Marine Engineering and Shipbuilding Abstracts

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Propeller Design

Propeller design can be divided into two parts:

a) the selection of propeller type;

b) the determination of the main dimensions, such as diameter, rev/min and number of blades.

Special attention should be paid to the following requirements:

1) high efficiency or minimum required shaft horse power;
2) minimum danger of cavitation erosion;
3) minimum propeller-excited vibratory forces;
4) good stopping abilities;
5) good behaviour in a seaway;
6) favourable interaction with the rudder, to improve manoeuvrability.

In the selection of a propeller type all these hydrodynamic aspects of a ship propeller play an important role. Besides dependability, minimum vulnerability and low initial and maintenance costs have to be taken into consideration.

The conventional ship screw with fixed blades, designed for non-cavitating condition, has been far more than 100 years the most applied type of ship propeller.

The ducted propelled (screw and nozzle or pump jet) has advantages for ship types where the propeller load is high or the cavitation danger is serious.

Results of model tests show that application of ducted propellers on large tankers will be realized in the very near future.

Contra-rotating propellers for a type of propulsion that might be a serious competitor of the conventional ship screw on large container ships with such high speeds that the required power cannot be installed on one screw. Gradually more design information becomes available for this propeller type. The selection of the blade number of fore and aft screw is of particular importance for the control of the propeller induced vibratory forces and so for the transmission solution between propulsion plant and propeller.

The number of applications for controllable pitch propellers has increased very rapidly during the last years.

Up to 30 000 shp has been successfully absorbed by controllable pitch propellers. The supreme qualities of controllable pitch propellers with stopping (for tankers) and accelerating (for frigates) promise a continuing growth in the application of this propeller type.

Fully or supercavitating propellers with fixed or adjustable blades have operated successfully at speeds up to about 50 knots, despite problems of inclined shafts and part immersion.

Pulse jet propulsion and air propulsion are examples that underline our insufficinet knowledge to solve the problems of high speed propulsion in a satisfactory way. In this respect it is worthwhile to mention the development of two phase hydrojets (water ram jets) in the U.S.A., the Netherlands and Italy. This type of high speed propeller may become the most valuable contribution of all our extensive research activities in the field of high speed propulsion.—*Van Manen, J. D. 7th Symposium on Naval Hydrodynamics, Rome, 25–30th August 1968; International Shipbuilding Progress, March 1969, Vol. 15, pp. 71–104.*

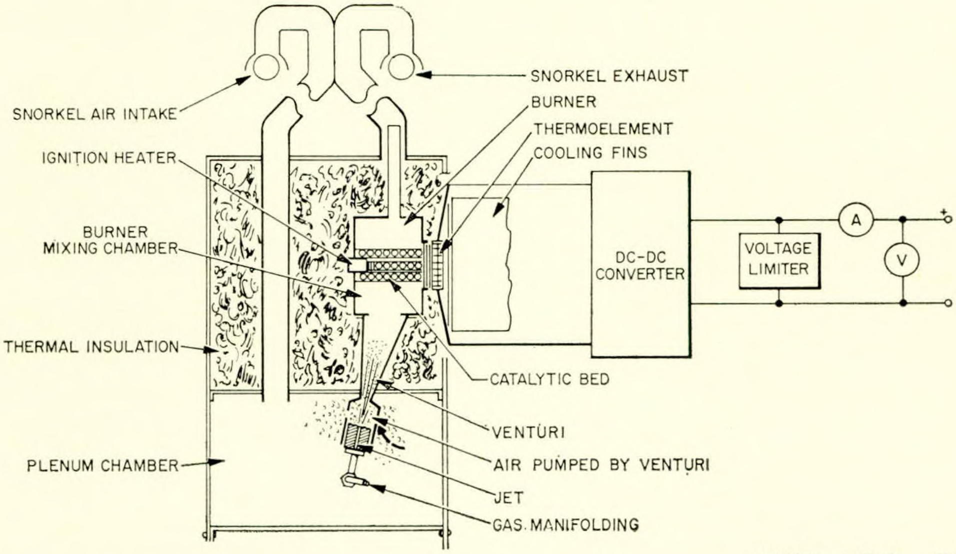
Thermo-electric Power Sources for Buoys

If ocean buoys are to become feasible for long duration oceanographic operations, dependable and economical power sources must be available. While batteries provide a few watts of power for periods up to six months, fossil fuel thermo-electric generators (TEG) have the capability to provide from two to six watts for periods over three months.

Buoy designers have a choice of three TEG versions depending on buoy size and power requirements.

Thermo-electric power sources are inherently reliable because they have no moving parts and all electrical and electronic active comonents are solid state. Heat energy is converted directly into electrical energy in a semiconductor thermoelectric module. Two heat sources are suitable for buoy applications, e.g. fossil fuels and radioisotopes.

TEG based on radioisotopes heat sources have long life,



Cross-section of typical above deck thermo-electric generator with snorkel breathing

require no refuelling during a typical five-year life period and are extremely reliable. They also have the advantage of requiring least total weight and space. They are, however, very expensive, generally costing twenty times as much as an equivalent TEG using fossil fuels.

Liquid petroleum gases, such as propane and butane, are the best fuels for TEG because they eliminate two very unreliable processes, e.g. fuel pumping and fuel vaporization. These gases can be burned either in a flame or catalytically.

For a TEG breathing through snorkels, as will be typical in many buoy applications, catalytic burning is essential since the snorkel could close for two to four minutes. When breathing stops, burning ceases but the gases spontaneously reignite when the breathing system is restored. In the case of flame burning, the flame would be smothered.

The simplest and least expensive installation on a buoy would be a standard land based TEG unit adapted for marine environments provided the generator can be mounted high enough on a large buoy to be sure that waves will not completely break over the unit.

No redesign is required on existing generators, and the installation is relatively simple. There are two main disadvantages: the centre of gravity of the buoy is raised because the generator must be mounted above maximum wave height and because the heat rejection is to ambient air, this system also tends to be less efficient.

A second version is a standard generator in a redesigned waterproof housing with snorkels. Such a generator can now be mounted above the water line, but at a level where waves will occasionally completely break over it. The diagram shows a cross section of such a scheme; this unit might be mounted on a standard buoy. This construction is still relatively inexpensive because it is an adaptation of standard hardware, permits the generator to be mounted lower for a more advantageous centre of gravity and is very accessible since it is usually mounted at or near the main deck area of the buoy. This version, therefore, is more suitable for smaller buoys.—*Schreiber, O. P., UST, March 1969, Vol. 10, pp. 36–37; 51.*

Distant-water Trawler with High Degree of Automation

Built by Ferguson Bros. (Port Glasgow) Ltd., to the order of Thomas Hamling and Company, Hull, the 231 ft refrigerated stern trawler *St. Jasper* is the first vessel in the British distant-water fleet to incorporate a fully automated engine room.

Propulsive power is provided by a British Polar 6-cylinder, 2-stroke, M66T-type engine capable of developing 2400 bhp at 225 rev/min coupled to a Liaaen stainless steel c.p. propeller giving a trial speed of 14 knots.

Electrical power is provided by a 5-cylinder, 750 bhp British Polar SF15RS engine driving a Laurence, Scott and Electromotors alternator at 750 rev/min giving an output of 446 kW at 440 V. A smaller set comprises a 3-cylinder, 450 bhp British Polar SF13RS engine driving a 750 rev/min alternator producing 280 kW. For harbour duties a 6-cylinder Gardner LX-Type engine developing 80 bhp drives a 55 kVA alternator at 1000 rev/min.

The main engine and auxiliary pumps are electrically driven except for the main hydraulic pump which is driven through a clutch from the free end of the main engine. Power from this pump is taken to the trawl winch and windlass, both of which are manufactured by A/S Hydraulik Brattvaag. An emergency electrically driven pump of 80 hp is also provided.

The system incorporates extensive alarm scanning capable of supplying data on defects, pinpointing the cause of the fault and indicating the course of action to be taken.

At the centre of the information system is a small computer designed to receive all data from the engine and inform the staff by alarms and recording of any fault.

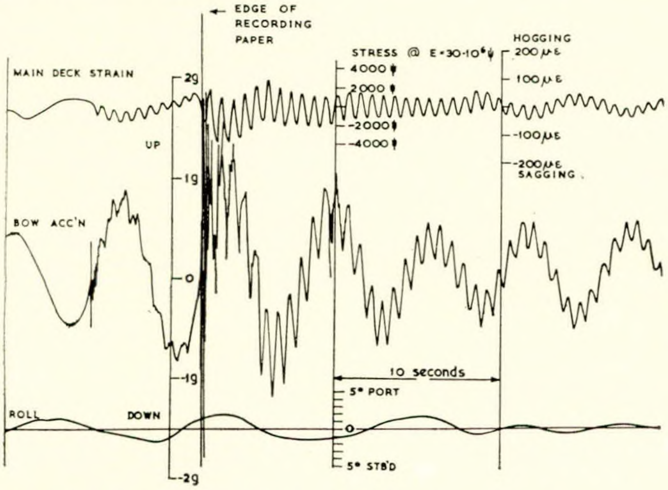
The main information devices comprise a mimic display panel of the main systems of the plant, fitted with a warning light for each monitored point.

The computer is also designed to give automatic corrective action whenever appropriate and to provide adequate information to serve the owner in maintenance ashore.—*Shipbuilding and Shipping Record, March 28th 1969, Vol. 113, p. 421.*

Control of Ship Slamming

Slamming is an increasingly severe problem for the owners of fast cargo ships. For container ships, which run to an exacting schedule, there is a need to maintain a high speed even in adverse weather conditions, yet if speed reductions are left until too late, bottom damage due to slamming may ensue. Dry docking for plate replacement will be even more expensive for these ships than for ordinary dry cargo vessels which spend a much smaller proportion of their life at sea. Work on the practical diagnosis and possible alleviation or prevention of slamming has been taking place at Ship

Division, National Physical Laboratory (NPL), and sea trials have been undertaken on board two ships owned by Manchester Liners Ltd.



Records taken during severe slam experienced by Manchester City

The first of the Manchester Liners to be equipped with slamming instrumentation by NPL was *Manchester City*. She has dimensions 470 ft × 62 ft × 37 ft, and carries general cargo across the North Atlantic; her service speed is 17 knots. Strain gauges have been affixed in two locations and their output is recorded on an ultra-violet paper recorder on the bridge during severe weather. One set of gauges is on a longitudinal girder on the deckhead of No. 4 upper tween deck; this set measures whipping strain of the whole ship. A second set is on the bottom plating just aft of No. 1 double bottom tank at the far end of the port side duct keel and is designed to record transient plating deflexions under slamming loads. The method of recording will not permit measurements of long-term sets.

In addition there is provided a microphone and loudspeaker system, which amplifies the sounds of slams at the end of the duct keel for the benefit of the officers situated on a well insulated bridge. This should provide a direct warning of the dangers of maintaining an excessive speed, but no reports have been received on the realism of these sounds or of the officers' reactions to them.

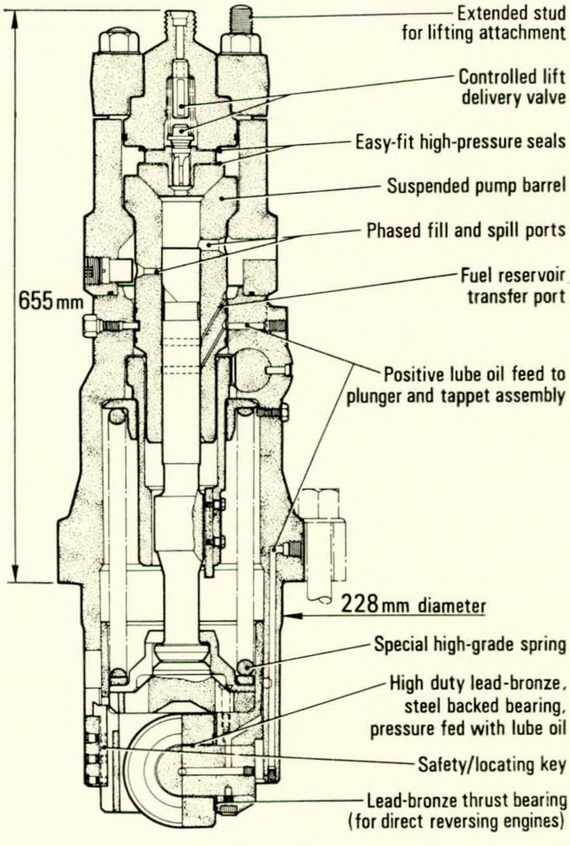
In order to protect the three new container ships *Manchester Challenge, Courage* and *Concorde,* 498 ft × 63 ft 6 in × 48 ft × 11 698 grt, NPL was asked to develop an instrumentation system. This was designed to achieve two purposes, to provide an early warning on the bridge that conditions conducive to damaging impacts were occurring, and to indicate if any damage had occurred.

The warning system is based upon the number of times that the forefoot emerges from the water in a given interval of time. If it exceeds a pre-set rate, which depends upon the static draught at the fore perpendicular and for *Manchester Challenge* is typically between 20 and 40/h at a station 15 per cent aft of the fp, then it is recommended that ship speed be reduced. Conversely speed may be increased again when the count has dropped satisfactorily. The recommended count levels are determined from calculations of motions for the ship in irregular head waves carried out at NPL. For given conditions, these permit the frequency of bow emergence and the frequency of slamming to be estimated. For a slam to occur it is necessary for the bow to emerge from the water and to have relative re-entry velocity exceeding some particular value, dependent upon ship length and speed. But it turns out that over quite a range of speed and sea states the number of bow emergences closely parallels the number of slams on a criterion based upon the work of Aertssen. This is convenient as it means that a single reading of a counter can be taken as an indicator of the relative danger of slamming damage.—*Shipping World and Shipbuilder, June 1969, Vol. 162, pp. 801–803.*

Fuel Pump

Bryce Berger Ltd. have introduced the F-size fuel injection pump, which has a plunger stroke of 50 mm and which can be fitted with plunger barrels of from 36 to 50 mm bore giving a maximum output of 32 cm^3 per stroke. It is designed to operate at injection pressures in excess of 1100 kg/cm^2 (15 500 lb/in^2) and is suitable for engines with running speeds of 400 rev/min and over.

The pump body is in two parts and these are tied, together with the heavy collar securing the delivery valve head, by four long through-studs which transfer the pumping stresses to the lower part of the housing. This construction has an additional benefit in that it is possible to provide a number of alternative configurations for the fuel inlet and control rod positions. Patented features in the plunger design are available to ensure complete control of the pumping rates at the end of injection.



Section through Bryce F-type fuel injection pump for high-powered medium-speed engines

Forced lubrication is applied to the plunger and the tappet block, both of which are located by keys. The robust cam-follower tappet assembly is fitted with a roller which, although wide enough to remain conservatively stressed, can incorporate large edge radii for use on direct-reversing engines. This pump is suitable for the new generation of medium-speed engines now coming forward with outputs of 1000 bhp per cylinder and upwards.—*Marine Engineer and Naval Architect, May 1969, Vol. 92, p. 206.*

Total Power Systems

Fig. 1 illustrates the side view of a cargo-ship power unit where two 3600 bhp Diesel engines each drive through a generator into a twin-pinion, single-output reduction gear to supply 7000 hp to a controllable pitch propeller. Each Diesel engine is mounted on a common base with its accessory module, ac/dc generator, and air clutch.

Both Diesel engine unit common bases at the power take-off end are supported on the common reduction-gear frame. The accessory end of the Diesel units is supported by the ship's structure. The unit, as illustrated by Fig. 1, is made up of a standard production Diesel engine, a prefabricated engine accessory module, generator, and air clutches. The common reduction gear is of conventional design but is subject to variation in the housing configuration and reduction gear ratio to meet the ship designer's specific requirements. The Diesel engine, accessory module, generator, and air clutches are volume produced and used extensively in several major industries and the marine industry.

Fig. 2 follows from Fig. 1 and illustrates by block diagram the total power system for a self-unloading cargo ship. A total of 14 000 shp is available for propulsion through two controllable-pitch propellers and four prime movers. When propulsion demands are reduced, in channels and harbours, one engine can be released from each propeller by deflating the air clutches. These engines can now supply electrical power from their generators to drive the bow and stern thruster motors. After the vessel is secured to the dock, all four engines are available to furnish electrical power from their generators to the ship's unloading machinery motors.

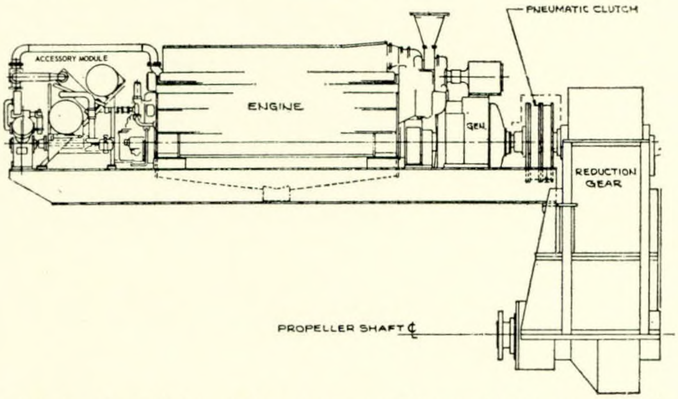


FIG. 1—*Propulsion and power generation unit for a cargo ship*

Programming of the ship's power has been kept as simple as possible without sacrificing maximum flexibility. Controls consist of a central control panel, generator control cabinets for each power unit, a common motor control cabinet and an unloading control station. The central control station is a compact panel pushbutton type which can be located in either the pilothouse, engine room, or both.—*Ramsey, R. S., Maritime Reporter/Engineering News, January 15th 1969, Vol. 31, p. 12.*

Russian Catamaran Fishing Vessel

Experiment is 40 m (131 ft 3 in) in width and has a displacement of about 1000 tons. The two main Diesel engines are each of 600 bhp and the vessel has a speed of up to 9 knots. The vessel was developed and constructed by three organizations operating in Kaliningrad: the Central Design Bureau of the Soviet Ministry of Fisheries, the Atlant-NIRO Institute of Fisheries and Oceanology, and the Technical Institute of the Fish Industry and Economy.

Experiment has been conceived as a multipurpose commercial fishing vessel with two trawling decks providing for continuous catching.

Depending on the species of fish, the crew can change the tackle and fishing methods, using bottom and pelagic trawls as well as large purse nets.

It takes one hour to change over from trawl fishing to purse seine fishing and *vice-versa*. This is important in areas with quickly changing fishing conditions. The vessel is adapted for fishing with electric lights when necessary.

Each of *Experiment's* two hulls is shaped like the conventional SRT-300 medium-sized trawler which is the most

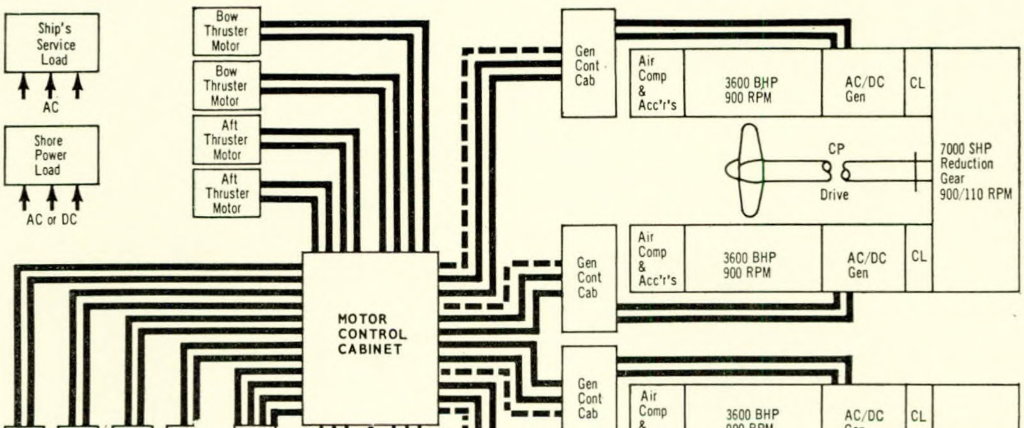


FIG. 2—*Block diagram of the total power system for a self-unloading cargo ship*

popular type of Soviet fishing vessel. The vessel is not threatened so much by dangerous rolling and heeling and is obedient to the rudders in both calm and in rough weather. With propellers which turn in opposite directions, the vessel can turn on the spot. Steering characteristics are good when running at both high and low speeds.

