UNATTENDED MACHINERY SPACES IN SHIPS—THE ESSENTIAL SAFETY FEATURES

D. Gray, B.Sc., C.Eng., M.I.E.E., M.A.I.E.E.E. (Member)*

The last five or six years have seen a great deal of interest in the subject of automation in ships in nearly all the maritime nations. A large number of ships have been built throughout the world containing widely varying amounts of control equipment. Many of these installations have been perhaps experimental with shipowners attempting to gain experience with such equipment. More recently, opinion has been crystallizing and in the last year a number of ships have been ordered and designed as suitable for operation with unattended machinery spaces. Such arrangements allow the engineer officers to work an eight hour day similar to that of their shore-based contemporaries.

Ships of this type with the machinery spaces unattended from say, 16·00 to 06·00, pose problems of safety for the shipowner. The paper describes the requirements which are considered to be essential in a ship intended to operate with an unattended machinery space.

These may be described briefly as:

i) Bridge control of the propulsion machinery.
ii) An automatic fire detection system in the machinery spaces.
iii) A fire extinguishing system in the machinery spaces.
iv) An alarm to warn of excessive bilge water.
v) An alarm system on the bridge and in the accommodation to warn of faults in essential machinery.
vi) A central control station for control of essential machinery.
vii) Security of electrical supply.
viii) Local controls for essential machinery.

The paper describes these various features in some detail.

INTRODUCTION

Since the *Kinkasan Maru* went to sea in 1961 and was hailed by her builders as the first "automated" ship, automation has been a topical talking point with all concerned with the marine industry throughout the world. Since that date many ships have been built with widely varying amounts of control equipment fitted. The extent of this interest can be seen from the fact that of the new ships classed each year by Lloyd's Register of Shipping the following can be described as "automated":

1962	1·7 per cent
1963	1·3 per cent
1964	4·6 per cent
1965	30 per cent
1966	37·5 per cent

Such installations vary from little more than rationalization of existing instrumentation and controls to very sophisticated control arrangements involving control of all the machinery from a central station, often with control of the main propulsion machinery from the bridge. These concepts frequently include the provision of air conditioned control rooms, automatic closed-loop controls and automatic data processing equipment.

The next logical step, for the future, would appear to be to employ one common control point for the whole ship by installing the machinery control position in the bridge/wheelhouse area. Such a concept has not yet been adopted, except in very specialized ships, most shipowners taking the view that the reliability of control equipment must be proved and that of main and auxiliary machinery must be improved before adopting such an advanced policy.

Whilst it is true that most shipowners are, very rightly, adopting this cautious approach, the current difficulties in obtaining and retaining the services of engineer officers has prompted some owners to order ships designed to be operated with unattended machinery spaces for part of the day. This allows the engineer at sea to work an eight hour day similar to that of his shore-based contemporary and, indeed, a small number of ocean-going ships has been operating in this manner for the past 2-3 years.

During the period that the machinery space is unattended it is normal practice to have one engineer "on call" to deal with any emergency that may arise. It is also normal practice that the machinery space is "manned" when the ship is in narrow waters, or in hazardous conditions, such as fog.

SAFETY FEATURES FOR UNATTENDED MACHINERY SPACES

The following features are considered to be essential in any ship intended to operate with the machinery spaces unattended, no matter what period of time is envisaged:

i) Bridge control of the propulsion machinery.
ii) An automatic fire detection system.
iii) A fire extinguishing system.
iv) An alarm to warn of excessive bilge water.
v) An alarm system on the bridge and in the accommodation to give warning of faults in the essential machinery.

* Principal Surveyor for Automation and Electrical Engineering, Lloyd's Register of Shipping.

vi) A central control station for the control of the essential machinery.
vii) Security of electrical supply.
viii) Local controls for the essential machinery.

Of course, items iii) and vii) are already required for any ship by statutory requirement and it is normal for item viii) to be provided. However, all the above items will now be described in more detail.

BRIDGE CONTROL OF THE PROPULSION MACHINERY

This must be fitted so that the sole watchkeeper, viz, the bridge watchkeeper, may take suitable action in an emergency. This must be accompanied by sufficient instrumentation to inform the bridge watchkeeper that his commands have been carried out.

The bridge control and associated instrumentation should be as simple as possible and consequently extra safeguards must be built into the system over and above those required for engine room or control room control. The object should be to take as much responsibility as possible from the bridge watchkeeper so that he may be free to devote his attention to ship handling: he should be able to move the bridge controller without having to consider its reaction on the main machinery. In other words the control system must now supply the servo link previously provided by the watchkeeping engineer in the chain of command between bridge and machinery.

Thus with a Diesel engine the extra safeguards would include:

a) When on bridge control the other control positions should be ineffective.
b) Automatic starting should be incorporated with bridge control so that the bridge watchkeeper has maximum freedom to concentrate on ship handling.
c) In the event of failure to start, the control system should return to zero and the starting operations should then be repeated. Only a limited number of starting attempts are acceptable, dependent on the design of the engine plus the control system. An alarm should be given at this point. An unlimited number of starting attempts without an alarm may exhaust the available air supply.
d) It should not be possible for the engine to run continuously in a barred speed range.
e) Time delays should be built into the system so that emergency manoeuvres e.g. full ahead to full astern are carried out with safety on the engine no matter how rapidly the bridge controller is moved. These delays will be dependent on the design of the particular engine.

With steam turbine propulsion machinery the extra safeguards should include:

f) When on bridge control the other control positions should be ineffective.
g) The throttle control system should be arranged so that it cannot be energized until the turning gear is disengaged.
h) Time delays must be built into the control system so that the bridge watchkeeper may operate the bridge controller as rapidly as he wishes, yet the rate of opening or closing of the ahead and astern valves should be so arranged that it does not exceed the set maximum rate laid down by the turbine designer; or as adjusted during trials. Both ahead and astern valves should be fitted with overspeed limiting devices.
j) If the controller is moved rapidly from ahead to astern, the astern valve should open while the ahead valve closes. This will speed up the change in shaft speed and will also reduce the range of load swings on the boiler. A similar action should take place when moving the controller rapidly from astern to ahead.
k) In order to further reduce the possibility of excessive boiler level swings and pressure swings the control system should continuously sense boiler level and turbine inlet pressure. Thus the turbine valves should not open more rapidly than the boiler level and steam pressure will permit.
l) When preparing for manoeuvring it has been normal practice for the bridge to request the watchkeeping engineer to set the plant up for manoeuvring. Such a facility must now be provided by the control system. Frequently this is achieved by means of a "Mode" switch. Actuation of the switch from "Normal" to "Manoeuvring" carries out some, or all, of the following actions:
   i) opens the astern guardian valve;
   ii) starts the main circulating water pumps on high speed;
   iii) opens L.P. turbine drains when speed has fallen below a certain figure;
   iv) shuts off bled steam and provides alternative heating of either feed water or combustion air.

