are carried in the hold on two levels. Access to the car decks is by ramp from the main deck through a sliding water-tight door.—*Maritime Report/Engineering News, 1 July 1970, Vol. 32, p. 43.*

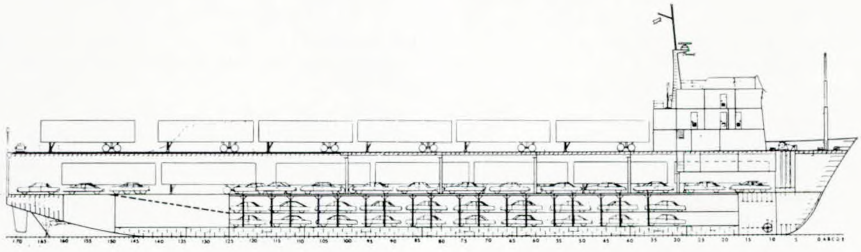
Container Ships From Bremer Vulkan

The article compares the various types of containerships built or under construction at Bremer Vulkan shipyard (eight types with total container capacities between 316 and 2300 containers of the 20 ft size). Main dimensions, container arrangement, ships speed, hatch covers, rudder arrangement, structural strength and stability are discussed.—*Erlenwein, H. H., Hansa, Special Issue, November 1970, Vol. 107, pp. 1867–1878.*

Semi-Containership "Transamerica"

M.V. *Transamerica* has been built by AG "Wesser", Seebeckwerft, for Poseidon Schiffahrt GmbH, Hamburg. She is an ice-strengthened semi-container vessel for operating between Canada resp. the USA/Great Lakes ports and Europe. The capacity of the holds amounts to total 494·840 ft^3 grain and 20·286 ft^3 refrigerated space. No. 3 hold has twin-hatches with 80 per cent of the ship's beam open. In the holds 148 containers of the 20 ft type can be stowed. The cargo handling gear includes 10 derricks of 5/10 tons, 2 derricks of 5 tons and one 50-tons Stülcken container derrick.

The vessel is propelled by one MAN K 6 Z engine of 8400 bhp giving a speed of 17·1 knots at an engine output of 90 per cent.—*Arntz, W., Lucht, W., Schomburg, E. and Tertel, S. Hansa, Special Issue, November 1970, Vol. 107, pp. 1969–1978.*



Inboard profile of the proposed 360 ft containership and car ferry