Compared with single-hull vessels, *Experiment* keeps a steadier course and is less subject to drift under the effect of wind and waves. There is another important advantage—a much better transverse stability is shown compared with single-hull predecessors. This makes is possible to continue fishing in much poorer sea conditions.

The trawler returned from it North Atlantic trials after having covered 4500 miles in particularly severe weather conditions. During storms, winds of force 10 to 11 were experienced by the vessel.

As the purpose of the trials was to check the vessel for seaworthiness and strength, such weather did in fact serve well. Information from 140 sensors installed in what were considered to be the most vulnerable parts of the vessel's structure has revealed after computer analysis that strength and reliability are satisfactory.

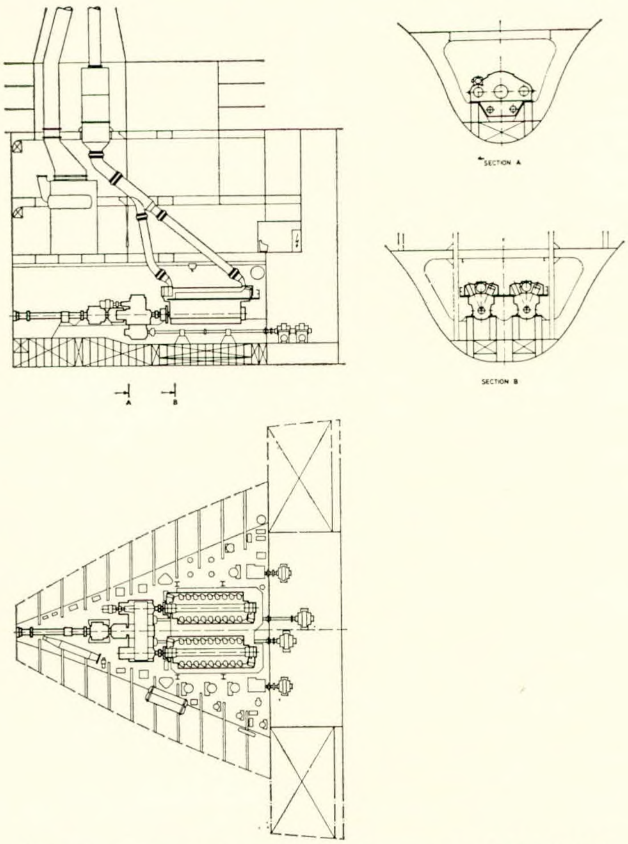
In the opinion of the skipper and the scientists on board during the trials, *Experiment* would not capsize in the severest hurricane, and in the conditions met with, the vessel answered the helm perfectly.—*World Fishing, March 1969, Vol. 13, pp. 37; 59.*

Propulsion Systems with High-output Medium-speed Diesel Engines

The illustration shows a proposed arrangement for tanker propulsion with two reversible V9V52/55 main engines each developing a maximum continuous output of 18 000 bhp at 430 rev/min. Through a twin-input, single-output gear-box, the two main engines drive the fixed-pitch propeller with a rated speed of 80 rev/min, flexible couplings being arranged between the engines and the reduction gear-box. In the combining gear-box are manoeuvring clutches which are arranged in series with the afore-mentioned flexible couplings. This propulsion layout can be manoeuvred by de-clutching the propulsion engines, reversing them, and clutching them in again once they have been run up to a specified speed.

Two power take-offs have been provided each of which is driven through a clutch and a flexible coupling off the bull gear of the propulsion gear unit. Since the pumps in question would normally only be in operation during discharging, i.e. with the propeller at rest, the propeller shafting must make provision for a toothed coupling to be arranged between the propulsion gear unit and thrust bearing. A Diesel propelled tanker always requires steam for heavy oil heating, but sometimes also for the tank cleaning system and driving of the turbo-generator. While relatively small steam quantities are sufficient for heavy oil heating, the steam consumption of the tank cleaning system, if provided, is considerable. If the tanker features a tank washing system operating on hot water, it is recommended to have steam turbine drive for the two remaining cargo oil pumps. However, interest has also been aroused in gas turbine drive of the cargo pumps.

With a view to improving economy, a Diesel propulsion plant of this rating will in any case use the exhaust heat of the main engines for power generation and heavy oil heating. The steam generating system used for this purpose usually consists of a La Mont-type exhaust-gas boiler and an oil-fired watertube boiler with common steam drum. The steam pressure of the system is kept automatically constant. If, with the oil burner inoperative, the system generates an excess of steam; the steam pressure is controlled through bypassing the exhaust gas by actuating the register of the La Mont boiler. If there is a shortage of steam, the bypass register will close. Should the steam pressure still fail to reach the rated value—which, for instance, may be the case if the main engine output is reduced—the auxiliary boiler will come into operation. If the steam pressure tends to exceed the rated value, the burner of the auxiliary boiler is again cut out.—*Dipper, H., The Motor Ship, "Special Survey", May 1969, Vol. 50, pp. 47–50.*



Machinery arrangement plans of a proposed 220 000 dwt tanker propulsion plant

Ebeltoft-Odden Ferry

Aalborg Vaerft AS has recently delivered the twin screw car and passenger ferry *Mikkel Mols* which was built for the account of Mols-Linjen AS, the subsidiary of the United Steamship Company of Copenhagen. In service, *Mikkel Mols* will carry about 1200 passengers as well as cars and lorries on the Ebeltoft–Odden route.

Principal particulars are:

Length, o.a. abt.	303 ft 6 in
Breadth	54 ft 1 in
Depth to the car deck	17 ft 7 in
Draught, loaded	13 ft 2 in
Deadweight	625 tons
Speed	19·5 knots

The ship can be navigated from a wheel house aft as well as from the forward wheel house to facilitate safe berthing at the ferry ports. To further enhance berthing at these ferry berths, the ship is equipped with two spade rudders aft, a bow-rudder, and an 800 hp KaMeWa bow-propeller giving a transverse thrust of about 9 tons.

Mikkel Mols is equipped with the most modern navigational aids including gyro-compass, three radar installations, echo-sounder, radio telephone, etc.

Main propulsion machinery consists of four 14-cylinder

B and W four-stroke turbocharged single-acting, non-reversible trunk piston Diesel engines of type 26MTBF-40V. Each engine has a continuous service output of 2520 hp at 600 rev/min and a maximum continuous output of 2770 hp at 620 rev/min. The main engines are coupled in pairs by elastic couplings to a Renk double reduction gear, with a gear ratio of 2·22:1, thus the maximum continuous and continuous service engine speeds correspond to propeller shaft speeds of 280 and 271 rev/min respectively. A KaMeWa 4-blade controllable pitch propeller having a diameter of 2700 mm is fitted to each shaft and these are arranged in such a way that operation can be effected from the control panel in the engine room as well as from both the forward and aft navigation bridges.—*Shipbuilding International, June 1969, Vol. 12, pp. 14–15.*

Spanish-built Log Carrier

Spanish shipbuilding has undergone a major transformation in recent years and the pace of development in Spain probably matches that of any other European shipbuilding nation. Current orders range over the whole gamut of ship types including very large tankers and bulk carriers, passenger ferries, LPG and LNG ships and trawlers and fishing vessels of advanced design.

A recent delivery which typifies the versatility of Spanish builders, particularly in the smaller vessels range, is the 8640 dwt log carrier *Marcosa 1*, built at the Union Naval de Levante shipyard to the account of Cia. Maritima Continental y Comercio S.A., Valencia.

To meet the requirements of the South American river trade in which the vessel will mainly be employed, *Marcosa 1* had to be fully equipped for self-handling of large logs with provision for rapid stowage of this intractable type of cargo.

The ship is of the all-aft type with three large cargo holds forward of the deckhouse accommodation block and machinery space. The deep cellular double bottom is strengthened to take impact loads from heavy logs and internally it is divided in the usual manner to provide tanks for ballast, fuel oil, lubricating oil and so on.

Principal particulars are:

Length, o.a.	132·350 m
Length, b.p.	122·000 m
Breadth, moulded	17·400 m
Depth, moulded	9·400 m
Draught, fully loaded, general cargo	7·514 m
Deadweight, at above draught ...	8640·6 tons
Speed	15 knots
Range	6000 miles
Capacities, m^3	
Ballast total	1091·4
Heavy oil total	587·8
Light oil total	108·6
Fresh water	293·5
Lubricating oil	74·9
Holds. grain, total	13 239

Timber deck cargoes can be stowed on the main deck and there are suitably arranged stanchions on the bulwarks to facilitate easy stowage of bulky loads on deck. As previously stated the cargo handling gear is comprehensive to suit working in rivers and non-equipped ports. It comprises no fewer than ten 10-ton derricks, one 20-ton derrick and one of 40 tons. They are carried on three pairs of goal-post type derrick posts which also serve as ventilation ducts for the cargo holds. Machinery associated with the cargo handling equipment consists of an outfit of ten 10-ton winches of Norwegian Hydraulik make. They are provided with oil at 28 kg/cm^2 by five 68 hp electrically driven pumping sets, installed in the winch houses on which the Hydraulik machines are mounted.

Propulsion of *Marcosa 1* is by a Burmeister and Wain engine of the 850 VT2BF-110 design built by the Manises works of Ast. de Cadiz. It is rated at 6150 bhp at 176 rev/min and enables a service speed of 15 knots to be maintained. Ancillary equipment includes Houttuin screw pumps for lubrication and fuel transfer duties, Ruhrpumpen units for coolant circulation, bilge and ballast services and Sihi pumps for domestic water tanks.—*Shipbuilding and Shipping Record, May 16th 1969, Vol. 113, pp. 675–676.*

Doppler Sonar as New Navigation Tool

The doppler sonar navigator provides an excellent means for ship's navigation and velocity and positioning determination in many situations where no other reference is available. The development of this system has provided excellent navigational tools for deep submergence vehicles, geophysical survey vessels, and large tankers and cargo ships.

The concept of doppler sonar navigation is similar to doppler radar methods used extensively in airborne applications. Four sonar beams are directed forward, aft, port and starboard and the velocity measured relative to the ocean floor by the doppler shift of each of the four beams. The ship's velocity along each one of the axes is determined in this manner, drift angles computed and velocity components displayed along desired co-ordinates. It is then possible to navigate the ship from any starting position to any terminal point by coupling the doppler equipment to an appropriate heading reference.

The successful development of the pulse doppler system now permits a substantial extension in the applications of the technology. The equipment is now being used in the geophysical survey industry to determine exact position during surveys and to determine drift from anchor positions during non-operational periods.

The equipment is also receiving major acceptance in navigation and docking applications for supertankers. These vessels have navigational accuracy problems in coastal water that are only partially satisfied by shore based radio navigational aids. The doppler sonar system provides a completely self-contained navigational system.

In the tanker application a complete array of sonar transducers is placed in both the bow and stern, with the bow and stern velocities displayed separately on bridge wing mounted docking displays. The first docking and navigation system is in operation aboard the tanker *Esso Austria*.—*Buford, W. H., Under Sea Technology, March 1969, Vol. 10, pp. 34–35; 59.*

New Royal Dutch/Shell Laboratory in Amsterdam

Research into the lubrication of marine Diesel engines at the Royal Dutch/Shell laboratory in Amsterdam, is now being carried out under ideal conditions in a new building. This establishment is the largest of its type in the world, and is concerned with research and development work on lubricants for large, low-speed marine Diesel engines. The main feature of the new building is a 680 mm bore Sulzer type 2RF68 crosshead Diesel engine fitted with two-stage turbocharging. The installation of this engine will permit the further development of Shell marine lubricants—a task which cannot be carried out at sea under controlled conditions on account of the complexity of ship operations today.

The new engine, which will be used mainly on long endurance tests, has been built by Koninklijke Maatschappij de Schelde, Flushing. It is the non-reversing version of the well-known Sulzer RD68 marine engine and is capable of developing 3400 bhp at 150 rev/min. This output corresponds to a bmep of over 11 kg/cm^2 (155 lb/in^2), which is much higher than the normal rating of the 680 mm bore Sulzer engine. This high output has been made possible by the use of the two-stage turbochargers with intercoolers after both stages of compression.

Because of its relatively low capital and operating costs a single-cylinder engine is generally preferred for research purposes. However, the two-cylinder version has been chosen in this case because it offers better possibilities for turbocharging and easier balancing. Two-stage turbocharging was chosen so that mean effective pressures of at least 12 kg/cm^2 (170 lb/in^2) can be attained; bearing in mind the cylinder pressures and temperatures that can be expected for the next generation of low-speed Diesel engines. It should be noted that as far as the very large-bore engines are concerned, research work is still in its early stages.

A BBC VTR 500 turbocharger operating on the impulse principle is directly connected to the exhaust ports via the oscillating exhaust valves, discharging its exhaust gases into an 11 m^3 exhaust receiver. From the receiver the exhaust gases pass through a BBC VTR 400 turbocharger, operating on the constant pressure principle. The latter turbocharger forms the first step of the scavenge air compression process. The air is delivered through an intercooler, for further compression by the first turbocharger. After passing through a second intercooler the air enters an 11 m^3 scavenge air receiver. About 80 per cent of the air compression is carried out by the VTR 400 and the rest by the VTR 500 turbocharger.

In order to prevent unacceptable vibration of the foundations and to avoid outside disturbance considerable attention has been paid to the balancing. The mass forces of the running gear are entirely balanced for those occurring at crankshaft speed since the cranks are at 180 degrees. However, the forces arising at twice engine speed are not inherently balanced and to compensate for them special balancing gear (Lanchester balancers) has been arranged at both ends of the engine. The reciprocating forces at 135 rev/min have a total magnitude of 30 tons. A pair of counterweights rotating in opposite directions at twice engine speed are chain-driven from each end of the engine.—*Shipping World and Shibuilder, May 1969, Vol. 162, p. 667–668.*

U.S. Designed and Manufactured Diesel Engine

The purpose of this paper is to present an American designed and manufactured Diesel engine, suitable for marine propulsion. The engine described is the Model 38A20 opposed-piston engine, as produced by Fairbanks Morse Power Systems Division of Colt Industries.

The 38A20 Diesel engine is a two-cycle, uniflow scavenged, opposed-piston engine with cylinders in line or a 45° vee. It has been designed with six and nine cylinders in line or 12 and 18 cylinders in vee, all rated at 1250 hp per cylinder. For marine propulsion, the engine may be direct reversing.

The cylinder block and lower base are mild steel weldments with low stress levels. A series of transverse bulkheads carry the stress between the upper and lower portions of the cylinder block.

Power is transmitted to the shaft through a cast-iron cocktail shaker, oil-cooled piston, and a nodular-iron connecting rod. The large lower piston controls the air inlet parts while the small upper piston controls the exhaust parts.

Since the valving action of the upper piston develops 15 per cent of the rated power, it is connected to the engine output by a rocker arm, rods, upper crankshaft, and vertical gear train.

The crankshafts are high-strength, nodular-iron castings with large corings in the mains and pins to reduce weight.

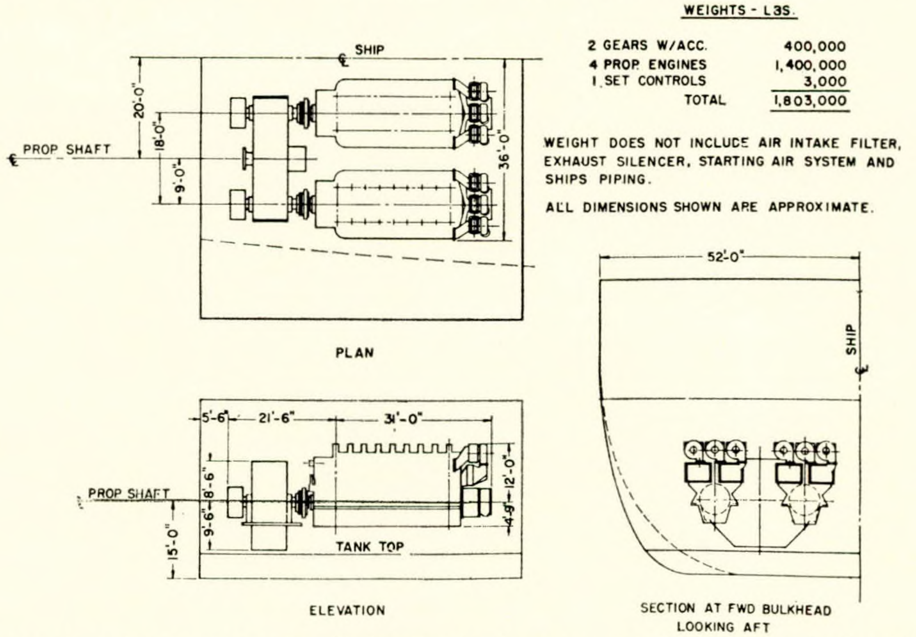
Successful operations on heavy-oil fuel have been achieved on cast-iron liners with an untimed cylinder lubricating oil system. The success is attributed largely to the low metal temperatures in the engine.

As marine Diesel engines must operate on the fuels available in the area in which the vessel is scheduled, the 38A20 engine has been operating on a heavy fuel which has a wide range of chemical and physical characteristics.

For the purpose of this study, 3500 sec. Redwood 1 at 100°F has been used. Maintenance schedules for the engine were laid out on this premise.

With proper design considerations, a 400 to 450 rev/min trunk-type, two-cycle engine without valves can operate on residual fuels successfully. As in other engines, the piston ring and ring groove wear will be slightly more rapid than on light oil. Increased maintenance on the fuel injectors may be required, depending on the fuel filtering and treatment system employed. Manoeuvrability on heavy fuel is not a problem if adequate heating of the fuel system is provided.