   If for any reason the bridge operator should find it essential to go rapidly from ahead to astern and should fail to operate the mode switch then the movement of the controller into the astern position should automatically set the mode switch to the manoeuvring position.
m) Means should be provided so that if the turbines have been stopped temporarily from the bridge they are rotated slowly, or from time to time, so as to prevent damage to the turbines.
n) The steam valves should be closed for a number of emergency conditions such as high and low water level, loss of electric power, low condenser vacuum, failure of extraction pumps, loss of lubricating oil pressure, excessively high temperatures in gearing or turbine bearings, excessive axial movement of rotor or excessive vibration in the turbine.

With controllable pitch propellers:

o) A pitch indicator should be fitted to indicate not only the amount of pitch but also the direction, i.e. ahead or astern, the thrust will propel the ship when the engine is turning in what is normally the ahead direction. If a reversible engine is fitted means should be fitted to indicate the direction of rotation of the engine.
p) A means of preventing excess torque on engine and shafting is required. One common method is to provide interconnexions between engine governor, pitch controller and speed sensor so that pitch is automatically reduced if torque becomes excessive.
q) The system should give advance warning of failure of pitch control power, i.e. the pitch control power for the bridge controller which transmits a signal to the propeller blade mechanism. This is usually pneumatic and must not be confused with the control power which actuates the propeller blades.
r) The control power to actuate the propeller blades is usually hydraulic and if both pumps should fail then the blades should be adjusted and locked in the desired position, e.g. the full ahead position, so that the vessel may get home (with a reversible engine the vessel may be manoeuvred in the orthodox manner which provides a certain advantage for such a system).

AUTOMATIC FIRE DETECTION SYSTEM

Probably the main factor which deters a shipowner from moving to an unattended machinery space is the fire risk. Machinery space fires are the most dangerous of all fires for the following reasons: They involve flammable liquids; there is plenty of air and often plenty of fuel, sometimes under pressure, so that development and spread can be very rapid. Furthermore such a fire may put essential services, such as pumps and lighting, out of action. The principal characteristic of machinery space fires is speed, the time scale being measured in seconds instead of hours.

The most common causes of fire are blowbacks or leaks from boiler fronts and overflows or leaks of fuel oil, or lubricating oil falling or spraying on to ignition sources. Such fires involve flame from the beginning and, therefore, heat and other electro-magnetic radiation.

Lubricating oil is often regarded as being fairly safe. However, investigations into crankcase explosions have made it more widely known that when such oil is finely divided, as for example, by vaporization from a hot surface, spontaneous ignition can occur at temperatures as low as 270°C (515°F).

Hitherto, machinery spaces have been occupied by watch-keepers and automatic fire detectors and alarms have not been considered necessary except for special risk areas such as scavenge belts and oil purifier flats. In unattended machinery spaces it will be obvious that there must be an automatic fire detection and alarm system and that the detection system must be capable of responding very rapidly.

Fire Detectors

a) Probably the fastest response can be obtained by using detectors which sense *Infra Red* or *Ultra Violet Radiation* from the flame but they are not widely used. Detectors have been produced which respond to visible light but, in order to prevent natural or artificial light from giving false alarms, the amplifiers are d.c. coupled and, therefore, do not respond to a steady output. Instead they have a band-pass characteristic which means that they accept only fluctuations in a particular frequency band. It has been found by experiment that the band which is characteristic of flame flicker is 5-35 c/s.

In a machinery space there is a normal background of infra red, visible light and ultra violet. The detectors must distinguish between this background and the greater radiation levels associated with fire. Probably the main reason why radiation detectors have not been widely used is the difficulty of making the above distinction with adequate safety margin and, at the same time, achieving high sensitivity.

In addition there is another, more serious, objection to this type of detector. If no alarm occurs in the early stages of the fire, say, as a result of mechanical screening of the detector, subsequent operation of the detector is likely to be prevented by dense smoke blocking the path between the fire and the detector. For this reason alone one cannot rely solely on radiation detectors. They could be valuable as part of a larger, comprehensive scheme.

b) *Thermal detectors,* which sense excessive temperature or excessive rate of change of temperature, can be cheap and have been so widely used for so long that the reliability of the best types is well known. Nevertheless, the response time is long, and certainly longer than that of smoke detectors and ionization detectors.

c) In the past *Smoke Detectors* have been mainly of the photo-electric type using a beam of light and one or other of the many types of photo-electric cell. The popular concept of such a device is that smoke enters a space between the light source and the photo-cell; increasing smoke reduces the amount of light reaching the photo-cell and thereby alters its electrical output or characteristic. Such devices have been, and are, used in ships. However, their sensitivity is poor if the smoke/light path is short as, indeed, it must be if the detector is to be reasonably compact.

Combustion smoke scatters light through a small angle rather than reflecting light. By taking this fact into account, it is possible by placing even one photo-cell carefully to obtain several times as much electrical change as is produced in an "obscuration" photo-cell 30 cm away. Using four cells of the barrier layer photo-voltaic type it is possible to build a detector 30 cm long and using about 50 watts of lamp power to detect one per cent smoke with adequate long term stability. This allows for the lamp being supplied at only 80 per cent of its rated voltage so as to give long life.