The figure is proposed layout for twin-pinion, 18-cylinder 38A20 engines used to develop 45 000 bhp in a twin-screw ship.—*Schumacher, G. F., Maritime Reporter/Engineering News, February 15th 1969, Vol. 31, p. 14.*



Overall arrangement of twin-pinion 18-cylinder Fairbanks Morse Model 38A20 Diesel engines used for twin-screw propulsion developing a total of 45 000 bhp

East-German Built French Line Cargo Motorships

French Line has taken delivery of the two 12 200 dwt cargo liners *Anjou* and *Auvergne* from VEB Warnowwerft of Warnemunde. These are of the so-called Type VI of this shipyard, modified to suit the owners' requirements by the installation of cargo refrigerated spaces and portable car decks. These vessels have the following principal particulars:

Length, o.a.	494 ft 0 in
Length, b.p.	459 ft 6 in
Moulded breadth	65 ft 7 in
Depth to main deck	37 ft $9\frac{1}{2}$ in
Depth to second deck	27 ft 2 in
Draught	29 ft $0\frac{1}{2}$ in
Displacement	17 780 tons
Equivalent maximum deadweight	12 200 tons
Maximum cargo deadweight ...	10 700 tons
Gross measurement	8718 tons
Net measurement	5084 tons
Cargo capacity (bale)	539 013 ft^3
Special lockers	5438 ft^3
Refrigerated space	25 320 ft^3
Trial speed, light ship	18 knots
Range	11 000 miles

There are five main cargo spaces, plus a refrigerated hold. Four of these are forward of the machinery and the ship is rigged with three bipod masts and a pair of samson posts, also a two-ton electric crane. The raised poop deck extends into the superstructure which embraces the accommodation for the crew at main deck level, petty officers, galley and mess rooms at poop deck level, officers and passengers on the bridge deck, and the captain and chief engineer on the boat deck. The outfit of cargo handling gear is generous, with conventional derricks for 5/10 tons at each hatch providing four and a half ton lift in union purchase plus a 60-ton lift into No. 3 hatch. This boom can be re-rigged to serve No. 2 hatch. The ship is fitted in No. 4 hold with MacGregor Extradecks.

Main machinery consists of a DMR (Rostock-MAN) engine type K9Z70/120S with nine-cylinders giving 8150 bhp at 130 rev/min. There are four Diesel generators, three of them of 340 kVA at 500 rev/min driven by an 8NVD36·1 DMR engine and one of 240 kVA. The engines for these were built by VEB Schwermaschinenbau Karl Liebknecht of Magdeburg.—*Marine Engineer and Naval Architect, April, 1969, Vol. 92, pp. 191–192.*

Declassified Data on SS United States

Perhaps the most interesting fact to come to light when the U.S. Navy took the liner SS *United States* off the secret list, was that for the past 15 years only six boilers out of the eight have been lit off (of course they have been rotated) and even the operating boilers have been run at an average of 60 per cent of capacity.

With these data in mind, and synthesizing the speed-power curve, it becomes apparent that the engine plant was not opened up all the way when the ship won the Blue Riband of the Atlantic way back in 1952. Estimating the top horsepower (220 000) and the horsepower for $29\frac{1}{2}$ knots cruising speed (about 108 000) either the Navy did not allow her to be run at her full speed of 40 or so knots (they wanted to keep that speed secret) or that something unforeseen happened above 37 knots so she could not be run at a faster speed than that.

At any rate, this enormously powerful plant drags across the Atlantic at only a fraction of its capacity.

An interesting touch is the four-bladed propellers on the forward shafts and the five-bladed screws on the after shafts. This choice was presumably dictated by vibration characteristics. Another fact is that there is less vibration if the forward propellers are run at a slightly lower rev/min than the after. At a sea cruising speed of $29\frac{1}{2}$ knots, the forward propellers, driven by twin sets of geared steam turbines in the forward engine room, run at 139 rev/min. The speed of the inboard after propellers, however, is 141 rev/min. These are driven from the after engine room.

Propulsion machinery of *United States* is neatly and logically laid out in a series of seven watertight compartments just above the tank top. As in some modern American warships, the fire rooms separated from the propulsion machinery rooms, and there is a separate room for the evaporators and refrigeration compressors. Starting forward is the first fire room that supplies steam to the forward engine room turbines. This room contains the four Babcock and Wilcox boilers, each of maximum capacity 269 000 lb/h. With Bailey combustion controls (circa 1950) each has ten B and W burners. The forward fire room, besides the four boilers, contains three main feed pumps (Worthington, driven by GE geared steam turbines) and one 1500 kW General Electric turbo-generator. If the plant were designed for 1000 lb/in²g, 1000°F steam conditions, it is not today being run at those figures. Actual conditions are 950 lb/in²g and 965°F at the superheater outlet.

Immediately aft of the forward fire room is the forward engine room. Side-by-side are the port and starboard propulsion turbines of an estimated 55 000 hp each. These consist of a straightforward H.P. and L.P. turbine arrangement working into double reduction gears. All of the propulsion engines were built by Westinghouse Electric Corp. They are manually controlled by means of the usual throttle hand wheel located near the centreline of the ship and connected to the steam chests via mechanical linkage. Electrical equipment is arranged on a level above that of the main turbines and control boards; a main switchboard is athwartship and two more General Electric turbo-generators of 1500 kW each are arranged port and starboard. Diesel-driven emergency generators are well out of the engine spaces. One is in the forward stack and the other on the promenade deck aft. The usual auxiliary machinery is found in this engine room on the lower level. Lubricating oil pumps and coolers, big 350 hp turbine-driven main circulating pumps, and port circulating pumps, and two enormous feedwater booster pumps driven by electric motor.

Aft of the forward engine room is the auxiliary engine room, containing four air-conditioning machines and three evaporators. Each evaporator is rated at 250 tons per day.—*Marine Engineering/Log, November 1968, Vol. 73, pp. 69–73; 118.*

Planned Maintenance of Shipboard Automatic Controls

As more and more ships go to sea fitted with control equipment monitoring complicated and complex pieces of machinery the continued reliability of such equipment is of paramount importance.

One of the primary reasons for installing such control systems is that with the greater attractions in land-based employment there are fewer trained engineers available or willing to undertake seagoing jobs. Therefore, the equipment fitted in these ships will be either maintained by men not trained in the art of instrument repair or left until the ship's overhaul when the maintenance can be carried out by fully trained personnel. Unfortunately this must be carried out at a maximum speed during the limited ship out of commission period. The obvious answer to this situation is for the ship operator to adopt a routine of planned maintenance in an attempt to reduce the instrument down time due to corrective maintenance.

An assessment of the maintenance of pneumatic or mechanical equipment seems to have been completely overlooked by those who are faced with the task of ensuring continual operation of their plant. It could be argued that these components are so reliable that no one need put pen to paper on their maintenance problems. Whilst it is true that these items have a very high reliability factor it is still essential that this information is available. The guide lines can be set by the experience gained from the electronic field.

The maintenance record must be a full and accurate record of what takes place. It should not include irrelevant facts like cleaning restrictors in pneumatic systems or checking earth leaks on electronic equipment; these should be regular checks and will be listed in the maintenance routine. Where, however, a unique check is carried out because a part is suspected and subsequently found to be correct or failed, these facts should be noted.

It will also be necessary to provide some self regulating arrangement to ensure that: a) the correct instrument is brought up for maintenance at the correct time; b) those instruments to be maintained during a shut-down period are available. It should also be apparent that adequate spare instruments or components should be on hand during this maintenance period. For items requiring lengthy overhauls complete replacements should be fitted whilst those they replaced are removed for service after the system overhaul has been completed.

This indicates that a complete inventory or instrument schedule must be maintained by those in charge of the maintenance task. This schedule must accurately list the equipment fitted and periodically be up-dated to overcome system modifications and obsolete equipment. Secondly each item must be programmed into shut-down periods along with the major components with which they are associated. Furthermore these shut-downs must be in line with the mean time between failure rate and the reliability index.

In planning this maintenance period, adequate time must be allowed for the maintenance to be completed with the test and calibration necessary. Also the maintenance period should make as much use of the available time between expected failure as possible. The period between maintenance sessions should not exceed the mean time between failures. *—Roberts, L., Shipbuilding and Shipping Record, April 4th, 1969, Vol. 113, pp. 470–471.*

Series of Liberty Ship Replacements

All four vessels of the Apollo series of Liberty replacement vessels, ordered in Japan at the Shimizu yard of Nippon Kokan K.K., have now been delivered. Three of the 15 660 dwt vessels, *Golden Chalice*, *Golden Cross* and *Golden Lance* are already at sea, and the fourth vessel, *Golden Fleece,* was recently completed and delivered to the owners, a company of Apollo Shipping Inc., New York.

The following description of one of the vessels applies, of course, to all four ships.

The vessel has six cargo spaces, each divided into a tweendeck and hold by a continued second deck. Hold No. 4 can be used as a deep tank for water ballast and all the holds have partial centreline bulkheads. These divisions enable the vessel to carry bulk cargoes such as iron ore, coal, grain and packaged cargo and timber.

Main particulars of the vessel are:

Length, o.a.	477 ft $2\frac{3}{4}$ in
Length, b.p.	449 ft $3\frac{3}{4}$ in
Breadth, moulded	72 ft $2\frac{1}{4}$ in
Depth, to upper deck	40 ft $8\frac{1}{4}$ in
Tween-deck height (at ctr.) ...	10 ft $10\frac{1}{2}$ in
Draught design	29 ft $6\frac{1}{4}$ in
Corresponding deadweight ...	15 660 tons
Draught, loaded (maximum) ...	30 ft $7\frac{3}{4}$ in
Corresponding deadweight ...	16 492 tons
Cargo capacity	
(grain)	825 800 ft³
(bale)	759 600 ft³
Gross register	10 396 tons
Net register	6759 tons
Trial speed (maximum) ...	16·96 knots
Service speed (loaded)	14·9 knots

Hull coefficients at design draught.

Block	0·7326
Prismatic	0·7454
Midships	0·9835
Waterline	0·8506
L.C.B. from amidships	−1·31 per cent

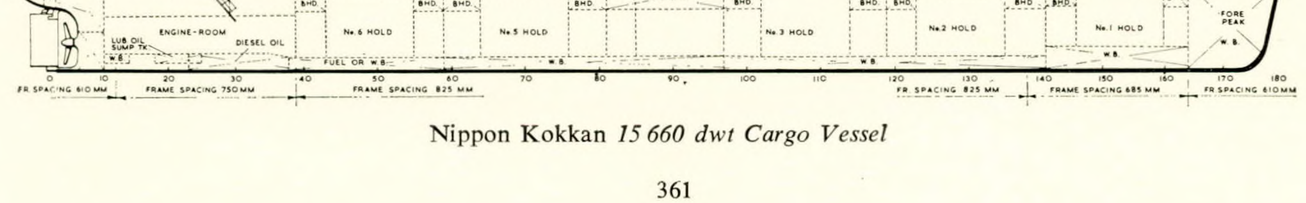
The Apollo series of vessels has a Sulzer 6RD68 engine built under licence by Uraga Heavy Industries Ltd. The engine is rated at 6470 bhp at the normal engine service speed of 130 rev/min. The fuel consumption is 25·3 ton/d with a bunker capacity for 46·6 days of 16 660 miles at service speed. The engine is directly coupled to a four-bladed solid propeller of 5 m diameter and 3·71 m pitch. A single rudder is fitted, which has an area of 18·22 m² with a balancing ratio of 3·0 and a 230 mm rudder stock diameter.

The machinery installation is partly automated, the main automatic items being starting and stopping of the main air compressors, temperature control for coolers, heaters and fuel tanks, purification of fuel and auxiliary boiler firing.—*The Motor Ship, June 1969, Vol. 50, pp. 137–139.*

Versatile Bulk Carrier

Upper Clyde Shipbuilders Ltd., have recently completed and handed-over a 38 457 dwt bulk carrier, *Volnay*.

Volnay, which was built by the Clydebank Division of UCS, is a versatile type of bulk carrier; it has been designed for the carriage of all types of grain cargoes without the use of shifting boards and it is of the self-trimming type. Other bulk cargoes such as cement, iron, ore, coke, etc., can be carried in the seven holds, all arranged forward of the engine-room/accommodation deckhouse in the now conventional manner for bulk carriers.



Nippon Kokkan *15 660 dwt Cargo Vessel*

An important feature of *Volnay* is that the vessel is designed to carry packaged lumber in the holds and on deck, up to a height of 22 ft 6 in. The ship is equipped with seven 10 ton capacity deck cranes of the ASEA electric design, using Ward-Leonard-type motor-generator-motor power. To give ample space for stacked deck lumber, the cranes are mounted on pillars well above the deck.

All accommodation and machinery are located aft and design features include a raked stem with a ram type bulbous bow, a transom stern and round sheerstrakes.

Principal particulars are:

Length, o.a.	193·06 m
Length, b.p.	182·88 m
Breadth, moulded	24·43 m
Depth, moulded to upper deck	15·24 m
Summer load draught	11·25 m
Corresponding deadweight ...	38 457 tons
Ballast capacity, including No. 4 hold (S.G.=1·025)	16 484 tonnes
Cargo capacity: grain	47 133 m^3
(without car decks) bale ...	46 361 m^3
Cargo capacity: grain	43 591 m^3
(with car decks) bale ...	42 891 m^3
Fuel bunkers	2426 tonnes
Service speed	15½ knots

Volnay is propelled by a Sulzer large-bore engine of the RD 90 design built by John Brown Engineering and installed by the Clydebank Division of UCS. It is a six cylinder machine of 900 mm bore and 1550 mm stroke and is rated at 13 800 bhp (metric) at an engine speed of 119 rev/min and with an m.i.p. of about 140 lb/in^2. The engine is fully equipped for operation on residual grade bunkers.

Two Brown Boveri turbochargers are fitted and at full load they will pass 112 500 lb/h of exhaust gas. At sea this is utilized in a Cochran exhaust gas boiler to generate steam at a rate of about 3200 lb/h and at a pressure of 100 lb/in^2. An oil fired Cochran boiler is also installed and this has an output of 2600 lb/h of steam, also at a pressure of 100 lb/in^2. —*Shipbuilding and Shipping Record, April 11th, 1969, Vol. 113, pp. 497–498.*

Polish-built Universal Bulk Carrier

The first of two bulk carriers ordered from the Stocznia Szczecinska shipyard, Poland, by Transportacion Maritima Mexicana, S.A., has been delivered. This vessel, *Azteca*, 25 897 dwt, the largest ship yet built in Poland, was designed by the Szczecin branch of the Ship Design and Research Centre. The plans were approved and the construction of the ship surveyed on behalf of the owners by Arnesen, Chistensen and Co., A/S, of Oslo. The hull incorporates a ram bow and bulbous stern, both used for the first time in Polish shipbuilding. During the measured mile trials, the speed of *Azteca* was found to exceed by between 0·1 and 0·2 knots that predicted from the model tests. The draughts over the mile corresponded exactly with those used during the model tests. A Diesel engine gives this new ship a service speed of 15·5 knots.

Principal particulars are:

Length, o.a.	610 ft 1 in
Length, b.p.	551 ft 0½ in
Breadth, moulded	74 ft 9⅜ in
Depth	46 ft 6⅞ in
Draught	34 ft 7 in
Deadweight	25 987 tons (m)
Gross tonnage	16 039
Cargo capacity, grain	1 239 840 ft^3
Ballast capacity with No. 4 hold filled	486 182 ft^3
Machinery output	9600 bhp at 119 rev/min
Cruising radius, approximately ...	14 000 miles
Speed at 10·55 m draught ...	15·5 knots

The shape of the rudder-stern connexion is designed to increase the efficiency by reducing water flow over the top of the rudder, thus increasing its lift, especially at a small angle which adds to the ship's course keeping.

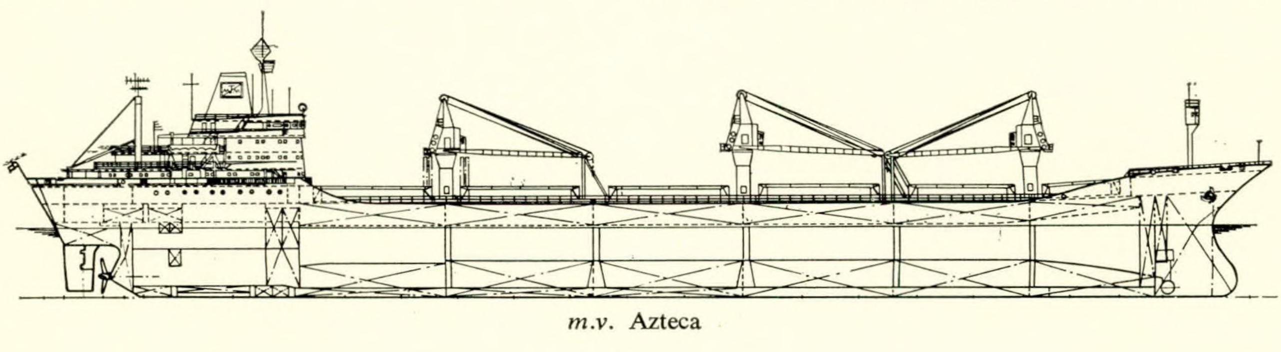
The propelling machinery in *Azteca* consists of a six-cylinder type 6RD76 H. Cegielski-Sulzer Diesel engine having an output of 9600 bhp at 119 rev/min, and arranged to run on heavy fuel of up to 3500 sec. Redwood 1 at 100°F viscosity. A remote control, automatic control and signalling systems enable the main and auxiliary machinery to operate unattended for 16 h/d. Remote control from the bridge has been arranged on the standard Sulzer system and is linked up with the controls in the control room, which are on a platform on the port side of the engine room.—*Shipping World and Shipbuilder, May 1969, Vol. 162, pp. 697–700.*

Ship Repair by Welding

The general principles of welding are the same in repairs as in construction. However, in repair work additional complications frequently occur. For example, the welding has often to be carried out on a rigid structure, i.e. the work must be done under conditions of restraint, the composition of the metal may be unknown and a combination of welding and riveting may be necessary. Corrosion, dirt, and oil can add considerably to the difficulties of the repair.

Speedy and successful repairs depend very largely on efficient planning and organization of the work. Usually the full extent of the repairs is only revealed after the vessel has been docked and first the extent of the material to be cut out and replaced must be ascertained and the amount of prefabrication possible should be calculated. Although drawings may not be necessary in all cases a schedule of welding procedure should be prepared. This should detail the technique to be used and give: a) details of plate edge preparation; b) gauge and type of electrodes; c) welding current and voltage; d) length of run per electrode or speed of travel; e) number and position of runs in multi-run welds; f) any other instructions or precautions.

Practical tests should be made to determine the details of welding procedures for the various joints to be made and they should take into account the availability of equipment and labour. The planning stage should include the making of arrangements for suitable staging and for the protection of



m.v. Azteca

the work from bad weather. It should also make provision for handling and holding devices and it may be necessary to make special arrangements for pre-heating and stress reliev-ing. When pre-heating is to be used, it should be borne in mind that it is usually better to pre-heat a large area to a low temperature than a small area to a high one. Cooling should also be slow.

Each repair must be considered individually but it is usually better to cut away all damaged plating as it is seldom possible to fair it without considerable difficulty. In cutting away damaged material, it is most important to avoid notch effects, e.g. corners should be cut to a radius and not made square. Cutting should be carried out with the maximum accuracy and fit up should have greater accuracy than is usually adopted in riveted work. Where excessive gaps and defective fittings occur in joints, these must be corrected, e.g. with distance or filler plates. Time and labour can also be saved if the cutting is arranged to give the correct angle of preparation for the joint to be made in sound metal. The edges of plates and sections should also be prepared so that adequate strength in the joint will be obtained with the least amount of weld metal and this will assist in avoiding trouble due to shrinkage.

The main object in planning the welding sequence should be to make allowances for contraction which will always take place because weld metal must contract on cooling. The guiding principle must, therefore, be to allow freedom of movement wherever possible to the parts being welded.—*Ailes, A., Ship Repair Number, Shipping World and Shipbuilder, May 1969, Vol. 162, pp. 79; 81; 83; 85.*

Maintenance of M.A.N. 52/55 Engine

It is now being shown that medium-speed engines burning residual fuel can operate for considerably longer periods between cylinder overhaul—several instances are known of 15 000–20 000 hours before cylinders have been opened up and this, coupled with the advantages of being able to drive electric generators, cargo and service pumps from either the forward end of the engines or from the gear-boxes, has contributed considerably to the growing confidence in medium-speed, geared installations.

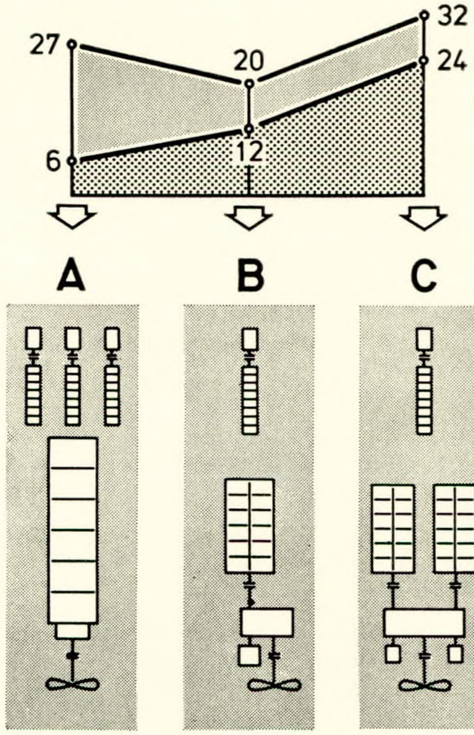
The newly developed M.A.N. type 52/55 engine, despite having a greater number of cylinders than a slow-speed installation of equivalent power, affords genuine advantages, particularly so when it is realized that this is an engine of 1000 bhp per cylinder designed with maintenance considerations in mind.

The advantages of driving generators or other auxiliary units through couplings off the engines or gear-boxes apply not only to operation at sea but also in harbour to provide sufficient electrical power for such items as cargo handling gear. Under certain conditions, such operation is also possible on heavy oil. For daily electrical power requirements in harbour, apart from when handling cargo, a single Diesel generating set is often sufficient. In view of the shorter periods during which this set is employed, it may therefore be satisfactory to use a high-speed unit of low initial and installation costs. Thus not only may costs be cut but maintenance work is also reduced.

Owing to the considerable increase in cylinder output of the new 52/55 engine and the reduced number of auxiliary engines required, the total number of cylinders of an installation can be reduced considerably. As a comparison between slow-speed engine installations and medium-speed plants incorporating VV40/54 engines the diagram given shows clearly the marked reduction in the total number of cylinders in the case of a layout incorporating VV52/55 engines. All three installations have approximately the same rating.

Layout A shows a main engine directly coupled to a propeller with three conventional auxiliary Diesels of type G7V23, 5/33A. In this case there is a total of 27 cylinders.

Layout C shows that, with the present medium-speed engines developing 500–600 bhp per cylinder, the total number of cylinders (in this case 32) is still high and that consequently the maintenance involved is somewhat considerable.



Comparison of three propulsion and generating plants with approximately the same output showing how the total number of cylinders is reduced in scheme B by the use of a V6V 52/55 main engine and one Diesel-driven generator set—The figures on the graph represent the total number of cylinders per layout (top) and the number of main engine cylinders (bottom)

In layout B, a V6V52/55 main engine with geared generator and a high-speed R8V22/30ATL auxiliary engine, giving an aggregate of 20 cylinders, the lowest total of three solutions, with correspondingly reduced maintenance work. —*Hellman, H., The Motor Ship, May 1969, Vol. 50, "Special Survey", pp. 36–44.*

Design of Harbour Launches

Many of the miscellaneous services required for the efficient operation of a port can best be fulfilled by small launches. Since these services are so varied the resulting boat designs cover a wide range but may be classified generally as follows:

1) towing launches;
2) mooring launches;
3) pilot or passenger launches.

The general considerations covering the design of each type are, of course, governed by the intended service. Type 1 must be designed for towing purposes and the screw, therefore, will have a finer pitch ratio than either of the other two types.

This type of boat must also be strong enough to withstand the knocks consequent upon the handling of laden barges. Free running speed is of no real consequence in this type of boat and is usually controlled by the need to obtain a given tow-rope pull at a speed of about three to four knots.

Type 2 must also be designed with towing in mind but free speed is of more importance. The after end of the boat must be wide to enable the crew to handle the mooring lines of the ships they are attending. Generally, therefore, these boats are transom sterned even though this may not be hydrodynamically necessary.

In type 3 the speed is of the utmost importance and the lines must be drawn accordingly. This type is often required to plane and this, in turn, means low deadrise and long parallel buttocks making the after section of the bottom as near a true plane as possible.

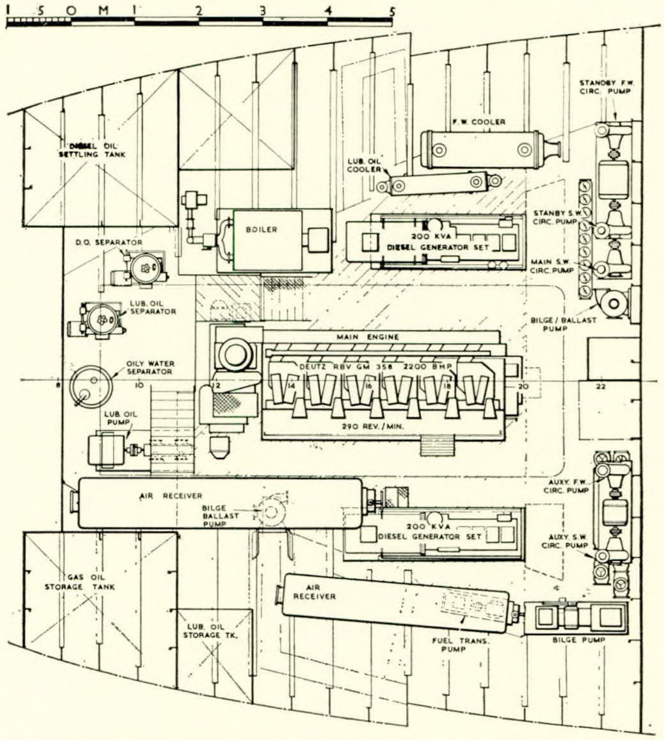
In all three types, the main dimension is the overall length as this affects not only the other dimensions and the speed but also the cost. To some extent it might be controlled by navigational hazards in a particular port but in all cases must be kept to a minimum.

Manoeuvrability is of prime importance in these boats and is an inverse function of length; the shorter the boat, the quicker she turns.

For all vessels operating in harbours manoeuvrability is of highest importance. Rudder areas for harbour launches are usually of the order of 5 per cent of the lateral plane area. Turning circles of between two and three boat lengths should be obtained with rudder angles of not more than 35 deg. Times for hard over to hard over are usually governed by the number of turns on the steering wheel since the torques generated are too low to justify a powered gear. This time nevertheless should be as small as possible. If the torque is high enough to justify a powered gear—4 tons ft being the dividing line—the time for reversing the helm should not exceed 15 s.

For the extra manoeuvrability required by the tug type fish tails can be fitted to the rudder with advantage although a small penalty in torque must be paid.

Stability is a prime consideration in any floating craft. In the case of harbour vessels it is of even more importance than usual owing to the hazards associated with their normal operating conditions. Static GM values of between 18 in and 24 in should be aimed for and should be checked by an inclining experiment. The range of stability should be as large as possible and must not be less than 55 deg.—*Hammond, N., Ship and Boat International, May 1969, pp. 18–20.*



Plan view at floorplate level of the engine room in the Deutz-engined Tasso

2800-dwt Vessel with Bulbous Forefoot

The 1600/2800 dwt shelterdeck ship *Tasso* designed to carry general and palletized cargo or containers was built by Martin Jansen Schiffswerft und Maschinenfabrik, Leer, Germany, for Reederei Johannes Bos, of Leer—a partnership of owners which operates a substantial fleet of small and medium-sized vessels both in its own services and on charter to other owners.

One of the most interesting features of the ship is that a bulbous forefoot is incorporated in the hull design—an unusual feature in so small a ship with a comparatively low speed of 14 knots. Furthermore, this is only the fourth merchant ship of under 100 m length to feature this type of bow design, which is normally associated with the larger ocean-going vessels of 20 knots speed or over.

When the order for *Tasso* was placed, the owner specified that a service speed of not less than 14 knots was to be maintained with an engine output of 2200 bhp while carrying a full load of 54 × 20-ft containers. The builders calculated that a normal type of bow would not allow these requirements to be met without lengthening the vessel and producing a set of finer hull lines.

A series of hull form tests were made in the Hamburg Schiffbauversuchanstalt ship model test tank which resulted in the bulbous bow being incorporated in the final design. The block coefficient is 0·65 to 0·7 over the loaded range of draughts and a saving on fuel consumption of up to 15 per cent is being made. A further advantage is better sea-keeping qualities in the adverse weather conditions which are frequently encountered on the North Sea service route.

Main propulsion power for *Tasso* is provided by a Deutz medium-speed engine of the RBV6M 358 type directly coupled to a fixed-pitch propeller. At 290 rev/min the rated output is 2200 bhp. It is arranged for local control or remote control from the wheelhouse by a pneumatic system jointly designed by the engine builder and shipbuilder. Operation is through a Deutz one-stop engine telegraph transmitter: an override switch is arranged in the engine room and normal telegraph transmitter/receivers are fitted. The remote control console situated in the wheelhouse of *Tasso* contains only essential instrumentation and running lights for the main engine which include a thrust overload alarm. Since the auxiliary engines are fully automatic in operation there are no starting buttons for them on this console, however, the Hatlapa air compressors can be started from the wheelhouse. Also included on the console are the talk-back facilities connected to the forecastle, etc.—*The Motor Ship, April 1969, Vol. 50, pp. 41–44.*

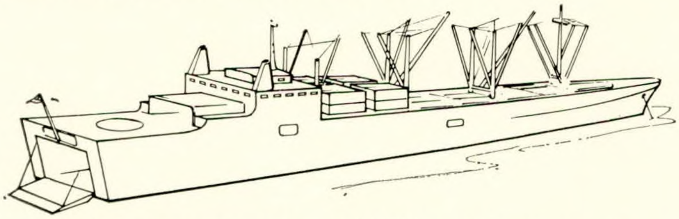
Ship Model Correlation of Five Similar Cross-Channel Twin Screw Motor Ships

Much thought has necessarily been given to the ship model correlation of single screw ships. Less is known of the correlation factors of twin screw ships. As carefully conducted measured mile trials were carried out on five cross-channel twin screw ships, of the same size, and as model results have been obtained separately for all these ships, a comparison between the results of the measured mile trials and the performance predicted by the tank trials and based on model results, has made it possible to obtain some more information on the validity of the tank prediction and the correlating factors.—*Aertssen, G., International Shipbuilding Progress, July 1969, Vol. 16, pp. 205–211.*

American Design of New Multi-purpose Cargo Ship

Details released by the U.S. Department of the Navy, of a new design of multi-purpose ship for the Military Sea Transportation Service, for which tenders to build are invited, show that although it is primarily a vessel to fulfil military requirements, its design can be adapted to commercial needs—especially container operations.

It is planned to institute a charter and build programme, based on this design of ships to replace existing MSTS-controlled ships and prospects exist for many of these vessels being built. It is emphasized that the military requirements for this ship design mean that it has characteristics not normally found in merchant ships.



Artist's impression of new MSTS multi-purpose ship

As the accompanying illustration shows, the strictly utilitarian design incorporates drive-on, drive-off facilities through a downward hinged stern door, twin funnels and a helicopter landing pad and hangar. The overall length is 648 ft (582 ft b.p.), the beam 92 ft, the depth 67 ft and the draughts 30·7 ft (full load) and 28 ft (designed). Displacement tonnages are: full load 31 960: design load 26 940 and light ship 9719.

The designed speed is 21·6 knots and full load speed 21 knots. Significantly no class of propelling machinery or power is specified, or whether single or twin-screw propulsion is required.

Regarding the cargo requirements, the roll-on/roll-off deck area is 120 870 ft^2, the dry cargo capacity 1 840 000 ft^3 (bale) and it is required that the ship can carry 1118 containers of the 8 ft × 8 ft × 20 ft size. Two heavy-lift 120 ton derricks will be fitted, in addition to 14 for 20-ton lifts and one of 10-tons capacity.—*The Motor Ship, June 1969, Vol. 50, p. 118.*

Large-bore Two Stroke Dual-fuel Engines

Broadly speaking, there are two main fields of application for large-bore dual-fuel engines: (a) methane tankers, and (b) power generation. So far, and in the absence of a suitable internal combustion engine, methane tankers have been powered by steam turbines using boilers with mixed burners. Taking such a typical case as, for instance, *Methane Princess* with a loading capacity of 12 700 tons of gas, an operating speed of 17 knots and a total shaft horsepower of 12 500, it can easily be figured out that, besides the gas flow obtained from natural evaporation, which usually amounts to 0·3 per cent per day, about 80 per cent as much liquid fuel must be added, if we consider the thermal efficiency of the steam plant to be 25 per cent.

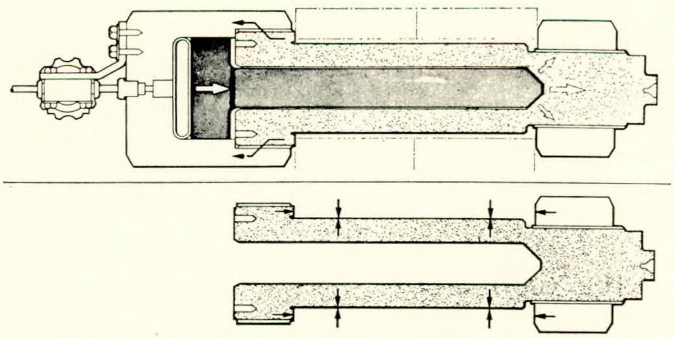
Replacing the steam turbine by a dual-fuel engine with a total fuel consumption of 1635 kcal/bhph would mean that as little as 8 per cent of pilot fuel is required in order to provide the same output as the steam plant. Or in other words, only a negligible fraction of the total fuel must be bought, the rest being provided, so to say, free of charge. Consequently, it does not even pay to use heavy fuel oil for that purpose. Further savings are realized by the fact that only about 10 per cent of the bunkering space for the fuel oil needed in the case of the steam plant has to be provided, and that no heating and purifying equipment for fuel-processing is required. This comparison illustrates, plain enough, the enormous savings which could be achieved by replacing the steam plant with a dual-fuel engine.

If future ships will be of larger tonnage, which is likely, the ratio of propulsive power to ship capacity will be reduced, provided the speed remains around 17 to 18 knots. In this case the evaporation rate required by the propulsion engine may fall as low as 0·2 per cent per day which would mean that the rest of the gas evaporated would be lost. However, it seems obvious enough and the known trends indicate that for such an expensive ship as a methane carrier, a higher speed might well prove to be more economical. This then would quickly put up the figure for the gas requirements to 0·3 per cent per day and over as mentioned before. This goes to show that even for future methane carriers the dual-fuel engine will again be able to provide the most economical means of propulsion.

A more severe problem may be presented if these carriers are to be super-tankers, requiring propulsive power above 25 000 bhp, an output which may still be provided by a 12 RND 90 dual-fuel engine. If this case should actually materialize (up to the present the largest methane carriers require an output of 20 000 bhp) twin-screw propulsion would be the answer.—*Shipping World and Shipbuilder, August 1969, Vol. 162, pp. 1148–1150.*

Hydraulic Bolt

As a result of research into the elasticity of metals and how this can be utilized to improve fastening methods for heavy engineering applications, Doncasters Moorside Ltd., have now produced the Morgrip hydraulic bolt. It is thought that this is particularly suited to marine applications such as flange and crankshaft couplings. Unlike conventionally fitted bolts which are usually hammered into their holes after heat treatment of the hole to expand it and chilling of the bolt to contract it, the Morgrip bolt has its shape temporarily adapted by application of internal hydraulic pressure so that it will slide easily into its hole.



Top—*Force distribution when the bolt is prestressed*
Bottom—*Force distribution when the bolt is fitted*
Diagram showing the principle of operation of the Morgrip bolt

The principle applied is that a bolt stretched along its length will suffer a contraction in its diameter. When pressure is released the bolt attempts to revert to its original dimensions and, being slightly oversize or under length depending on the application, grips the bore or ends of the hole with a metal to metal pressure of about 1·5 ton/in^2. To remove the bolt it is only necessary to apply pressure as before and slide the bolt out.

The required stretching force is generated within a nitrile rubber tyre, the thrust being transmitted through a piston to the bolt by a steel rod passing through the bolt's hollow centre. The reaction to this force is absorbed by the hydraulic head containing the tyre and piston. Although the bolt is hollow, its strength characteristics are at least equal to a conventional solid bolt.

Hydraulic pressures of about 30 000 to 50 000 lb/in^2 (2109–3515 kg/cm^2) are required to stretch these bolts and this requirement is met by a so-called air hydro pump developed by the company. Bolt sets are supplied complete with pump, operating gear and spare parts and the pump only requires an 80 lb/in^2 air supply to operate it.—*Shipping World and Shipbuilder, June 1969, Vol. 162, p. 821*

Ergonomic Aspects of Future Developments in Sea Navigation

As far as navigation is concerned the most important room on board a ship is the navigation bridge. With continuing and growing automation the importance of this room is increasing.

First, the bridge becomes increasingly the centre where everything happening in the ship is controlled. Already in many cases the operation of the engines, formerly performed in the engine room, takes place on the bridge. This remote engine control is a consequence of engine room automation. In this case the task of one man is reduced and another man's increased by controlling functions at a central station. In this way the number of men needed on board a ship is reduced. It is to be expected that in the distant future transatlantic freight traffic will be completely automated; these ships will have no crew at all. Supervision of such an automatic journey will be from the coast. This is the second aspect of automation's consequences. One can imagine that to moor and to enter into port, or even upon entering the English Channel, a small crew is flown aboard by helicopter much as a pilot is now brought aboard. But in this case, too, the navigation bridge will be the central control station.

This central station will have contact with the shore similar to an aircraft pilot's contact with the traffic control tower. In the future, ships on much frequented sea routes will be directed in much the same manner as aviation is controlled from a tower.

Radar stations along rivers with important ports like Rotterdam, along the rivers Elbe and Weser, are forerunners of more extensive radar control centres along the English Channel and on both sides of the North Sea. Sea traffic control as a parallel to air traffic control will increase to a large extent.

These future developments in navigation will present ergonomic problems connected with both aspects mentioned above. The shape of the navigation bridge should therefore be thoroughly studied.

One tendency is to arrange the instruments in a compact fashion behind which the officer of the watch has a central position. This arrangement is similar to that of a cockpit. According to another point of view a bridge should —besides having the advantages of the cockpit-type arrangement—also allow sufficient space in which to move about.

The solution is a combination of the two view points, a split-level bridge consisting of an enclosed pilot house and a bridge-extension one deck lower. In order to be able to keep control when standing on the wings of the bridge, instruments must be at least partially duplicated.

As has been stated in the introduction, activities on the bridge and those in the radar control centres should be integrated. For this purpose a greater uniformity in bridge construction is needed, in regard both to the instruments and to their location. A crew flown aboard to bring a ship into port should be familiar with any given bridge. It is therefore necessary to standardize. To be able to view in all directons greater use should be made of televison cameras which can be monitored on the bridge. Presently radar screens can be accurately interpreted only in the dark. During the day the screen receives too much ambient light and for this reason the display ought to be covered by a tube or be located in a separate cabin. The ultimate aim must be to have radar screens that can be scanned in broad daylight. Translating the radar image into a picture in the television monitor might be a possible solution to that effect. The same problem presents itself with the radar control centres ashore. The ambient light level cannot be high in order to inspect the radar screens properly; on the other hand, there should be sufficient light to allow writing notes and to prevent people from colliding with each other when moving about. In this case the "blue" radar lighting system is advisable.—*Walraven, P. L. and Lazet, A., Holland Shipbuilding, May 1969, Vol. 18, pp. 46–47.*

Container Damage and Repair

The various damages to containers can be divided into the following causes and resultant repair work:

Incorrect loading:

a) fork-lift truck damage to door sills and adjacent floor bearers, necessitating the renewal of the first four or five floor bearers;
b) internal loads breaking loose, causing damages to side and end panels, necessitating renewal of side panels and frames;
c) uneven distribution of internal load, causing sagging of containers, requiring removal of lower cant rails and fairing or renewal of them.