An obscuration cell can still be of advantage but not primarily for its smoke sensitivity. Its value lies rather in providing a "backing off" output and thus reducing the sensitivity of the detector to variations in supply voltage or lamp output. Also, if the device which senses the change in photo-cell output is able to respond to both positive and negative changes then a means is provided for giving "fault" indication in the event of serious changes in the photo-cell characteristic. The common practice of under running the lamp also has a disadvantage as it produces redder light. This is undersirable because it is the blue end of the spectrum which is more affected by smoke than the red.

d) *The Ionization Chamber or Combustion Product Detector* introduced about 25 years ago is now well known for its ability to give warning in the earliest stages of a fire and is used at sea in many or most unattended engine rooms. It is not possible to make a direct comparison of performance between the ionization detector and the optical or photo-electric detector because the former is able to detect the invisible products of combustion as well as the visible products.

The principle of operation of the ionization detector is shown in Fig. 1.

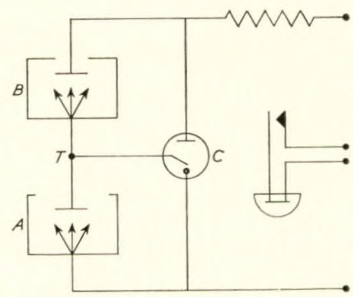


FIG. 1—*Two ionization chambers in series*

Two ionization chambers are connected in series across a d.c. supply. Both chambers A and B are influenced by very small quantities of radio-active material to provide a continuous supply of ionizing particles and thus permit a very small, steady current flow. One chamber is exposed; the other is not exposed. Smoke or combustion products enter the exposed chamber, obstruct the mobile charge carriers and tends to reduce the current. This alters the effective resistance of the exposed chamber and produces a voltage change at the mid point T between the chambers. The change in potential is substantial (60 to 70 volts) which can reliably and effectively turn on trigger tube C, to give an alarm.

e) The selection and layout of a detector system depends on the size of the machinery space and on the physical layout of the machinery; careful planning is essential. Good sensitivity is required yet spurious alarms are a nuisance. The obvious danger areas are the purifier flat, tank tops, boiler fronts and other areas where overflow or leaks of oil may occur; also the main switchboard and generating sets. Hot air and combustion products rise and detectors should be located where they will be actuated by rising combustion products e.g. at the corners of the engine casing and the inlet of exhaust ventilating systems.

The number of detector heads fitted in the machinery spaces of ships already at sea appears to vary from say twenty to as many as forty. Each ship must be planned individually. There are specialist firms in existence who will advise on this.

FIRE EXTINGUISHING SYSTEM

Before dealing with methods of fire extinguishing it may be as well to study what will happen when the fire detecting system has sounded the alarm for a fire in an unattended machinery space.

Ships' personnel, called from the accommodation by the alarm, will visit the engine room. If the fire is small and localized they will enter the engine room and attempt to extinguish the fire with hand extinguishers. If the fire is large this course of action may not be practicable and the fire extinguishing system will have to be used. The personnel may not, in fact, be able to enter the machinery space and, for this reason, the controls for the fire extinguishing system should be outside the machinery space.

If attempts with hand extinguishers have been made but are unsuccessful, there will be delay in operating the fire extinguishing system due to the need for evacuating personnel.

In vessels with manned machinery spaces the emergency controls which are used in fire fighting have often been distributed throughout the ship in the past. For example, the closing of skylights and shutting down of ventilation fans have been effected from the boat deck; the controls for watertight and fire resistant doors have often been on the bridge; the controls for closing fuel oil and lubricating oil tank outlet valves are often in the port and starboard alleyways of the accommodation; control of CO_2 can be adjacent to the machinery casing and CO_2 bottle room; controls for the emergency fire pumps, generators and bilge pumps may also be scattered.

With unattended machinery spaces, seconds are important when fighting a fire and speed of operation is the main requirement of the fire fighting system.

These considerations require that not only should control of the fire extinguishing system be outside the machinery space, but also control of all services concerned with fire. This means that there should be a fire-fighting control station outside the machinery space and that from this station it should be possible to control:

The fire extinguishing system
Ventilation fans
Skylights
Watertight and fire resistant doors
Fuel and lubricating oil outlet valves from storage and gravity tanks
Emergency fire pumps
Emergency generator
Bilge pumps

In large ships more than one fire fighting station will be necessary and it will also be necessary to have a display panel or mimic diagram to show the area of the fire.

Fire Extinguishing Media

a) Some engine rooms are equipped with systems to deal with fires in known areas of risk—tank tops, boiler fronts, oil purifier flats, etc. One system is *mobile foam,* similar to a water sprinkler system. This can be put into action without evacuation of the machinery space. However, it protects only known areas of risk and could be ineffective in the event of a fire in an unusual location, say, an oil pipe fracture or leak.

b) The most common system for an unattended machinery space is *CO_2 flooding.* This has the advantage of being simple, very quick and does no damage to the machinery. Its only real disadvantage is that the machinery space must be evacuated before the gas discharge begins. As normally fitted the gas quantity is sufficient for only one discharge so that its use deprives the vessel of further protection.

c) Alternatives to CO_2 have been proposed from time to time, usually *halogenated hydrocarbons* such as bromo-chloro-difluoro-methane. On the basis of laboratory tests these are more effective than CO_2 but such substances decompose in the heat of fire to form toxic products. However, an additive can be mixed with the gas which prevents the formation of toxic products and such non-toxic compounds are in use ashore. There is no knowledge of the use of such compounds at sea, as yet. A problem with such compounds is whether they are readily available around the world.

d) *Water spray systems* have been installed in some ships. These have an inexhaustible supply of extinguishing medium, which can be used within the ship's stability requirements, but the pump capacity required is large. Another advantage is that the system can be sub-divided so that only the nozzles in the vicinity of the fire are turned on. The main disadvantage of this system is cost and the injurious effect of sea water on the machinery, particularly on electrical equipment.

e) There is another method of providing an almost inexhaustible supply of extinguishing medium — *high expansion foam* — and this is receiving a lot of attention at the present time. This differs from conventional fire fighting foam in that it has an expansion ratio of about 1000/1 instead of the normal 7/1 or 8/1 (the expansion ratio is the volumetric ratio of foam/water). The concentrate used is a type of synthetic detergent. However, it is specially compounded so that it holds together and persists, unlike the domestic detergent. The mechanism of fire extinguishing with this medium is a combination of radiation-absorption, blanketing and cooling by the absorption of the latent heat of the water fed to the fire. The principal characteristics are the speed with which it can be produced and its effectiveness against fire. To give an indication of generation rate—a generator 1 metre square and 1·1 metres in length can produce 150 cubic metres of foam per minute. Two such generators would produce sufficient foam to fill a typical machinery space in about 15 minutes. To date, so far as is known, most machinery space foam systems have protected the boiler flat only although there appears to be no reason why the machinery space should not be divided into areas, e.g. cargo pumps, tank top, purifier room and fuel oil service, each with its own grid network controlled from a distribution manifold so that any or all grids may be operated. Such an arrangement would prevent the unnecessary use of foam and the nuisance of foam in areas unaffected by fire.