Incorrect handling:

a) lifting with fork-lift trucks under the lower cant rails in containers not fitted with fork-lift pockets, requiring part or complete renewal of lower rails, and possibly renewal of adjacent side panels;
b) dragging of empty containers over uneven ground, entailing renewal of sometimes, all the bottom bearers, and part renewal of the internal floor;
c) a very common damage—puncture of the roof in the vicinity of the corner pockets, due to misalignment of the lifting spreader by the terminal crane driver, resulting in renewal of the end roof panels, and possibly part of the top or end rails.

Incorrect stowing or storage:

a) over-stowing of the container in non-container vessels, causing complete collapse of the roof and complete distortion of the container frame. Although many damages of this type have been repaired, the major ones are not economical and are usually a total loss;
b) storing of loaded containers on uneven or unmade ground, causing damage to isloated floor bearers and possible distortion of the lower side rails.

Road haulage:

a) contact with low bridges or building overhangs is the most common damage of all, resulting in renewal of the front corner posts, the end, side and roof panels, and in most cases distortion of the lower side rails;
b) surprisingly, containers continue to be carried on road vehicles not fitted with proper securing devices, and those that come off while under way are usually a write-off.

Except for temporary repairs and patching it is essential that container repairs are carried out on a continuous or flow basis, with a routine procedure:

i) container arrives in the yard and a survey sheet is compiled, noting all damages, the underside and floor bearers being examined while lifting from the road transport;
ii) recorded damages are then divided, where necessary, into wear and tear, and recoverable damages;

iii) the different damages are costed on a labour and materials basis;
iv) quotations for non-recoverable damages are submitted to owners or hirers by telephone and in writing, and authorization to proceed received;
v) quotations for recoverable damages are submitted to insurer's surveyor after his survey and authorization to proceed received.

The patching and replacement of non-structural panels and stiffeners does not present any problems, provided there is competent labour available and a complete range of hand power tools, such as cup spanners, screwdrivers, shears, rivet guns, disc cutters, drills and fastening guns. With the thin sections in use gas shielded continuous wire arc equipment is the most advantageous.

With structural frame repairs welding sequences and contractions must be carefully controlled, in order that the repaired container conforms to the ISO dimensional limits, and to ensure this jigs for the various ISO container sizes for alignment purposes during repair and subsequent dimensional checking were produced.

The most difficult repairs are to containers the frames of which are distorted outside the ISO dimensional tolerances and on which thermal plastic deformation straightening has to be used.—*Hicks, J., Shipping World and Shipbuilder, July 1969, Vol. 162, pp. 978–979.*

Model Tank

A giant wavemaking test facility—believed to be the largest privately-owned installation of its type in the nation—has been placed in service at the Marine Research Center of Chicago Bridge and Iron Company at Plainfield, Ill.

Capable of simulating wave forces of virtually any body of water in the world, the new wave test tank is 250 ft long, 33 ft wide and has a unique, movable bottom which can be adjusted to desired depths to a maximum of 18 ft. When filled to capacity, the tank contains 1 250 000 gallons of water.

Fundamentally a design tool, the facility is used to test scale models of proposed underwater structures, such as oil storage tanks. Results of the tests provide design engineers with accurate information about the effect of waves on very large static or dynamic structures which will be affixed to the ocean floor.

The tank also is used to develop information about wave forces to be encountered in towing large structures from on-shore construction sites and submerging them at final under-sea locations.

While the regular waves created in the tank are less than two feet high, they can exert essentially the same forces on scale models that 100-ft high waves do on full-size structures.

In addition to the model wave test facility, the Marine Research Center has another major tool—an underwater test tank some 40 ft deep and 24 to 20-ft in diameter. Its primary missions are: to test very large-scale models of dynamic marine structures by setting the structures in motion, rather than the water, and to develop new techniques in welding and other underwater operations.—*Maritime Reporter/Engineering News, 15th June 1969, Vol. 31, p. 18.*

Cavitation Erosion Resistance of Propellers

The successful accomplishment of the primary missions of merchant marine and naval vessels is dependent to a large extent on their resistance to deteriorating and other natural effects of the environment in which they operate. A serious deteriorating effect of the environment which occurs in only isolated areas of ship's structures, is cavitation erosion. Cavitation erosion is the localized damage and removal of a material resulting from exposure to a cavitating liquid environment. It is normally associated with high velocity flow systems such as propellers, hydraulic turbines, pumps and hydrofoils. The erosion resistance of alloys is related to mechanical and metallurgical properties, including strain energy, hardness, tensile strength, fatigue strength, grain size, and cold working properties. In general erosion resistance increases with increase in strain energy, hardness, tensile strength, and fatigue strength, and with decrease in grain size. Cold working resulting in increase in hardness (strain hardening) also tends to increase erosion resistance. The erosion of polymeric materials has been shown to be related to the elasticity (related to the hysteresis or relaxation time), tensile strength, tear strength, and extensibility, the cavitation erosion resistance increasing with increase in these properties. High strength elastomeric materials are observed to be more erosion-resistant than metallic and plastic materials and serve effectively as erosion-resistant coatings when adequate adhesive strength is provided.

The significance of corrosion in contributing to cavitation erosion has been demonstrated. Investigations of the application of impressed current cathodic protection to suppress cavitation erosion in corrosive liquids have shown a decrease in current density. However, it was observed in these investigations that hydrogen bubble generation accompanied such cathodic protection. As aeration of water has also been found to be effective in decreasing cavitation erosion, it is believed that decrease of erosion by application of cathodic protection is associated with the formation of hydrogen bubbles. These bubbles increase the compressibility of the liquid and tend to cushion the cavitation bubble collapse—*Lichtman, J. Z., The Symposium on Naval Hydrodynamics, Rome, 25th–30th August 1968; International Shipbuilding Progress, April 1969, Vol. 16, p. 137–142.*

Hull Vibration

Within recent years it has become recognized that the divergence at the higher modes of vertical vibration are caused by local resonances of the hull, sometimes a deck structure, but most often the inner bottoms through the holds. improved methods also are being developed for studying the vibration of a ship transversely. This mode of vibration is strongly coupled with torsional modes so that reliable results cannot be obtained unless the complex bending-torsion model is used.

The theoreticians are now working on a finite element technique in ship vibration analysis. The practical difficulties here are the amount of time, expense, and experience that will be required to prepare the inputs to the computer and the large storage capacity that will be required of computers. (Present-day computers could not handle the calculation that has sufficient elements to improve the accuracy.)

Littleton Research sets up accurate mathematical models for the hull, its weight distribution and then analyses the model on a computer. A vital part of the prediction is using good engineering judgment on the selection of the stations along the beam (20 to 50 stations, depending upon the structural design). The calculation of a specific ship starts with a survey of local vibrations in different compartments. The eight-step calculation procedure is performed as follows:

1) compute the elastic properties of the hull as a function of length;
2) compute the weight distribution and the weight moments of inertia of the hull as a function of length and for different loading conditions;
3) compute the added mass, vertically and laterally, associated with the entrained water;
4) scan the ship for possible local resonances that might occur within the excitation frequency range and establish weight stiffness and damping values;
5) compute the harmonic forces and moments generated on the propeller due to the non-uniform wake;

6) compute the pressure forces generated on the propeller blades;
7) compute the amplitudes of vibration in the hull in the vertical bending modes over the frequency range excited by the propeller blade beat for the displacements of interest;
8) Compute the amplitudes of vibration of the hull in the coupled transverse bending-torsion modes over the blade beat frequency range and also for the hull displacements of interest.

The main propulsion machinery for ships is modelled into a multi-degree-of-freedom mass-elastic system. The values of the masses, stiffnesses, and damping constants are determined from available drawings and calculations. The forces transmitted to the hull via the main thrust bearings and the machinery foundations are calculated with the aid of a computer.

Three ships are now undergoing a hull vibration prediction. These are the Lykes *Sea Barge Clipper*, LASH ships and the high speed container ships.—*Reed, E., and Bianchi, R. A. Marine Engineering/Log, May 1969, Vol. 74, pp. 56–57.*

Slide Forces and Sidewise Movements During Launching

Over the years 1959–63, tankers of increasing size (up to 68 000 dwt) launched from Uddevalla's Sörvik berth were observed to slew on entering the water. Since it was hoped ultimately to launch ships of up to 150 000 dwt from Sörvik, a team from K.T.H. (Royal Institute of Technology, Stockholm) were called in to investigate the matter. This article describes the investigation, and gives the results obtained from the tests.

Tests were performed on a 1:100 scale model of the slipway using two tanker models, exactly scaled to have the same launching weight, draught, and moment of inertia as ships of 68 000 and 150 000 dwt. Measurements of water surface motion and of horizontal and vertical components of water pressure were taken during simulated launches, and water-induced moments were thereby calculated. The effect of wind was also measured.

Results of the tests were then compared with observations made of actual launches of two tankers of 78 000 and 93 000 dwt respectively, and good agreement was shown to exist between the two sets of results. It is now thought that ships of up to 250 000 dwt can be launched from this slipway without risk.

These conclusions are limited insofar as they apply only to the particular surface and undersea topology of the Sörvik launching way. They do, however, provide considerable data on the interaction of ship and slipway during the actual launch, and of the hydrodynamic effect of interference with the sea-floor. It was also possible to show that dredging or filling operations would not, within the limits of economic feasibility, materially affect the launching performance.—*Aberg, B., Teknisk Tidskrift, February 20th 1969, Vol. 99, pp. 153–167; Journal of Abstracts of the British Ship Research Association, May 1969, Vol. 24, Abstract No. 27 423.*

Refrigerated Gas Tankers

Three trends are apparent in the design of refrigerated gas tankers, namely full refrigeration (i.e. for the transport of gases such as L.P.G., anhydrous ammonia, and butadiene at their boiling points and at substantially atmospheric pressure); a considerable increase in size; and versatility, to carry more than one product simultaneously or in succession. Examples of the second of these trends are the orders placed with Cammell Laird and with the Swan Hunter Group, each for a gas tanker to carry more than 10 000 000 ft^3 of liquid gas. These two ships, which were ordered during the second half of 1968, are due for completion in 1970; the total value of the orders is about £8 million.

Ships of this kind can be broadly subdivided into low-temperature and very low-temperature types. The former carry gases such as L.P.G. (at about $-40°C$), ammonia, and butadiene; and those for natural gas (methane) and ethylene, whose boiling points at atmospheric pressure are about $-165°C$ and $-105°C$. The densities of the latter group of gases are lower than those of the first group, but both are low enough to require, when account is taken of the need for separate water-ballast containment, fairly deep ships' hulls with high freeboard.

The cargo-tanks for the first group of ships are usually self-supporting, but need special arrangements to prevent their movement at sea and to allow for expansion and contraction. They are generally insulated by a cover of polyurethane foam, protected externally by a material such as reinforced glass fibre, which also prevents ingress of moisture.

The cargo tanks of the very low-temperature ships may be of the self-supporting type, made of nickel-steel or aluminium; or the membrane type, which reduces the capital cost of the tanker by at least 10 per cent, but requires special precautions in the choice of insulating materials and in their application during construction. The article discusses methods of insulation of self-supporting tanks for natural-gas transport, and gives details of two designs for insulating membrane tanks in three ships now under construction. Cargo-handling equipment is also briefly discussed.

Future prospects of the refrigerated gas trade are considered at some length. If suitable refrigerated storage is provided at the reception terminals, L.P.G. vessels of capacity exceeding 18 000 000 ft^3 may be built. At present L.P.G., ammonia, and butadiene form the largest portion of the refrigerated-gas trade, and L.P.G., the most important member of the group, is likely to become more in demand for some years. Further in the future, however, natural gas may become the most important of the gases to be moved by ocean-going tankers. *Jules Verne*, of 9 000 000 ft^3 capacity, was completed for this trade in 1965; and tankers of over 35 000 000 ft^3 have been under consideration.

The demand for ammonia for fertilizers seems likely to increase over the next ten years. Butadiene world shipments are of 100 000 tons annually at present and are likely to remain at this level for the next few years.—*Modern Refrigeration, January 1969, Vol. 72, pp. 67–71; Journal of Abstracts of the British Ship Research Association, May 1969, Vol. 24, Abstract No. 27 403.*

Asymmetrical Lap and other Non-linearities in Valve-controlled Hydraulic Actuators

The results of a theoretical investigation into the effect of asymmetrical lap on the open-loop performance of valve-controlled hydraulic actuators are presented. The governing differential equations of the system are developed in a non-dimensional form. The effects of supply lap and exhaust lap on actuator peak pressures, ram amplitude and cavitation, as well as the effect of inertia load on actuator peak pressure and output amplitude are shown.—*Paper by Montgomery, J. and Lichtarowicz, A. submitted to I.Mech.E., 1969, paper P33/69.*

Study of the Movement of Water and of the Forces on Moored Ships in a Water Slope

Water motion in the "water wedge", which, it is proposed, may be used for transferring ships between different levels, is studied by using the linearized long-wave theory, which is shown to be sufficiently accurate for this problem by comparison with nonlinear calculations. Water and ship motions are minimized by a linear acceleration of the wedge such that it reaches its maximum velocity in a time equal to the fundamental period of oscillation of the system.—*Chabert, J., Annales des Ponts et Chaussees, March/April 1968, Vol. 138, pp. 67–90; Applied Mechanics Reviews, April 1969, Vol. 22, p. 370.*

Centripetal Flow in Face Seals

Measurements have been made of radial flow of liquids between flat annular rings, one of which rotates. As found by other investigators, a flow opposed to the centrifugal force can be observed. Experiments with dye showed that the flow is a one-way process, and is greatly influenced by film cavitation. It is concluded that cavitation may play a role similar to compressibility in causing a net inward flow when annuli are not truly flat and parallel.—*Nau, B. S., Lubrication Engineering, April 1969, Vol. 25, pp. 161–168.*

Microscopic Study of Metals Fatigued at Ultrasonic Frequency

This paper is devoted to a description of the microscopic observaton and the results of hardness tests conducted on the surface of metals fatigued at ultrasonic frequency of 17·8 kc/s. It was found that in iron and steel microcracks were initiated at the boundaries of pearlite and ferrite without any accompanying slipbands. This is in marked contrast with the surface structure in metals fatigued at conventional frequency.—*Awatani, J. and Katagiri, K., Bulletin of the Japan Society of Mechanical Engineers, 1969, Vol. 11, No. 49, pp. 10–18.*

Performance Tests of a High Yield Strength Steel for Ships

Increased use is being made of higher strength steels for ships. The present paper concerns the results of tests to evaluate the performance of ½, 1·2, and 2½ in thick plates of a 100 ksi yield strength constructional steel—ASTM A 517, Grade F—by means of explosion-bulge tests of unwelded and butt-welded specimens and of tension tests of butt-welded wide-plate specimens.—*Doty, W. D., Benter, W. P. and Manning, R. D., Welding Journal, December 1968, Vol. 47, pp. 534-s–542-s.*

Two- and Three-dimensional Fluid Transients

This paper presents an approach for the analysis of low-velocity two- and three-dimensional transient fluid-flow problems. The method assumes the continuum can be represented by a latticework of piping elements and that motion in the continuum can be described by solving the one-dimensional transient flow equations in the piping elements. The approach offers the advantage of being able to handle unusual and irregular boundary conditions, fixed or movable, but is restricted to the limitation of low match numbers.—*Streeter, V. L. and Wylie, E. B., Transactions of the ASME, Journal of Basic Engineering, December 1968, Vol. 90, pp. 501–510.*

Structural Growth Induced by Thermal Cycling

A study is made of the ratcheting growth of an elastic-plastic one-dimensional element subjected to thermal cycling in the presence of a sustained axial load. The cyclic temperature distribution across the element is taken as either linear or parabolic. The cyclic growth of the element is computed as a function of the cyclic temperature and sustained axial load.—*Burgreen, D., Transactions of the ASME, Journal of Basic Engineering, December 1969, Vol. 90, pp. 469–475.*

Selecting the Method of Turbocharging Four-stroke Diesels

The advantages and drawbacks of conventional methods of turbocharging are described. A quantitative comparison is presented, based on results of calculating the gas exchange process. The pulse system is shown to be superior to the constant pressure system over the entire range of charging pressures employed today, provided that groups of three cylinders with a common exhaust pipe can be formed.—*Ryti, M. and Meier, E., Brown Boveri Review, 1969, Vol. 56, No. 1, pp. 10–18.*

Possible Non-destructive Test for Hydrogen Content of Metals

The intensity of the nuclear magnetic resonance signal of hydrogen can be used as a non-destructive test to determine the amount of hydrogen absorbed on the surface of a metal. Descriptions of the measurement of nuclear magnetic resonance signals and techniques designed to increase the signal-to-noise ratio are discussed. Problems peculiar to ferromagnetic metals are mentioned.—*Fernelius, N., British Journal of Non-Destructive Testing, March 1969, Vol. 11, pp. 22–23.*

Research Methods for the Experimental Study of the Scavenging of Two-stroke Large Bore Diesel Engines

A description is given of the experimental equipment used and the test procedures employed at the FIAT Gas Dynamics Centre, for the study of the scavenging in two-stroke Diesel engines. The fluid-dynamic testing is based on both the static and the dynamic methods. The results obtained on the test rigs are compared with the performance of actual engines.—*Oggero, M., FIAT Technical Bulletin, 1968, Vol. 21, No. 3, pp. 86–92.*

Research on Scavenging of Two-stroke Large Bore Engines

The author describes the results of recent research carried out by FIAT on the scavenging of two-stroke large bore engines. A report is also given of the results obtained both through laboratory tests at the FIAT Gas Dynamics Centre, and on the full size engines by means of which it is possible to follow the evolution of the FIAT scavenging system.—*Ciliberto, G., FIAT Technical Bulletin, 1968, Vol. 21, No. 3, pp. 61–85.*

Sulphuric Acid Condensation from the Flue Gases Containing Sulphur Oxides

In one proposed method for removing sulphur oxides from flue gases, catalytic conversion of SO_2 to SO_3 is followed by controlled condensation of sulphuric acid. Previous work on acid condensation in this system has shown some divergences between the results of different authors. Recently published vapour pressure data for H_2O,SO_3 and H_2SO_4, above aqueous solutions of sulphuric acid, claimed to be more extensive and more accurate than those available hitherto, have made possible the construction of a general condensation chart with the co-ordinates of gas phase H_2SO_4 and H_2O partial pressures.—*Snowdon, P. N. and Ryan, M. A., Journal of the Institute of Fuel, May 1969, Vol. 42, pp. 188–189.*

Determination of Gross Chemical Kinetic Data for the Combustion of Common Fuels Using a Motored-piston Engine