With high expansion foam there is the problem of foam disposal after the fire has been extinguished. The foam will collapse after some 48 hours. It can be collapsed by application of water spray but this may have a deleterious effect on the machinery particularly electrical machinery.

BILGE WATER LEVEL ALARM

An alarm is obviously required to signal that water in the machinery space bilges has reached a certain level. It is usual to fit the high level sensing devices in the after bilges of the machinery spaces since a ship usually trims by the stern.

A bilge pump(s) must be provided to pump out such water.

ALARM SYSTEM FOR FAULTS IN THE MACHINERY SPACE

An alarm system must be installed to give audible and visual alarm of fault conditions in all machinery essential to the safety of the ship. The extent of the alarm system will obviously be dependent upon the type of machinery installed.

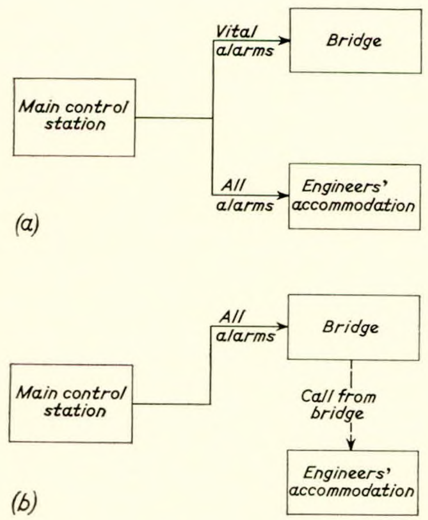


FIG. 2—*Arrangement of alarm signals*

However, a good guide is given in "Automatic Controls in Ships 1966" published by Lloyd's Register of Shipping.

At the present time there appears to be some difference of opinion as to the layout of the alarm system. The two alternative systems are shown in Fig. 2 (a) and (b).

With the system shown in Fig. 2(a), all alarm conditions are signalled in the engineers' accommodation. At night the alarm would be given in the cabin of the "duty" engineer. The engineer on duty would then proceed to the main control station, "accept" the alarm, then locate the precise fault from the control console alarm panel and carry out the necessary corrective action.

The alarm conditions which are signalled to the bridge watchkeeper are only vital alarms and indicate a machinery fault which requires some action by the bridge watchkeeper, e.g. fall in L.O. pressure which necessitates slowing of the main engine.

The advantage of this system is that the bridge watchkeeper is left to devote his attention to ship handling and is disturbed only by vital alarms.

With the system shown in Fig. 2(b) all alarms are led to the bridge and the bridge watchkeeper then calls the engineer in the accommodation by some suitable means. The advantage of this system is that all alarms are now focused at a common point on the bridge and the bridge watchkeeper is awake when an alarm is sounded. The disadvantage of this system is that the bridge watchkeeper now has an additional task added to his duties, i.e. he may have to leave his ship handling responsibilities in order to deal with an engine room alarm and to call an engineer. In addition, psychological difficulties may arise, since with this system it could well be that a junior deck officer may have to inform a senior engineer officer that his presence is required in the machinery space.

In the opinion of the author, with present systems of training and manning for deck and engineer officers, system (a) is to be preferred. Both are equally acceptable although system (b) may give rise to disciplinary problems for the shipowner. System (b) may be adopted in the future if, and when, training methods for both deck and engineer officers are revised.

CENTRAL CONTROL STATION

In ships with manned engine rooms instruments and controls were frequently placed locally to the machinery concerned, e.g. at lower platform level, middle platform level, or upper platform level.

With the unattended machinery space and with the state of affairs whereby an engineer is called to the engine room in response to an alarm signal, such a layout is no longer practicable. All instrumentation and controls must now be brought to one common point—the central control station—so that from this point the "on call" engineer can rapidly ascertain the nature of the fault and take appropriate action.

Most shipowners have very rightly insisted on the provision of an air conditioned and sound-proofed room for the central control station. The great advantage of such a room is that it provides steady ambient conditions for the control equipment located there and provides a calm quiet atmosphere for the engineer to exercise logical thought.

As far as the extent of instrumentation and controls is concerned a good guide is given in the publication "Automatic Controls in Ships 1966" and referred to previously. These recommendations are intended to deal with machinery spaces which are unattended 24 hours/day. To date no shipowner is operating an ocean-going ship in this manner, so far as is known. Consequently when studying the problem of instrumentation and control the designer must consider the effect of the watchkeeping scale (or attendance scale) upon these recommendations. For example, when dealing with oil fuel systems the storage and settling tanks must be of such capacity that they can satisfy the machinery demands during the period in which the machinery spaces are unattended. The alternative is to fit automatic controls to ensure that an adequate supply is maintained at all times.

SECURITY OF ELECTRICAL SUPPLY

Total loss of electrical power or "blackout" could mean the loss of the ship, particularly if in narrow waters. Consequently every endeavour must be made to preserve continuity of supply of electric power.

In addition, in a ship with steam turbine machinery, if loss of electric power occurs, either the turbines must be brought to rest against the propeller water torque or a supply of lubricating oil for the bearings must be made available, as soon as possible.

In ships where two or more generators are normally connected and are necessary to supply the ship's load, if a generator fails for any reason, the electrical protection normally fitted, i.e. preference tripping system, will open pre-selected feeder circuit breakers so that the remaining connected load is within the capacity of the generating plant still connected. If correctly engineered and maintained such a system should give satisfactory security of supply.