The authors describe a method of obtaining gross kinetic data of the combustion of common fuels on the basis of combustion heat release pattern derived from a knowledge of initial conditions in the reacting charge and its pressure and density-time variations in a motored auto-igniting engine. The procedure adopted is largely dependent on the accurate provison of these input data and on the detailed knowledge of the thermodynamic and transport properties of the working system.—*Karim, G. A. and Khan, M. O. Journal of the Institute of Fuel, May 1969, Vol. 42, pp. 190–193.*

Thermal Properties of Combustion Gases from a Residual Fuel-oil-fired High Intensity Combustion Chamber

The temperature and heat transfer properties of gases produced by the high intensity combustion of a residual fuel oil have been used giving a maximum temperature of about 2400°K. Heat transfer rates have been determined by passing the gases through water-cooled 3-inch bore stainless steel tubes, and a numerical method has been used for obtaining the corresponding gas emissivities.—*Dombrowski, N. and Johns, W. R., Journal of the Institute of Fuel, May 1969, Vol. 42, pp. 194–199.*

Formation of a Shock Wave in a Blade Passage of a Partial Admission Turbine

The problem of unsteady flow in the blade passage of a partial admission impulse turbine with supersonic nozzle flow is introduced. Previous work carried out at Massachusetts Institute of Technology revealed the presence of a shock wave at the entrance to the blade passages and this report sets out to predict the formation of such a shock wave using a one-dimensional theory.—*Woods, W. A., Kuo-Hua Chu, F. and Mann, R. W., Transactions of the ASME, Journal of Basic Engineering, December 1968, Vol. 90, pp. 555–562.*

A Suction Scheme Applied to Flow Through Sudden Enlargement

This paper describes an experimenal study of the incompressible flow through a step expansion in a circular pipe as affected by suction through an annular gap lining the convex corner of the step. A uniform inlet flow with this boundary layer is considered. Application of suction at a rate greater than some critical value caused the flow to expand rapidly into the larger diameter, the degree of expansion greatly depending on gap orientation and size.—*Heskestad, G., Transactions of the ASME, Journal of Basic Engineering, December 1968, Vol. 90, pp. 541–554.*

Critical Speed Range of Ships in Restricted Waterways

A description is given of the flow phenomena which appear in a canal when a ship passes at a speed in the critical range. A brief discussion is included concerning the theoretical additional resistance of a ship, travelling at a critical speed due to the bore. This energy absorbing bore occurs throughout the critical range and travels ahead of the vessel. Model resistance tests were performed and indicate that the additional resistance due to the bore substantiates the theoretical findings.—*Hooft, J. P., International Shipbuilding Progress, May 1969, Vol. 16, pp. 145–154.*

Noise of Involute Helical Gears

This paper presents experimental results and a study of the noise of involute helical gears of different facewidths and pitches, running at different speeds, and transmitting different loads. The source of gear noise and noise generating mechanisms are also discussed.—*Attia, A. Y., Transactions of the ASME, Journal of Engineering for Indusry, February 1969, Vol. 91, pp. 165–171.*

Non-periodical Forces and Moments on a Ship in Waves

A method is advanced of determining the average of non-periodic hydrodynamic forces and moments exerted on a ship in waves. The calculating formulae are derived for unmoving and moving ships among waves in deep and shallow water. The results of Kochin, Havelock, Maruo, Newman, are obtained from the author's analysis as particular cases. A very simple formula is proposed for practical evaluation of the added resistance of a ship in oblique waves. The results can be applied to ships in irregular waves.—*Ankudinow, W. K., International Shipbuilding Progress, July 1969, Vol. 16, pp. 199–204.*

On the Balancing of the Fluctuating Input Torques Caused by Inertia Forces in the Crank-and-rocker Mechanisms

Some methods have been investigated both theoretically and experimentally to reduce the fluctuating torques in the driving shafts caused by the inertia forces in the crank-and-rocker mechanism; the spatial four-bar mechanism having two revolute and two speric pairs is cited as an example. The fluctuating torque has been actually reduced to one-twentieth–one-third.—*Ogawa, K. and Funabashi, H., Transactions of the ASME, Journal of Engineering for Industry, February 1969, Vol. 91, pp. 97–102.*

Rolamite Geometry and Force Analysis

The rolamite is a precision roller-band mechanism which was recently developed. The looseness of the rolamite geometry is a function of the band tension. The tight geometry and the slightly loose (small-deflexion) geometry may be described by simple equations. An energy method is used to derive a general form of the force equations.—*Cadman, R. V., Transactions of the ASME, Journal of Engineering for Industry, February 1969, Vol. 91, pp. 186–192.*

Configurations for Gas Turbine Compressor End Seals

Modern high performance multistage axial flow compressors have several air leakage paths which reduce compressor performance. A large number of seal concepts and ideas were examined for suitability. Each concept was evaluated on the basis of leakage rate, tracking capability, gas film stability, thermal and elastic distortion, wear, and reliability.—*Bjerklie, J. W., Cheng, H. S., Ludwig, L., Townsend, D. and Wilcock, D. F., Lubrication Engineering, April 1969, Vol. 25, pp. 169–175.*

Ultrasonic Inspection of Thin-wall Piping by Manual Methods

Utilizing ultrasonic inspection on thin-wall piping presents many problems when the transducer is manually operated. Drop through of weld material and excessive weld crown present the largest problems because of the different reflecting surfaces. The narrow contact surface is another major problem. These problems were solved through experimentation and applying a few ultrasonic principles that are often overlooked.—*Collier, J. W., Materials Evaluation, April 1969, Vol. 27, pp. 73–75; 84.*

Buckling of a Column with Random Initial Deflexions

The authors consider the buckling of an ensemble of infinitely long columns, with initial deflexions, resting on non-linear elastic foundations. The initial deflexions are assumed to be Gaussan stationary random functions of known autocorrelation, and the problem is solved by the method of equivalent linearizations. It is found that each column in the ensemble has the same buckling load that depends only on the autocorrelation of the initial deflexion functions.—*Fraser, W. B. and Budiansky, B., Trans. A.S.M.E., Jnl of Applied Mechanics, June 1969, Vol. 36, pp. 233–240.*

Comparative Study of Four Different Passive Roll Damping Tanks

Four passive roll damping systems have been designed for the same ship on the basis of equal loss in cubic capacity. As-design condition served the fully loaded condition leaving port. The unmodified tank installations are also considered in the loaded condition when arriving in port and when carrying ore. The ship's rolling in beam seas with each of the tank systems in action has been obtained by computation. A comparison of the respective properties is made.—*Vugts, J. H., International Shipbuilding Progress, July 1969, Vol. 16, pp. 212–223.*

Added Mass of Two Dimensional Cylinders with the Sections of Straight Frames Oscillating Vertically in a Free Surface

This is a general treatment of added mass calculation of two-dimensional cylinders with straight-frames sections and chines oscillating in the free surface of an ideal fluid with high frequencies. Two and three parameter families in vertical oscillations are treated by employing Schwarz-Christoffel transformation. The results are presented with regard to geometrical parameters such as chine angles, sectional area coefficient and beam draft ratio.—*Hwang, J. H., International Shipbuilding Progress, June 1969, Vol. 16, pp. 169–181.*

Removing Large Couplings by Hydraulic Pressure

Hydraulic pressure has been used for a number of years for removing couplings, bearings, rings and other machine components. Certain problems arise, however, with large couplings weighing several tons, and an investigation was carried out to find solutions to them. It is shown that it is possible to fit and remove large shrink joints several times.—*Chrobot, B., Brown Boveri Review, April 1969, Vol. 56, No. 4, pp. 195–200.*

Corrosion of Weathering Steel in Sea Water

The corrosion-fatigue properties of weathering steel in sea water were investigated with reference to its utility and efficiency as shipbuilding material. Repeated tension (in low cycle ranges) and reversed bending (in low and high cycle ranges) tests were applied on weathering steel plates. In low-cycle fatigue, the frequency of stress is, respectively, 10 c/min for repeated tension and 7 to 30 c/min for reversed bending. In the high cycle ranges for reversed bending only it is 1500 to 2200 c/min.—*Minami, Y., Ogawa, T. and Hashimoto, K., Jnl of Soc. Material Science, Japan, August 1968, Vol. 17, pp. 179; 718–722; Applied Mechanics Reviews, April 1969, Vol. 22, p. 358.*

Patent Specifications

Device for Tightening Joint Between Hatch Cover Sections

This invention relates to a device for tightening the joint between the adjacent cover section of a hatch cover comprising two or several sections.

Referring to Figs 1 and 2, the two cover sections (1) and (2) have a transverse joint (3) between them to be tightened by tightening means (4). The cover section (1) is provided, on the side (5) facing the cover section (2), with a number of horizontal bearing housings (6) attached to the side (5) by flanges (7) in such a way that a space (8) is formed between the bearing housing and the side (5).

Below the housings (6) there extends horizontally a flange (9) which at it free edge is provided with an elongated tightening projection (10) extending along the joint (3). This projection (10) engages from below a downwardly opening groove (11) on the adjacent flange (12) over the cover section

Fig.1

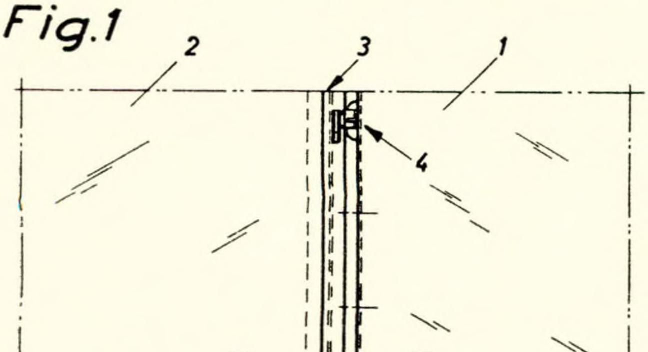
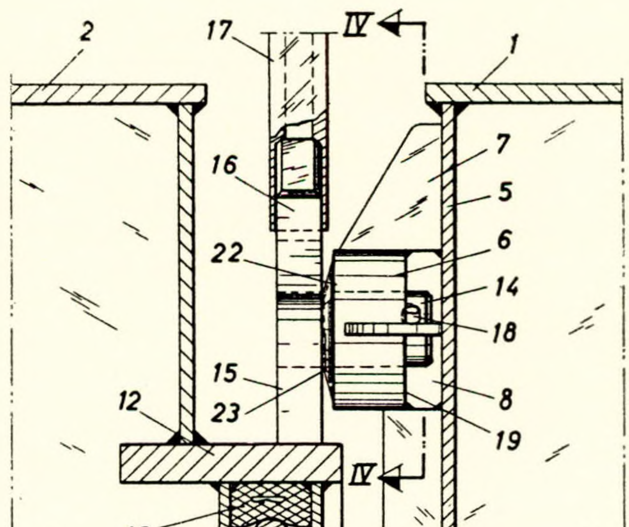


Fig.2



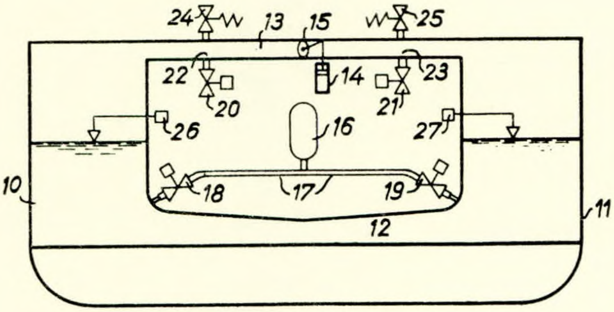
(2). In the groove (11) is inserted a sealing strip (13) which by means of a glue is attached to the bottom of the groove. In each of the bearing housings (6) is on a shaft (14) journalled an eccentric body (15) having an upwards extending arm (16) on which can be put one end of a lever (17), preferably in the shape of a tube, which by being swung into the operative position will effect tightening of the joint.—*British Patent No. 1 156 929 issued to Von Tell Trading Co., A.B. Complete specification published 2nd July 1969.*

Rapid Change of Liquid Level in Stabilizing Tank

This invention relates to a device for the rapid changing of the level of the liquid in the tank hold of stabilizing tank installations on board ships.

Two lateral tanks (10) and (11) in Fig. 1 of a passive anti-rolling installation are interconnected by a passage (12) and an air equalization line (13). A valve (15) is provided in the air equalization passage (13), which valve is operated by a setting member (14) and by means of which the air equalization passage (13) can be closed in airtight manner. A container (16) which contains dichlorodifluoromethane, under pressure, is connected through pipelines (17) and throttle valves (18) and (19) to the lateral tanks (10) and (11). Apertures (22) and (23), which can be closed by valves (20) and (21), and pressure relief valves (24) and (25) are provided. A device (26) and (27) respectively for measuring the level of the liquid is provided for each lateral tank.

Fig. 1

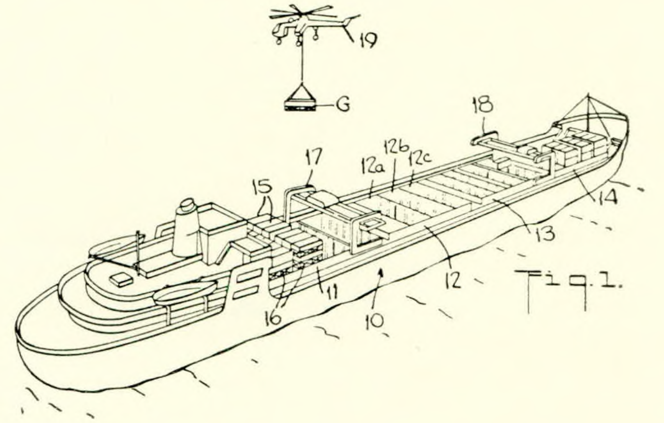


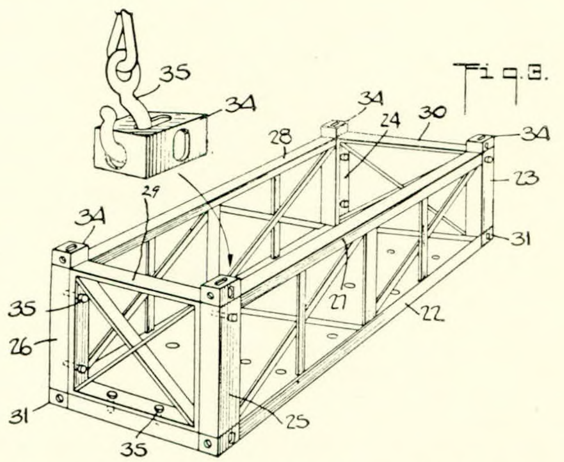
When a permanent list occurs in the event of a leak, the greater part of the tank liquid accumulates at the side of the ship where the list is and so emphasizes the heeling over.

After an alarm signal has been given, the valve (19) is opened and pressurized liquid dichlorodifluoromethane in container (16) is forced through valve (19) into the tank liquid in lateral tank (11). The valve (15) in the air equalization passage (13) is closed. The liquid gas expands and exerts pressure from above on the liquid in tank (11) so that some of the tank liquid flows to the other lateral tank (10).—*British Patent No. 1 156 587 issued to Licentia Patent-Verwaltungs-G.m.b.H. Complete specification published 2nd July 1969.*

Integrated Cargo Transportation System

This invention relates to a demountable gondola carrier of adjustable height which is capable of accommodating uncrated cargo. Fig. 1 shows an existing form of container ship (10), the hold of which is divided into major compartments (11), (12), (13) and (14). Each of these compartments is arranged by horizontal spacers and vertical beams into a number of cells such as cells (12a), (12b) and (12c) formed in compartment (12). The cells are dimensioned to receive standard demountable cargo containers, such as containers (15).





The same cells are adapted to accommodate gondola carriers (G) (see Fig. 3) in accordance with the invention. The gondola carriers have width and length dimensions corresponding to thase of the standard containers. The gondola carriers (G) and containers (15) are vertically stacked in the individual cells.

Both the gondola carrier and containers (15) incorporate top and bottom corner fittings, preferably of the type now standardized. It will be seen that container ship (10) is equipped with two travelling gantry cranes (17) and (18) which ride on rails. Each crane includes a transversely movable overhead trolley hoist. Rapid discharge of the vessel may also be effected by a cargo helicopter (19).—*British Patent No. 1 155 489 issued to C. H. Betjemann. Complete specification published 18th June 1969.*

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ANCILLARY SHIPBOARD SERVICES

Captain J. A. Smith, D.S.C., V.R.D., B.Sc., R.N.R., C.Eng., M.I.Mar.E.*

INTRODUCTION

A radical change in the pattern of ship construction and equipment has developed during the last two decades. In the early post-war years the ships which had been built during hostilities, usually steamers of utility design, were in demand. The need of ships built for landing and logistic operations was forgotten, except notably by Col. Bustard in this country, and the ship builder was asked to turn out conventional ships in large numbers.

These were similar to pre-war ships, but the main propulsion Diesel engines had improved in reliability to become a serious challenge to steam, and their ability to consume cheap grades of fuel oil established them as the favoured propulsion for all except the very largest ships.

The pressing demand for output from ship yards, and the abundance of goods waiting to be shipped prevented a clear appreciation of future requirements and various fleets were augmented by ships similar to their precursors, though somewhat bigger and more complex. It was therefore, possible for the tramp owner to charter his ship to a liner company, and later for the cargo liner to be chartered to tramping[1].

The bulk trades however, began to interest themselves in the movement of their raw materials. Atkinson[2] describes an ore carrier built in 1954 with machinery amidships. Later ships favoured the engines aft position and within limits imposed by facilities at loading and discharging points have increased in size.

Increase in size was most spectacular in tankers. Capey[3] has described how a drydock extension at Birkenhead was enlarged during the planning and construction stages, extending inland and into the river, as far as was possible, without catching up with the growth of tanker dimensions.

Drydocks on the Mersey can now take a ship of 120 000 tons. London River has accepted a tanker of 250 000 tons.

The largest tanker at the time of writing is *Universe Ireland* of 310 000 tons which has to unload offshore. Mintech has initiated design studies for tankers of 400 000 and 1 million tons. The Japanese shipbuilders have agreed to a limit of 400 000 tons.

EFFECTS OF SIZE

Size alone has little effect on the ancillary services, except in proportions, but the accommodation space in a big ship is such that living quarters can be provided on ample scale which in turn attracts amenity services. Such services are not exclusive to big ships, due to a high and rising standard of living ashore which is necessarily carried over to life afloat in all but the shortest and most regular passages.

Remote and, to some extent, automatic controls become necessities in the bigger ships, and have been found desirable for boiler steaming. Bigger ships, however, require higher power for propulsion and steam turbines have had a new lease of life in those ranges of output where a single Diesel engine was inadequate. Recent increases in cylinder dimensions and pressures have restored the Diesel to a competitive output (Table I).

* Superintendent Engineer Research and Development, Ocean Fleets Ltd.

TABLE I—LARGEST MARINE DIESELS CONTINUOUS SERVICE RATINGS

Maker	Bore mm	Stroke mm	B.m.e.p. Kg/Cm²	Rev/min	B.h.p. per cylinder
B. and W.	980	2000	10·45	100	3500
Fiat	1060	1900	8·95	102	3400
Götaverken	960	1900	9·34	105	3000
M.A.N.	1050	1800	10·2	102	3600
Sulzer	1050	1800	9·0	103	3200

Bigger ships require more auxiliary power and while in a steam ship it is convenient to use steam to drive the major auxiliaries, in the motorships electrical power is more convenient. In both classes of ship turbo-generators have been commonly used because, in steam turbine installations they can be integrated into the steam cycle with advantage and because high-power Diesels have considerable waste heat in the exhaust which can be readily extracted in a waste heat boiler.