In practice, however, the preference trip relays are set as close to full load of the generators as possible. After some years of service and particularly in tropical ambient air conditions, there are many instances where the Diesel prime mover is not capable of developing any overload. A frequent cause of "blackout" in such circumstances is when one of two parallel running Diesel generators develops a fault and runs down. The remaining healthy Diesel generator now has to supply the total connected load plus the power to motor the unhealthy Diesel generator, prior to the operation of the reverse power relay. Frequently the prime mover of the healthy Diesel generator will not develop sufficient power to operate the preference trip relay and shed load. The prime mover of the healthy machine stops due to overload resulting in total loss of power.

In other words, because the prime mover will not develop an overload capacity (kW) in tropical temperature conditions, the electrical protective devices do not receive sufficient current for operation.

With unattended machinery spaces this feature will assume even greater importance than in the past. Greater care in maintenance will be necessary in the future.

In a two generator ship where it is normal to have only one generator connected, failure of the running generator will cause blackout. With an unattended machinery space an auto-start generator is essential not only to supply lighting but to supply power to safeguard the turbine bearings. This auto-start generator preferably should not be connected to the main busbars but to a separate emergency busbar.

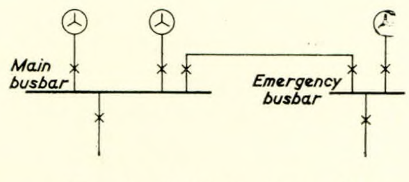


FIG. 3—*Solid busbar system*

Consider the solid busbar system with auto-start facilities fitted to the two main generators, as shown in Fig. 3.

If a busbar fault were to occur the circuit breaker of the running generator would open due to fault current. The standby set would then be run up and the control system would attempt to close the generator circuit breaker. This would be closing on to a fault and would re-open immediately. The sequence could then be repeated with possible damage to circuit breakers and to the system, for each time a circuit breaker attempted to close, the peak-making fault current would flow into the ship's network. This latter damage can be minimized by arranging for a circuit breaker to make only one attempt at closing. However, "blackout" conditions would remain.

If, however, the emergency generator only is provided with auto-start facilities, this set would be started up, be connected to the healthy emergency busbars and supply power both for lighting and to ensure the safety of the main turbine. This requires an emergency generator of larger rating than is normally fitted at present.

If, for some reason, a shipowner requires auto-start facilities for main generators then a split busbar system is essential for maximum security. Such an arrangement is shown in Fig. 4.

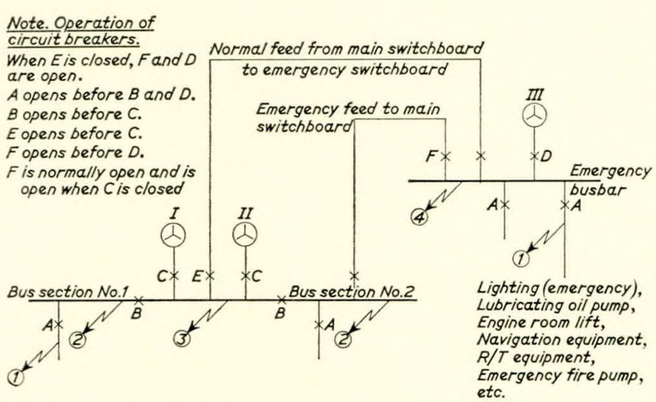


FIG. 4—*Split busbar system for maximum security—Auto-start generators*

In normal running conditions the busbar interconnecting circuit breakers, B, are closed and circuit breaker E is closed. Generator I or II supplies power to main busbars. Generator III starts up automatically when the voltage at the main busbars falls.

Four possible fault conditions have been considered and the action taken to clear each fault is:

Fault 1 Circuit breaker A opens. Power is still supplied by main generator.

Fault 2 Circuit breaker B opens, disconnecting faulty busbar section. Power still supplied by main generator to healthy busbar section.

Fault 3 Circuit breaker C opens; generator III starts up; circuit breaker E opens when circuit breaker D closes. Power supplied to emergency busbar by generator III.

Fault 4 Circuit breaker E opens. Power still supplied to main busbars by main generator.

If it should ever be desired to supply the main busbars from the emergency busbars, say, for starting from dead ship conditions or in harbour, then circuit breaker F can be closed to achieve this (this would be considered a special emergency condition).

The above illustrates a major point in design philosophy, viz., that control engineering techniques and the machinery being controlled are completely interdependent. They cannot be treated in isolation and the addition of controls frequently involves modification to the arrangement of the controlled machinery; in this case the electrical system.

LOCAL CONTROLS

Finally, local hand controls of machinery essential to the propulsion of the ship must be fitted so that the ship can be operated in case the control system(s) is lost. This must be accompanied by sufficient instrumentation. The use of these controls would obviously be an emergency measure and it would be a case of all hands "turning-to".

RELIABILITY

It will be evident that if ship safety is to depend on automatic alarm arrangements, not only must the sensitivity be adequate but also the whole system must be reliable. The technical or engineering soundness of materials and components is only one aspect of reliability; others might be described as "good design", the "fail-safe" principle and "redundancy".

By good design is meant a design of mechanical linkages or movements such that they continue to function correctly after wear, corrosion, layers of dirt etc., have altered dimensions, clearances or frictional forces. This consideration is of even more importance with electrical and electronic equipment where one has to consider variation in performance of transistors and in resistors over the years.

Most alarm equipment is designed as far as possible on the fail-safe principle. This is to say that when something goes wrong, an alarm or "fault" indication is given rather than a lapse into quiescence. This principle cannot be applied throughout, however. An alarm bell cannot be arranged to fail to the alarm condition. In such cases one must resort to redundancy. In other words, provide at least one alternative. If two detectors are fitted to protect one space, or if two alarm bells are connected in parallel, the probability of both failing is very much less than that of either failing separately. It also means that during routine testing each device shall be tested separately and that a fault in one cannot cause failure of the other.

Relevant to reliability is environmental testing. It is well known that satisfactory operation in the laboratory does not necessarily mean satisfactory operation at sea in the arctic and the tropics. This means that equipment must be tested over the whole range of temperature, humidity, vibration, shock, corrosion etc., likely to be encountered. Such testing is expensive but there is no doubt that the industry must move further in this direction.

VERSATILITY AND FUTURE DEVELOPMENT

It is comparatively rare for a ship to complete its 15 or 20 year life without receiving some modification. The same will apply to some ships now building and perhaps particularly so as regards watchkeeping scales. Many ships are currently building, the control arrangements for which have been based on a certain scale of watchkeeping. A large number of these ships cannot be considered as suitable for operation with unattended machinery spaces, since they do not embody the essential safety factors previously described, e.g. they may not have a fire detection system; they may not possess bilge alarms.

It is difficult to foresee how manning and watchkeeping scales will vary in the next twenty years. It would be most prudent to allow for such possible manning variations now and to install all essential safety features at the building stage even if, at the time of building, there is no intention of operating the ship with unattended machinery spaces.

INSTALLATION

Dirt and corrosion are the enemies of control. This means that clean conditions should be established in the compartment of a ship before control equipment is installed. It is asking for trouble to install control equipment and then to discover, at a later date, that dirty operations such as spray painting, installation of asbestos lagging, welding or caulking are taking place in the compartment. Wherever practicable, compartments destined to contain control equipment should be completed in every sense, including painting before the control equipment is installed.

PRE-COMMISSIONING TRIALS

With all machinery systems and with all control equipment there is an initial period when minor faults in design, installation or adjustment have to be discovered and rectified. This must be done before the ship goes to sea and most certainly not after the ship has commissioned.

This involves a formal sequence of testing and adjustment culminating in the appraisal of performance during the sea trials. The process is probably best dealt with by preparing a check-off list. To prepare such a list, the various "areas" of the machinery to which controls have been applied should be identified and then each area must be further sub-divided into the basic elements of the control system.

An example of such a check-off list is given in "Automatic Controls in Ships 1966". It must be appreciated that much care, thought and time must be given to the preparation of such a list. Also considerable time is involved in applying a check-off list. This latter period can vary from say two weeks to as long as six weeks depending on the complexity of the system.

The following points are essential if the check-off list system is to be successful:

a) Sufficient time must be allowed for the tests.
b) During the tests no persons should be working in the machinery spaces, other than those involved in the tests.
c) All necessary services should be available.
d) The various systems should have been set up previously so that minimum adjustment is necessary.
e) Instrumentation should be completed before any tests are attempted.

MAINTENANCE

It must be acknowledged that once a control system is functioning correctly, there is no test or tests which can be applied to guarantee successful operation for a given period of time. A control system is an assembly of components and random failure of such components can occur; these can never be forecast. Consequently satisfactory operation in service is the only practicable test to apply. This involves frequent checking of the system on the lines of the check-off list system or in accordance with instruction manuals supplied by the manufacturer.

The main machinery as well as the control system requires maintenance. All engineers know that many cases of unsatisfactory performance can be traced to faults in the main machinery. A partially blocked line or a clogged burner causes difficulty just as readily as a dirty air supply or a faulty electrical circuit. Pneumatic and hydraulic circuits require little maintenance provided dirt is excluded. Pivots and links should be free of friction and in good working order. Connexions should be tight; loose connexions not only waste air or fluid but also produce unsatisfactory operation.

The greatest problem with pneumatic systems is the maintenance of a supply of clean, dry air at constant pressure. Moisture, oil or foreign particles carried into the system from the air supply will cause trouble and the causes of failure are not always self-evident, e.g. a nozzle or orifice may be blocked by a bead of moisture; location of the defective component and its removal may dislodge the bead of moisture, thus removing the evidence of the cause of failure.

Cases are on record of air drying systems being adequate in temperate climates but inadequate in the tropics so that control systems have failed due to nozzles and orifices being fouled. Pneumatic controllers operating with clean dry air require virtually no maintenance or cleaning. Oil should be prevented from entering the system. Air compressors should not be overloaded since they will pump more oil when running at high loads.

The importance of maintaining a very high degree of cleanliness when working on control systems is vital. Because of the fine clearances involved in pneumatic and hydraulic components it is imperative that the system remains free of contamination. The same need for cleanliness applies to electrical or electronic equipment since dirt generates electrical noise and can cause failure. Before any work is commenced the following precautions should be taken:

a) Thoroughly clean the outside of fittings, pipes, components and the surrounding structure before disconnecting any components or pipes.
b) When pipelines are disconnected fit dust caps to pipes and unions, mask any exposed surfaces and make certain that it is not possible for foreign matter to enter the system. If suitable capping or plugs are not available place a plastic bag over the pipe or connexion and secure with an elastic band.
c) When drying pipes or components use only clean, dry compressed air, i.e. from a bottle and not from a compressor; never from a supply from shore.
d) When flushing pipes use clean carbon tetrachloride from a clean container.
e) Maintain clean hands and tools.

Most experienced engineers will admit that in existing ships there are many instruments installed, the accuracy of which is very suspect after some years of service. Such a state of affairs cannot be accepted in a ship designed for unattended operation. The safety of the ship is dependent on an alarm system and the alarm system itself is dependent upon accurate instruments. Periodic calibration and checking of instruments will be necessary. However, there are certain principles of good practice which need to be stated.

With instruments no repair should be carried out locally which can be done more efficiently in the workshop. Only minor servicing, e.g. zero adjustment and functional checking should be done *in situ*. When repairs or re-calibration are needed the instrument should be replaced so that maintenance can be done in the workshop.

The instrument workshop should be regarded as a place for testing and not for manufacture. It should be possible to check that an instrument is reading correctly but the manufacturer should be regarded as the repairer of defective instruments or the provider of replacement parts. Cleanliness should be maintained in the workshop and to facilitate this a generous allowance of space (more than is normal in a fitting or machine shop) is justified. The shop should be dry and warm as well as clean.

Finally an efficient record system should be maintained to show the amount of servicing required. Full records should be kept on all control equipment. Often it is necessary to know the date and results of a calibration check or whether any renewal of parts has taken place. Difficulties can often be traced to the omission of the cleaning of a filter or some similar detail.

BIBLIOGRAPHY

EVANS, J. L. 1967. "Foam Extinguishing Systems for Tankers", Ships Gear, Fishing News (Books) Ltd.

Gray, D. 1967. "Automatic Controls in Ships". *Safety at Sea,* May. Rhodes Marine Publications.

Lloyd's Register of Shipping, "Automatic Controls in Ships 1966".

Pucill, P. M. 1967. "Fixed Fire Protection Systems for Holds and Machinery Spaces in Dry Cargo Ships", Ships Gear, Fishing News (Books) Ltd.