EFFECT OF INCREASED CARGO SPECIALIZATION

Ships are now built with close regard to the particular requirements of the trade on which they are to be employed and to the terminal facilities available. Where the trade is in a single commodity or a limited range of commodities, the ships are consequently highly specialized and may incorporate elaborate systems peculiar to their trade.

Tankers are an outstanding example incorporating cargo, heating, pumping, and stripping systems of some complexity, tank cleaning and gas freeing systems, and a ballasting system of high capacity.

On the other hand, the ore carrier plying between terminals with full facilities has virtually no cargo systems in the ship, but will have a large capacity ballast system.

The ballasting arrangements are of great importance in ships with a quick turn round in port, since time in preparing for sea after discharge or for loading after a ballast voyage is unremunerative. The systems are relatively simple, but require remote control of valves for efficient and economical operation.

Heavy lift ships require more elaborate ballasting arrangements. A projected 500 ton lift ship will transfer ballast between pairs of port and starboard tanks of 800 tons capacity, using a pump of 800 tons output to keep the list within bounds when moving the lift athwartships.

In container ships, ballasting acquires a new importance in that the heel and trim must be kept within limits to permit the containers to move freely in their guides.

Systems other than ballast may be installed for moving and conditioning the cargo or for its protection.

A simple example is the bulk edible oil pumping and heating system for oils which solidify at normal temperatures. This is advantageous in that the cargo oil tanks in general cargo ships are often required for good quality dry cargo and absence of internal coils allows easier maintenance and cleaning.

At the other end of the scale there are carriers of bulk chemicals, liquid phosphorous and liquified petroleum gas. The latter is a well established cargo and while it can be carried under pressure and at atmospheric temperature, the containing vessels are heavy. It is, therefore, more economic to carry large quantities at reduced temperature and at about atmospheric pressure.

Temperature may be maintained by evaporation of the liquid petroleum gas and its subsequent liquefication and return to the tanks. The latter are insulated and enclosed in an atmosphere of inert gas which is available for purging and gas freeing the tanks and for pressurizing them at discharge, where it would be impossible to do so from the vapour return system or by gas generated in the vapourizer.

Some special cargoes require no equipment at all—cars and trailers may be driven on and off the special transporter ships, containers are lifted on and off by shore cranes. At sea however, they may be sensitive to excessive ship movement, and stabilizers may be fitted.

Hydraulically operated, gyro controlled stabilizing fins were brought out in 1920 and were effectively developed during the war. Since then they have become popular in passenger ships and ferry services for which they are admirably suited (Fig 1). The stabilizing effect is proportional to their speed through the water.

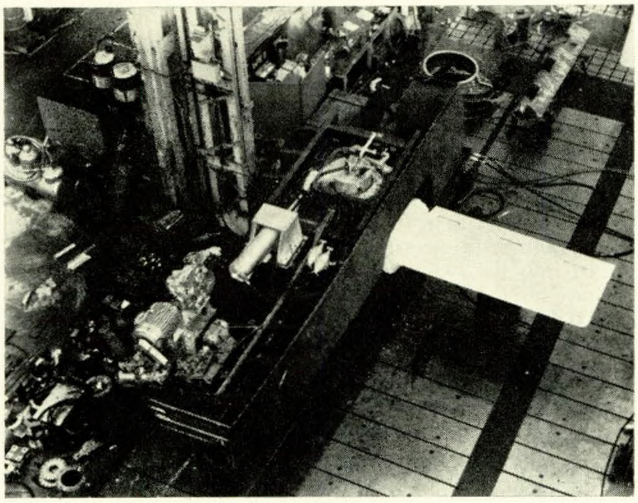

FIG. 1—*Stabilizer fin assembly*

Since the war requirements have arisen for stabilizing weather ships and missile tracking stations and for this purpose, an idea originally put forward in 1885 has been taken up with commercial success.

The roll of a ship may be excited by a relatively small wave motion, since it is the resonance of the wave pattern with the frequency of roll of the ship which causes exaggerated motion. By installing a tank, or a series of interconnected tanks, permitting free liquid flow back and forth athwart the ship with the same frequency as, but out of phase with the period of roll, a strong damping effect is obtained (see Fig. 2). The damping does not depend on the speed of the ship through the water and the system is cheaper and simpler than fins, although the installation may take various forms ranging from a simple tank fitted with swash plates to a system of port and starboard tanks connected through mechanically operated valves to tune the tank frequency.

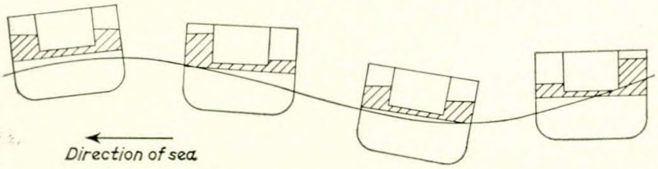

FIG. 2—*Damping effect of passive tank through a wave cycle*

This method is effective only at low values of GM and has the disdavantage of representing deadweight and free surface.

A 'passive tank' stabilizer has proved effective in ensuring that cars stowed on a vessel's transport deck are not subjected to excessive movement.

The care of many conventional cargoes has been improved by forced ventilation often associated with air drying plant or by methods of heating the cargo. Ventilation is not required for all types of cargo, but in most cases, and particularly on passages between extreme temperatures it is necessary to prevent excessive humidity. For this purpose the closed circuit ventilating systems incorporating a chemical drying plant for the air have proved very effective.

An alternative system has been proposed, whereby the atmosphere of the hold is circulated over a low temperature heat exchanger on which moisture condenses. This would be effective in drying the air, but would cool it thus reducing the temperature of the cargo. This could cause cargo sweat at discharge if the atmosphere were humid, and some form of reheating would be needed.

The conventional refrigeration of stores and cargoes has not changed much in recent years. The refrigerated gases have been standardized on Freon 12 and Freon 22 which are adequate for most applications. Elaborate brine systems are still needed for the large freezer ship, but the refrigerated cargo lockers fitted in so many smaller ships are usually cooled by air circulation direct over the evaporator, or by direct expansion into grids. Refrigerating machinery has improved, a screw type compressor has been developed and the technique of deep freezing otherwise perishable goods has led to lower temperatures being available in domestic stores and cargo rooms.

The small number of refrigerated containers carried in earlier years were usually self-contained, or could operate with a supply of electrical power only. A different approach is necessary to deal economically with the large numbers of tightly stowed containers in the latest ships, and systems have been evolved to distribute and return cooled brine or cooled air to the container stacks.

SAFETY

The statutory safety precautions demanded by governments have been the subject of various International Agreements, and common standards apply to a number of nations.

The requirements are directed to strength and stability and to the protection of the ship, by the provision of emergency power and of effective equipment for detecting and extinguishing fires in cargo holds and machinery spaces.

The traditional fire pump and fire main are still the foundation of ships' defence against fire. The latest rules are specific about the capacity of the fire pump and the size, materials and method of construction of the system. An emergency fire pump, outside the machinery spaces, with suitable valve arrangements to prevent loss of water through the machinery space system is required to prevent a fire in the machinery spaces putting the fire main out of action. The material of the fire main and joints must be fireproof.

Foam making branch pipes have a general use as well as particular application to hazardous chemicals. For machinery spaces and accommodation, small diameter hoses, pressurized up to the valve on the stand pipe have the advantage of being easily handled in the event of an emergency.

Fresh water from a tank charged by air pressure and arranged to cut in a sea water pump after a period might be used. This method is used for feeding of the sprinkler systems used in accommodation, where fixed piping systems are fitted with spray apertures sealed with temperature sensitive plugs. In the author's experience of three passenger ship installations, the rapidity with which the spray came into action extinguished the fire before the sea water pump cut in, and a great deal of consequent damage was avoided.

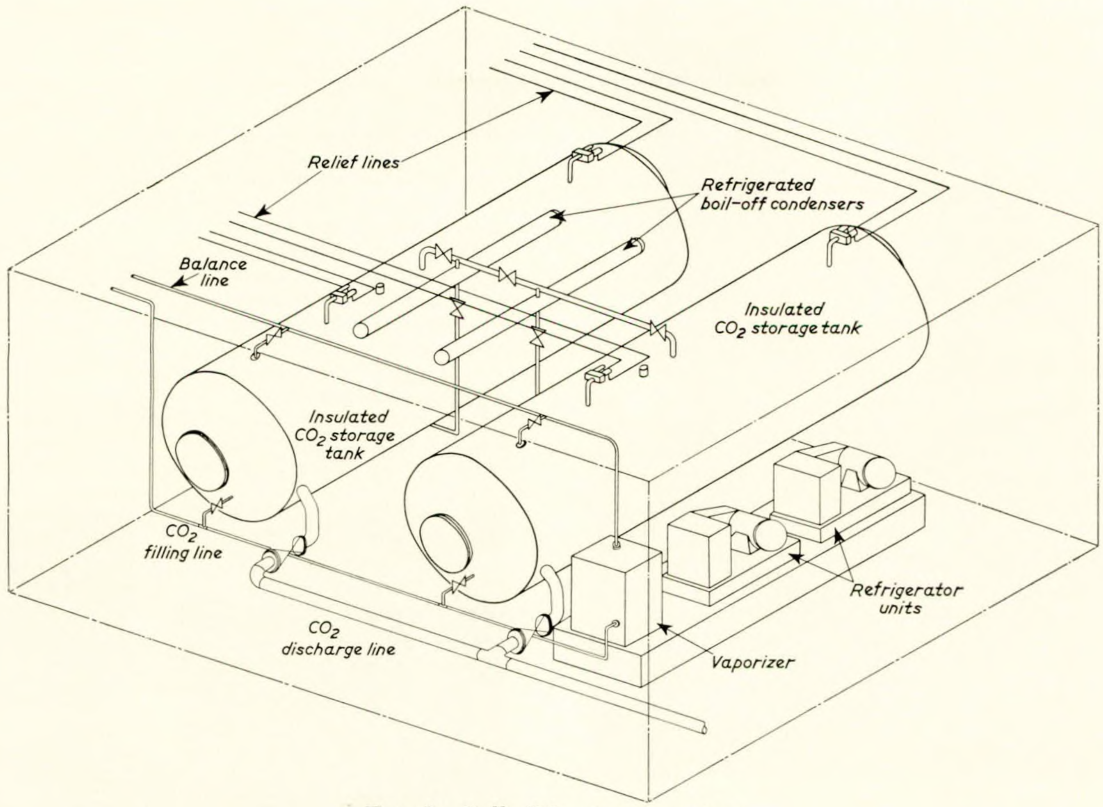

FIG. 3—*Bulk CO_2 storage system*

These installations, however, take up space, and the statutory requirement for inert gas fire smothering in the engine room and cargo spaces, takes up a good deal more, although less perhaps than some of the permitted alternatives. The quantities of CO_2 required for the big cargo spaces can be very large. For example, a hold of 7904 m^3 capacity will require a total of 94 cylinders each holding 45 Kg of gas.

An alternative to storage of CO_2 in cylinders is to hold the gas in two large insulated tanks, served by two small refrigerating plants. One or both of these are used to cool any gas boiling off the liquid, the condensate returning to the tank after losing its latent heat of evaporation. The temperature is maintained at 0°C and the pressure at 21 Kg/cm^2 in home waters (see Fig. 3). With this equipment it is practicable to carry a realistic quantity of carbon dioxide to provide protection for engine rooms and holds.

There have been other alternatives offered from time to time, including the continuous inert gas generator, which has been accepted for holds but not for machinery spaces and the latest high expansion foam which is B.o.T. approved for engine rooms but not for cargo spaces.

Both these have merit. The former has found applications not only in the liquid petroleum gas carriers, already described, but in an enlarged form in conventional oil tankesr, where during discharge a hazard exists from the mixture of air and petroleum. Pressurizing the tanks with inert gas prevents this hazardous condition being occasioned (see Figs. 4 and 5).

The second is fairly new, and has been tested and proved effective in spaces where it can flow freely. The foam is generated by a fan driving air through a mesh wetted with detergent. It operates by impeding free access of air to the seat of the fire, and by the cooling effect of the water entrained in the bubbles. It may be applied to car transporters and ferries, where the provision of CO_2 gas for the vast space of the decks is expensive and takes up space and deadweight. A system of distribution through ventilation ducting seems to be worth developing in the light of recent experimental work which appears to class as fairly limited the hazards associated with fires in parked cars.

Fire detection systems are required by statute in cargo

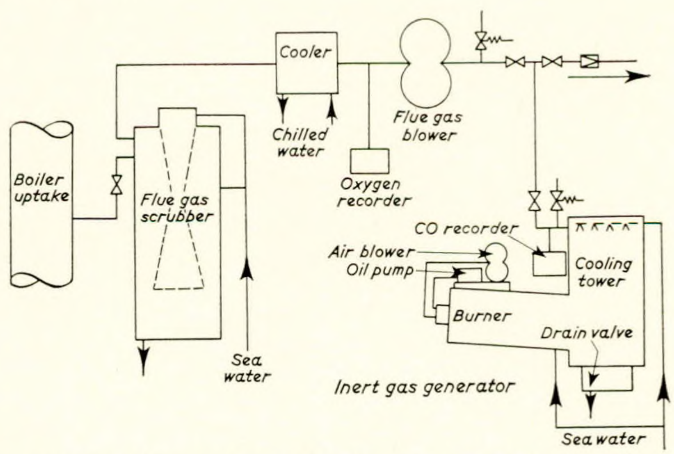

FIG. 4—*Flue gas system for inerting tanks with standby inert gas generator*

spaces and in unmanned machinery spaces. The conventional smoke detecting system, which can be used for distribution of CO_2 gas to the holds, is generally acceptable but although there is a visual indication of smoke and often a photoelectric monitor as well, the smell of smoke has been, in the author's experience, the most reliable indication of fire in cargo holds.

However, in the newer and larger ships especially where holds are fitted with closed circuit ventilation, smoke or fire detectors giving local indication of fire are desirable and the modern detector can be relied upon to detect early indication of smoke or fire.

AMENITIES

Of all the changes which have affected existing ancillary systems a rising standard of living ashore has had the greatest effect (see Fig. 6).

The larger ships and smaller crews provide opportunity

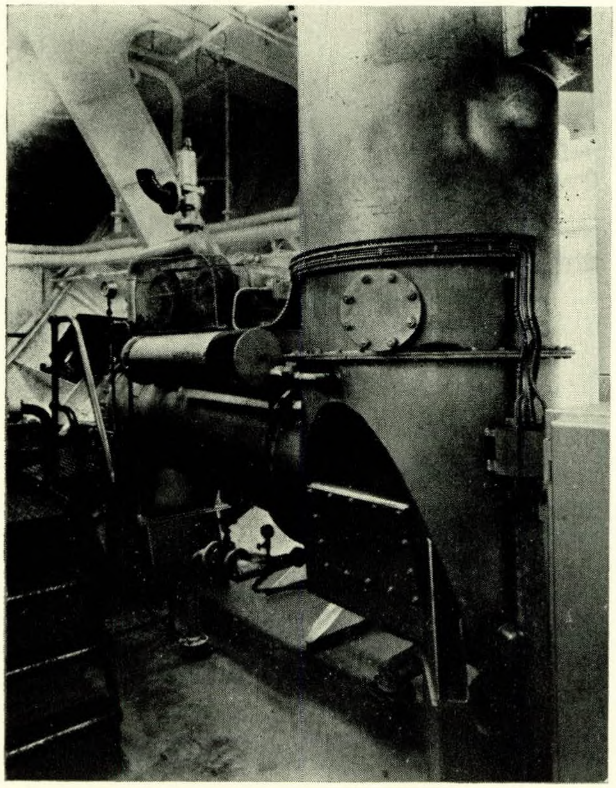

FIG. 5—*Inert gas generator*

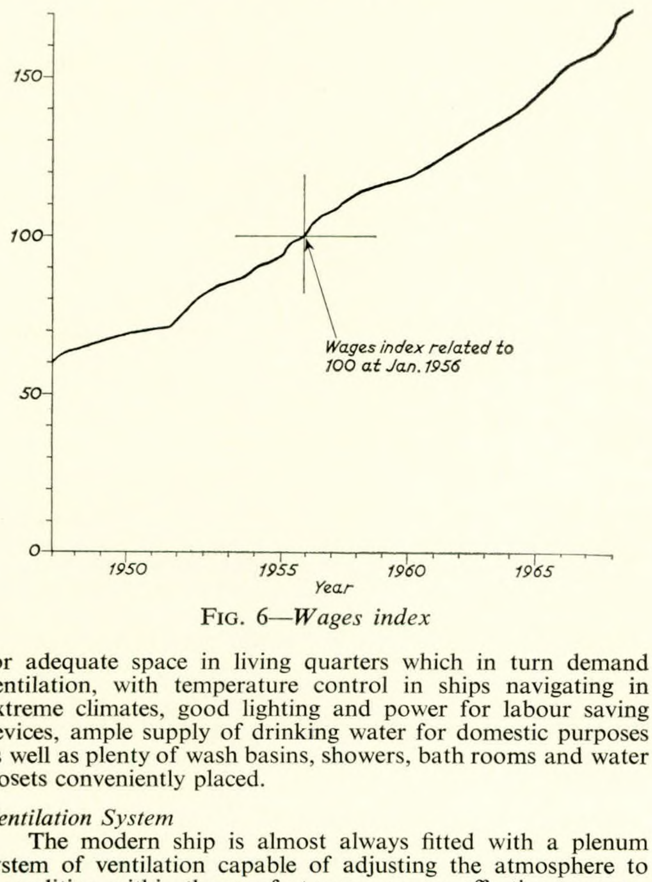

FIG. 6—*Wages index*

for adequate space in living quarters which in turn demand ventilation, with temperature control in ships navigating in extreme climates, good lighting and power for labour saving devices, ample supply of drinking water for domestic purposes as well as plenty of wash basins, showers, bath rooms and water closets conveniently placed.

Ventilation System

The modern ship is almost always fitted with a plenum system of ventilation capable of adjusting the atmosphere to a condition within the comfort zone, e.g. an effective temperature of approximately 23°C. Effective temperature is a useful concept deriving from the dry bulb temperature and the relative humidity, since one feels cooler at a given temperature when the atmosphere is dry than when it is humid. Suitable conditions are generally achieved by delivering heated or cooled air through a single trunking system, but with more elaborate systems twin trunks with hot and cold air are used.

A local mixing unit allows the temperature to be adjusted to suit individual requirements. A similar effect can be obtained from a single trunking system by delivering cooled air to a local unit embodying a heater.

Delivery of pre-conditioned air through a single trunking system is regarded as a standard application. The unit is generally a module, often complete as a unit containing a fan, heater and cooler with thermostatic control from the spaces served. The heater may be electric or steam. The cooler is usually a Freon unit with water cooled condenser (see Fig. 7). Freon 12 is the usual refrigerant because it is common with the ship's refrigerant plant but Freon 22 is used where the embarrassment of having two refrigerant supplies in the ship can be balanced against the greater efficiency of the Freon 22 unit which can be made smaller.

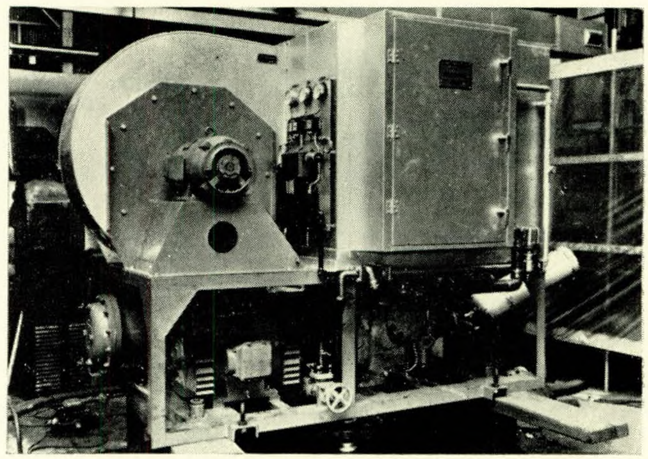

FIG. 7—*Air conditioning module*

The unit requires adequate drainage from the cooler since in humid atmospheres a surprising amount of water is taken out of the air. No satisfactory use has been found for this effluent although many efforts have been made to do so.

Distribution velocities are kept as high as possible and vary from 150 m/s to 300 m/s. The advantages of small diameter trunking, which are possible with high velocities, are balanced by the extra fan power required and the noise in trunking. Adequate sound installation is important, but it can be combined with the necessary thermal installation. Where trunking passes through unconditioned spaces, it is vital to ensure that the thermal insulation is sealed thus avoiding condensation on the outside of the trunking.

Where the ship has a brine refrigeration plant, a very effective arrangement can be made by using hot or cold brine, although this loses the advantage of the module system. It was used for a particular application by the author who engineered the installation of air conditioning in three passenger vessels already equipped with a brine refrigeration system. The ships were in the West African Mail Service where high humidity made conditions uncomfortable. They were originally built with a thermotank system of heating and ventilating and the conversion was made by replacing the original steam heaters by brine heat exchangers. A location for the plant was obtained in a lower hold space between the twin shaft tunnels and brine mains were laid from there to the units.

Vapour sealing of the existing trunking was overcome eventually by sprayed cocooning of the existing thermal insulation.

Domestic Water

Washing and sanitary facilities have lagged somewhat behind air conditioning but modern ships are well equipped.

It has been found possible to generate an adequate supply of fresh water by using waste heat, particularly from the jacket water of Diesel engines, in high vacuum evaporators which are a great improvement on the low vacuum evaporators used by the Navy up to the end of the war. The latter were adopted for passenger ships in the post war period but required skilled attention which cargo ships could not afford and bear no comparison with the automatic and fully reliable water generators available today (see Fig. 8).

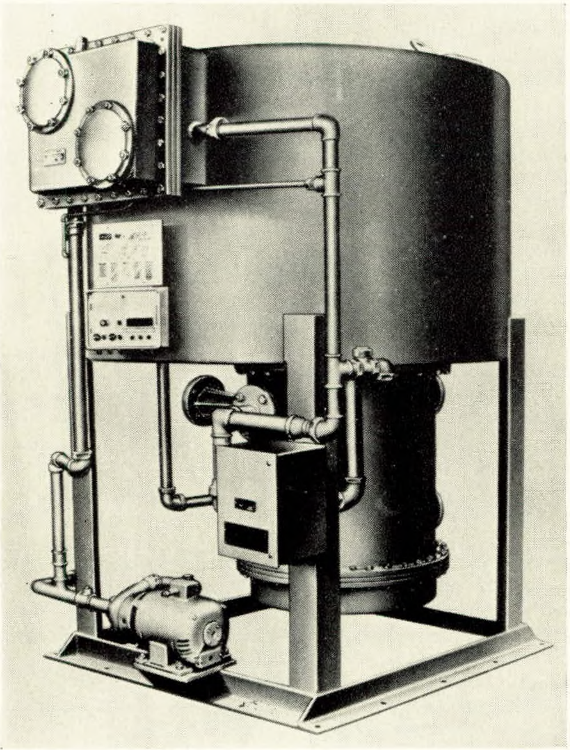

FIG. 8—*Fresh water generator*

Distribution for domestic purposes is by systems pressurized by air cushion tanks, the air pressure cutting in the supply pump as demand causes the pressure to fall. Treatment to make the water more palatable and safe to drink can be incorporated with injection of chlorine, alum and soda before filtration. Where the water is conveyed to storage tanks which may receive shore water, heavy chlorination is desirable. The water drawn from the tanks is passed through an activated carbon dechlorinator, after filtration.

The water is generally available to cabins throughout the ship and is intended primarily for washing purposes. There is still a statutory requirement for a separate drinking water tank to serve the galley and crew spaces. Chilled water has been supplied by way of a coil in the domestic cold room, but chilled water units with self-contained refrigeration are to be preferred.

Sewage Disposal

The availability of water on the present scale has raised problems of disposal of sewage. The original advantage of a sewage system was that the number of under water openings could be reduced to a minimum and for the ship trading generally, this remains the sole advantage. The incorporation of a solids collecting tank, however, enables the solid sewage to be retained on board in those ports where discharge of anything but liquid sewage is prohibited. Such ports and waterways are becoming increasingly common and where strict limits on the collecting of sewage discharge are insisted upon, considerable inconvenience can result unless the sewage system is adequate. In anticipation of the enforcement of strict limits over long distances, notably the St. Lawrence Seaway, elaborate bacterial and chemical sewage treatment plants have been developed. The bacteriological system illustrated gives an idea of the complication involved, although it is hoped that the system once set under way and appropriately treated will be largely automatic (see Figs. 9 and 10).

Chemical treatment has been more ambitious and rests on the principal of using fresh water flushing and by sedimentation and chemical treatment regenerating a supply of flushing water of acceptable purity. This has proved difficult.

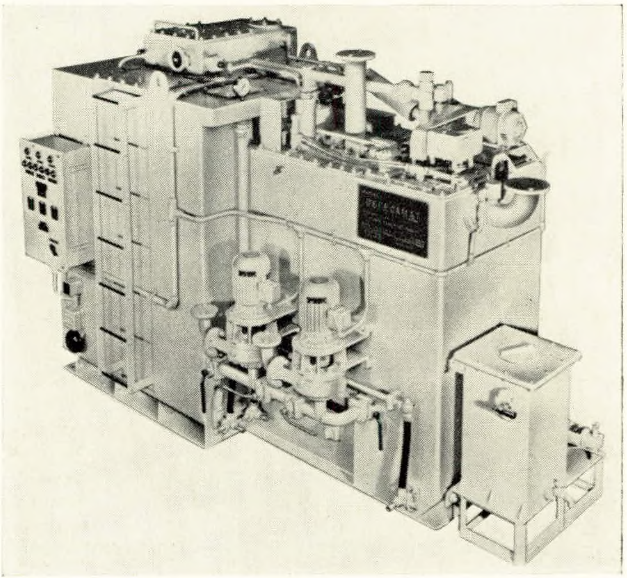

FIG. 9—*Sewage treatment module*

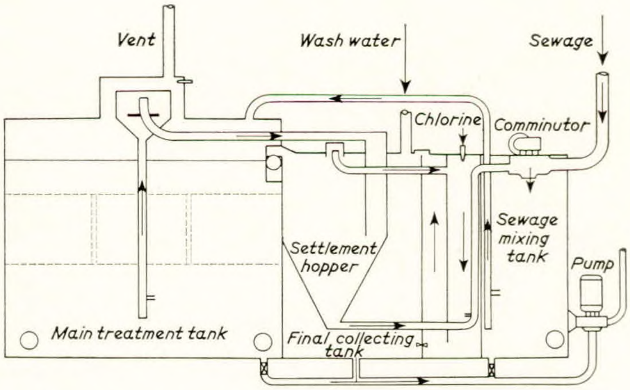

FIG. 10—*Diagram of marine sewage treatment unit*

AUTOMATION AND REMOTE CONTROL

The centralization of controls or their transfer to automatic means demand sources of power, for maintaining operating conditions and for activating valves and controls. Where power is electrical it does no more than add to the load on the electrical generating capacity of the ship, except in so far as the present state of electrical control development makes use of instruments susceptible to heat.

Where this occurs, it is effective to locate such instruments in an area which can be temperature controlled from the ships' air-conditioning system in a central control room, or in a console in the machinery space with air conditioning unit incorporated (see Fig. 11).

Control systems demand a source of power of which hydraulic and pneumatic are most effective.

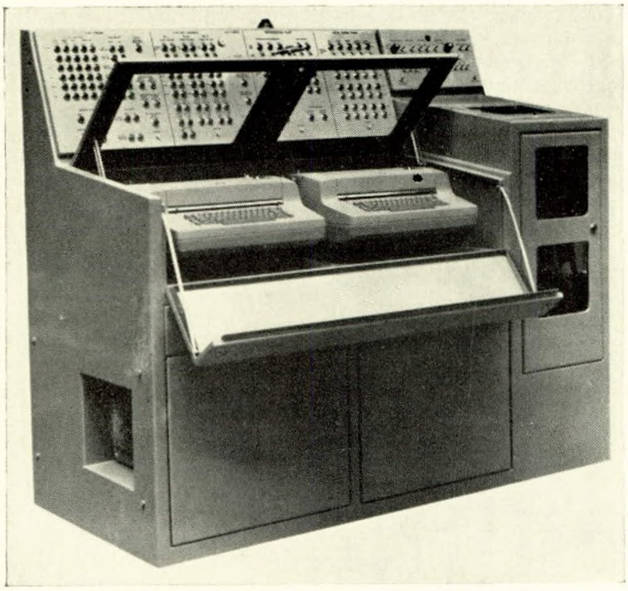

FIG. 11—*Data logger console with cooling plant incorporated*

Hydraulic systems can be combined with electrical control or may be in the form of simple servo mechanism. Generally they have the advantage of being sealed. Pneumatic systems, on the other hand, have the advantage that they can be used for sensing, particularly in tank sounding, as well as in the operation of valves.

The operation of valves has been made easier by radical improvement in design. Types of conventional valves can be operated by simple air motors, but butterfly valves are available and may be operated by an actuating cylinder. Improved methods of sealing make these valves completely effective.

For the source of power, the ship's air compressors can be used, though it is an advantage to have extra compressors operating at the pressure more appropriate to the function required. Filters and driers are vital components preventing interference with or damage to the operating parts.

THE VALUE OF ANCILLARY SERVICES

It is rewarding to examine critically all shipboard services before accepting them. In the context of the high cost of ship construction and maintenance it is necessary to weigh carefully the value of any component unit and system and to assess its reliability. Methods of doing this have been developed in management science which can be used profitably if discretion is exercised.

Work study is the systematic observation of the performance of tasks and the critical assessment of their contribution to the carriage of cargo in the ship. Falconer[4] has indicated how the technique can expose areas of wasted or misapplied expertise and how the information gathered may be applied to establishing a more effective work schedule employing a smaller complement of trained men on the work which is essential, while eliminating tasks which have no actual contribution to the effective running of a ship.

Some further work not yet published illustrates the method for assessment of areas where the frequency of essential tasks is undesirably high, and improvements to the stability and reliability of equipment are needed.

Where functions are found indispensible the system required to perform the function can be examined to establish the value of components in regard to the function.

The techniques for this, Value Engineering or Value Analysis, are relatively new and grew into a formal science in the U.S. Defence Programme. It was described by Matossian[5] and is defined as "an organized effort directed at analysing the function of hardware with the purpose of achieving the required function at the barest overall costs" [6].

A distinction is made between the value and the price of an item thus defining four basic types of value:

1) use value, based on the properties and qualities of a product and material fulfilling a specific use, work, and service.
2) cost value, based on the cost of a product in terms of money.
3) esteem value, based on the properties, features or attractiveness involved in pride of ownership of the product.
4) exchange value, based on the properties or qualities which make the product exchangeable for something else.

Only the first two would appear to be significant, although the third cannot be ignored and it is fortunate that they can be stated in precise objective terms for they must be related to a function also precisely defined in objective terms.

A great deal of care is required to define the term function. As an example a waste heat boiler in a motorship of medium power provides steam from the exhaust gases at sea and from oil firing in port. To do this, it requires a feed system, feed tanks built into the ship, feed treatment, blow down system, safety valves and waste steam pipes, oil burner installation and supply.

Its function in most cases is to provide heat for accommodation and ventilation, for the galley steamers, and possibly for heating cargo or fuel oils, all of which might be better provided by electrical means at the small cost of increasing the generator output, and having the great advantage of dispensing with the hazard of an oil fired boiler, making boiler watch keeping duties unnecessary, and saving money on the installation and maintenance of the boiler equipment and systems.

A feature of Value Engineering is a diligent and systematic search for alternative methods and materials to perform a function more efficiently, for often the designer of a system relies on the suppliers of equipment to bring forward alternatives.

For instance, the great work of Lamb established that fuel costing little more than bunker fuel could be used for marine Diesels by suitable heating and two-stage centrifuging. One stage of the centrifuge acted as a purifier, discharging water and unwanted solids while the second stage was arranged as a clarifier, to discharge only clean oil, leaving the last residues to be cleaned out of the purifier manually.

This system has been improved by using self-cleaning separators which, usually hydraulically, empty their bowl of sludge and maintain in a single stage the necessary efficiency to eliminate the need for clarification.

An alternative has been found in filtration of the oil at a suitable temperature and a number of plants are in use. They have the advantage of doing away with the rapidly moving parts of a centrifuge although they are not completely static, and the controls for heating, pumping and fuel changeover appear formidable. The degree of filtration must be very fine.

A relatively new treatment process might be taken as a alternative for value engineering purposes. This is homogenizing, after heating and removal of metallic and large particles by filtration. The object of the process is to break up the fuel into such small particles that the liquid becomes homogeneous so that the less combustible matter is burnt with the rest.

The process consists of directing a jet of fuel at high pressure onto a target plate, and there seems no reason why it cannot be applied (with duplicate equipment in case of any failure) to the direct supply of fuel to the ring main of the main engine.

This would eliminate the "Clean" daily service tank and the sludge tank, reducing the initial cost of the ship's installation, its maintenance, and the staff required to operate it.

As an indication of the direction a value engineering application could take, the author would refer to an installation used for application where sludge disposal was very difficult.

The elimination of part of the fuel system in this application is a very desirable end to the process. The demand for more services in ships and the sophistication of control mechanisms and systems causes so much equipment to be crammed into ships that maintenance has become a problem, and if systems can be eliminated they should be eliminated on that score alone.

THE RELIABILITY OF SERVICES

It does not seem possible to greatly reduce the maintenance burden on the ship's staff, but a great deal can, in part, be done by the systematic examination of the reliability of machines and systems, and the establishment of maintenance routines which ensure that work of refurbishing machinery is done to a plan, at times which are convenient and at such a frequency that, on the one hand unscheduled, i.e. breakdown, repairs are seldom if ever occasioned, and on the other that the plant is not opened up unnecessarily.

Systematic examination of the deterioration of performance is a field of Reliability Engineering, also borrowed from the Defence Programme, and while it appears as a very familiar outline to many experienced engineers, it is necessary to be more accurate in assessing procedures for investigation and correction of breakdowns.

A number of machines and systems has been developed over years to a high degree of reliability, and the optimum frequency of inspection has been established, often at lengthening intervals following developments in, for example, cylinder lubrication of Diesel engines, or of water washing techniques in main boilers. It is true to say that machinery in the modern ship requires less frequent attention, but closer adherence to overhaul schedules and procedures.

At one stage it seemed as if the machinery would outlast the systems themselves, particularly sea water piping system which, when made of galvanised mild steel, gave shorter and shorter life. This was due to higher speeds, and to galvanic action, and it is now common practice to make sea water piping of non-ferrous material to ensure that inconvenient renewals are not required during the life of the ship. The choice of material, the design and manufacturing methods have caused difficulty, but it is clear from recent experience described by Falconer[7] *et al*, that these difficulties can be overcome by a rigid application of good design and close specification throughout.

A British Standard embracing all aspects of design, specification, installation and testing is in preparation and B.S.R.A. are producing Standards for valves to match.

A further activity of B.S.R.A. is the publication of designs for modules, whereby in designing an installation the parts can be ordered up in a form which reduces the detail siting of units and gives the manufacturer an opportunity for standardizing his product.

FUTURE PROSPECTS

It is clear from the present state of the shipping industry, and its history, that ships as we know them are only likely to survive as part of an integrated transport system, and under conditions where they can be used to their fullest economic capacity.

They must be constructed to maintain such schedules as will satisfy the availability of cargoes and the requirements for delivery, and must have such gear as is needed to handle the cargo. At the same time, port facilities should be engineered to make cargoes readily available and to permit rapid discharge and quick turnround.

The ship should not have to carry additional weight, machinery, or be more complex than is necessary, nor should it be constructed to such standards as would outlast its useful life. In the provision of ancillary services, those for cargo handling will probably receive most careful attention, partly on account of their general novelty these days, but the ships' services require to be closely tailored to the ships' requirements to obtain a reliable and economic installation.

In pumping services this is greatly facilitated by the use of non-ferrous materials for piping which retain smooth surfaces and permit accurate calculation of pressure drop, and the choice of pump size to give the most efficient operation. Modern a.c. power supplies demand constant speed motors matched to their load requirements. Oversized motors operate at low power factors, and oversized pumps cause unacceptably high water velocities which demand output regulation by throttling, and cause undesirable turbulence.

This is important, because whereas the manual control of d.c. driven motors and operation of valves achieved with acceptable accuracy the flows required in the systems, the present day automatic controls are generally expected to work to closer limits, without the benefit of motor speed control. The required stability is difficult if not impossible to achieve if the working conditions are obtained by drastic throttling.

Successful design of a ship, therefore, must be founded on clear 'staff requirements' formulated in the light of the expected transport pattern. It seemed at one time impossible to contemplate an economic successor to the 'Liberty' Ships, which like other general cargo ships were coming to the end of their useful life. It is interesting to review the different solutions to this particular problem

As it appears likely that the function of new ships must be closely defined to permit them to operate profitably, their size, shape and method of propulsion may be radically affected in the future.

Heretofore the approach of Naval Architects has been understandably conservative, and in this country, according to Bishop[8] stultified to a degree by the lack of educational and professional opportunity at both graduate and post graduate level.

The effect of university participation on a grand scale in ship design and construction has been seen in the progress made by the Japanese, and while it has had most effect in their country in the development of large tankers, the general application of similar effort will radically change the style of other classes of specialized ship.

The impact of such change on ancillary shipboard services is hard to assess, but, for example, the requirement for low headroom in car ferries gives the medium speed engine an advantage. Such engines often incorporate pumps and heat exchangers, which simplify the ancillary engine room services.

The impact of Defence Programme thinking on general design principles has already been mentioned, and some significance attaches to the decision of the Royal Navy to use exclusively gas turbines for main propulsion and main power generation, also to the entry into service of the gas turbine driven vessel *Admiral Callaghan.* The simplification of the systems and the installation generally must be considerable.

On the other hand nuclear propulsion, which has been hanging fire for so long, may find a place in vessels employed in tanking and in container traffic, where a sufficient proportion of time is spent under way, and where terminals may be used which are safely out of range of areas of dense population. The ancillary services for the prime mover would in this case be greatly extended.

Two types of vehicle have been developed for marine transport, the Hovercraft and the Hydrofoil. Both are increasing in size and effectiveness, and in spite of the present drawbacks, appear to be establishing themselves in the short-sea fast ferry services.

Looking into the future, as clearly as can be seen, the shape of ancillary services appear to take the forms of:

1) an increasing extension of amenity services, but in proportion to restricted manning scales.
2) continuance of the present growth of automatic and remote controls and power assisted operation of the ship's gear.
3) a systematic use of modules and packages in design which will reduce the installation costs of units.
4) an attention to the durability and reliability of systems by improving reliability of machinery, and by the use of superior materials for piping systems.
5) an extension of cargo handling, and conditioning, and installed tank cleaning systems.
6) an increasing demand for electrical power.

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