Discussion

Mr. H. N. E. Whiteside (Member of Council) congratulated the author on the presentation of his paper.

He was not clear what was intended by "When on bridge control the other control positions should be ineffective". Change-over from bridge control to control room or manual control should be quick and effective. There was a difference of opinion amongst marine engineers on the advisability of one position being in control of the machinery under all conditions, one argument being that personnel in the machinery space or an engineer officer called below to investigate an alarm might find it essential in the interests of safety to take immediate action to slow down or stop the main machinery. Suitable warnings must be given automatically to all control positions, indicating the change. The American Coast Guard in a recent circular stated: "The engine room station should be able to override any remote station at all times".

Mr. Whiteside said he did not agree that the steam valves should be closed on loss of lubricating oil pressure unless there was an independent supply immediately available; astern steam should be available to bring the machinery to rest quickly in order to save possible damage to bearings.

Both on land and at sea most of the boiler accidents were due to shortage of water. With loss of water level, the fuel should be immediately shut off from the burners by means of an automatic control which should be entirely separate from the normal boiler water level control and its connexions. Investigation of boiler accidents on land had shown that many accidents had been because the normal water level control systems and the low level control and alarm systems had not been entirely separate; a fault on one had rendered the other ineffective.

The ignition of hot oil sprayed under pressure from a joint or broken pipe in Diesel or steam machinery spaces could, in a very short time indeed, produce a fire which could not be dealt with by the personnel in manned machinery spaces though many minor fires, generally detected by sight or smell, were extinguished by watchkeeping personnel.

With unattended machinery spaces, wherever possible, oil spray or leakages should not fall on to a part which could be a source of ignition. Shields around hot surfaces, or parts containing oil under pressure, and flexible sleeves round high pressure oil pipes were some of the safety measures which could be adopted. Mr. Whiteside did not consider any type of fire detector for machinery spaces completely satisfactory. Many were good, each having its own advantages and disadvantages. The most common system adopted today by British shipowners was the ionization chamber or combustion product detector. In this system the products of combustion likely to be present in machinery spaces in the event of a fire must find their way to the sensitive detector heads. With modern high powered Diesel propelling machinery the quantity of air drawn into the machinery spaces for combustion and ventilation was very great, over three hundred tons of air an hour in some ships. The air currents in such machinery spaces would vary considerably, particularly between full power and low power or according to the number of generators operating. The siting of detector heads in order to ensure an early warning of a fire starting anywhere in the machinery spaces could not be decided on the drawing board. The most suitable arrangements must be made in the ship and, if necessary, indicators such as smoke candles must be used under varying conditions of machinery operation to ensure that the detector heads were in the best places and not in "dead" areas. The siting of detector heads in exhaust ventilation trunking had not always proved satisfactory, dust and dirt rendering the heads ineffective in some cases.

An accident occurred recently to a new British motor ship of some 9000 hp. The machinery could be controlled from the bridge, from a sound-proof, air-conditioned manned control room and manually at the engine platform. An inlet valve broke when the ship was under way, the piston crown was fractured and cooling oil from the piston flowed into the inlet and exhaust manifolds where it ignited and damaged the turboblower causing a serious fire at the funnel level. Fortunately there were personnel in the engine room who quickly stopped the engine but the personnel in the control room were unaware that anything unusual had happened until the engine slowed down. This type of accident was not common but indicated that fire detectors should be fitted in all parts of unmanned machinery spaces to cover possible accident conditions.

There were several fire extinguishing media which Mr. Whiteside considered had properties superior to CO_2 but the International Convention for the Safety of Life at Sea prohibition: "Fire extinguishers containing an extinguishing medium which either itself or when in use gives off gases harmful to persons shall not be permitted", resulted in many being unacceptable since the additive referred to in the paper did not comply with the prohibition.

Ships had been lost because of choked bilges, fractured sea water pipes and valves, and broken condenser and cooler covers, etc. In many of these cases the water quickly became too deep to close the sea inlet valves. It was suggested that, in unattended machinery spaces, extended spindles should be fitted to sea inlet valves so that, in the event of an accident, water inlets to the spaces could be shut from a safe place to prevent further ingress of water.

The safety of a ship with an unattended machinery space as Mr. Gray affirmed, depended upon the reliability of the automatic and remote control systems and the alarm arrangements. Any alarm systems should be in duplicate and should operate independently. Routine testing and maintenance must be easy and carried out regularly, and should be recorded. Alarm systems should not be capable of being shut off and, following an alarm, there should always be some form of warning until the alarm condition had been cleared. Systems should be self-monitoring so that an open circuit would cause an alarm condition. A large French bulk carrier arranged to operate with an unmanned engine room had six closed circuit television cameras in the machinery space and a viewing set installed on the bridge. Some of the cameras in the machinery space could be controlled from the bridge to point in any direction, there being a deck officer and a seaman on watch on the bridge. This innovation had not, as far as he knew, been adopted on British ships but it was an additional useful safety feature.

Industry ashore had successfully operated automated and remote controlled systems for many years but development was slow. In the marine field adoption of such systems had been fairly rapid but, in many cases, machinery and equipment which had proved very satisfactory ashore had failed when required to operate under seagoing conditions.

The paper was based on common-sense views, on comparatively limited seagoing experience with ships having unmanned machinery spaces and it was a little disappointing that only a few shipping companies had come forward to report their experience and troubles in the operation of automatic and remote control arrangements.

Mr. Whiteside suggested that unattended machinery spaces be manned for the first three to six months in order to sort out troubles that might show themselves during these early weeks of operation. Engineer officers could meanwhile familiarize themselves with the ship's machinery, controls and alarm systems.

Mr. Whiteside said that he had read the publication, "Automatic Controls in Ships 1966", referred to by Mr. Gray and was shocked by the number of audible and visible alarms recommended, irrespective of their being particularly applicable to the ships and realized the worth of the watchkeeping engineer officer and the possible fallibility of marine machinery. Ship's machinery and the necessary control equipment should be developed on lines which would lead to reliability and simplification.

Mr. R. Munton, B.Sc. (Vice-President) was aware that Lloyd's Register must be preparing the rules or regulations for automated ships, and he expressed apprehension at the current competition among the classification societies to get in first with rules and requirements for automated and non-continuously manned systems. Lloyd's Rules had carried considerable weight throughout the whole of world industry for a long time because they had been based on experience but he deplored the regulations of the classification societies at the present time being based to a high degree on lack of experience. Maximum freedom in designing the systems was needed without regulations which might or might not be necessary.

Mr. Munton's company no longer favoured the employment of one common control point for the whole ship. It was felt that the ideal position for the machinery control position was on the engineer accommodation level and on the direct path into the engine room so that anyone called in emergency could assess the position as quickly as possible.

Mr. Munton's company was not guilty of Mr. Whiteside's accusation of not displaying their experience including the errors which they had made in this field. Mr. Gray mentioned that a number of ocean-going ships had been operating unattended machine rooms during the last two or three years. He had read of a number of ships that had been designed on this basis but he had not seen any written evidence or heard of anybody giving their experience of such ships. Such experiences were essential and should be shared.

When it came to the essential safety features, Mr. Munton said that he departed from Mr. Gray. Even with a non-continuously manned machinery space, he did not think that bridge control of the propulsion machinery was essential. The non-continuous manning was assumed to be away from manœuvring periods and closed water conditions. In the full away condition, a stop button on the bridge would probably be quite sufficient, provided the control room was properly sited. By the time the engines had slowed down sufficiently to enable them to cut astern, the engineer could be in the control room to operate the machinery.

Concerning item (v) he queried how much should be put on the bridge and thought it should be the minimum. The navigating officer should not be expected to exercise any judgement with regard to the operation of machinery. Slowing down and stopping operations ought to be automatic operations not dependent on the judgement of the bridge officer.

He did not agree fully with Mr. Gray over item (vii). In new installations, one was looking for something as safe as the present fully manned installations and, even there, blackouts occurred occasionally without detriment to the machinery. Lighting was essential, but he would not go as far as to say that there should be automatic starting and synchronizing for generators because one did not want to introduce complications, where avoidable.

He agreed with Mr. Whiteside, following a comprehensive series of experiments, on the absolute necessity for placing fire detecting probes by trial and not from plans.

Mr. Gray had said that, without knowing what the manning position would be in the future, one ought to put the equipment in now, even if it was not going to be used. This made economic nonsense. The equipment was very expensive and the only basis for fitting it would be a reduction in cost in some other direction. One could not afford to fit this type of equipment and not use it.

Mr. J. A. Duncan (Member) asked Mr. Gray for a clear definition of an unmanned engine room. Was it an engine room with absolutely nobody there or an engine room with a control station in it with an engineer in the control station? He said that if a control station was sited in the engine room, adjacent to it or at the entrance, and there was an engineer in attendance keeping a watch, then in his opinion the engine room was manned. He considered the proper place for the control station was in the engine room, so that the engineer who was in attendance had immediate access to the machinery. The bridge was not the proper place for it. The watchkeeper on the bridge had enough to do looking after the safe navigation of the ship, without having to keep a watchful eye on an alarm and summon the engineer if something went wrong. All he should have at his command on the bridge was sufficient equipment to enable him to manœuvre or stop the main engine, with the minimum of equipment to show him that the engine was manœuvring correctly.

In the event of fire, the safety of a ship depended on prompt intervention by the ship's staff. Mr. Gray's survey of this was extremely comprehensive both from the point of view of protection and alarm and of the smothering of the fire except for omitting to mention steam as a medium, though many ships had steam smothering arrangements today. Mr. Duncan had no personal experience of training courses but one of his colleagues who had attended a fire fighting course run by the Admiralty in Portsmouth had said that be would not have been afraid to enter any space under what would appear to be almost prohibitive conditions because he now knew exactly how far he could go. With unattended engine rooms, men might be called upon to enter a space which would be in complete darkness, full of smoke and with a raging fire and they ought to have suitable training.

Mr. Duncan recollected clearly one piece of advice given to him when he first went to sea: this was to remember the three "Bs", boilers, bilges and bearings in that order. This advice was still good today and he thought that the various controls and safeguards outlined as necessary for unattended engine rooms fulfilled these requirements on the whole, though the proposals for bilges were inadequate and a means of keeping them pumped out as required, also a means of determining and alarming when the suction became choked should be added.

The need to monitor bilge suction conditions stemmed from the fact that as soon as these suctions became heavily choked, bilge water started to accumulate at a time when it was believed that it was being removed. If there were a single high level alarm only, then this potentially dangerous condition would not be detected until the water level had reached high alarm position.

This was unsatisfactory, if not immediately unsafe. A prompt indication of defective suction conditions would allow early remedial measures. These were to be preferred to later desperate remedies. A secondary advantage was that early detection spared the bilge pump, which was not then kept working uselessly for long periods. Also, this suction condition alarm, when taken together with bilge high level alarm, gave increased protection against alarm failure.

MR. A. H. STOBBS (Member of Council) said that the lecture dealt with eight items, considered to be the essential safety features for an unmanned engine room. Items (iii) to (viii) were normally provided in any ship and of these no less than three were alarm systems. Was this, then, the difference in safety between a manned and an unmanned engine room? Alarm systems merely indicated the presence of a fault without location or correction. Automation, in his opinion, concerned the rectification of a fault. A good example was the boiler water level control which rectified a high or low water level.

If an engine room were to be depleted of engineers because of a claim that it was automated, what was the position when the automated facilities were not available because of defects? During the last six months five vessels had sailed from London without combustion control of the boilers because a special valve could not be supplied by the manufactures. These vessels sailed on manual control yet, because combustion control was fitted, they carried two fewer engineers than the remainder of the fleet not so equipped.

Did automatic controls operate under list and trim conditions? Vessels using the River Plate often grounded and listed to 25° when the tide receded. Low level alarms to boilers would then function and manual control to boilers would be necessary. Automation must be superseded by human direction at such times.

Recently aboard a large automated tanker, part of the survey requirement was to test the remote shut-down control of the oil fuel pumps. The remote control consisted of a push button which operated a switch. After pressing, the button returned to normal but the switch underneath remained open.

The following sequence of events was set in motion in the control room:

1) loss of pressure in the oil fuel system;
2) loss of steam pressure in boilers;
3) loss of revolutions in turbo-generators;
4) loss of oil pressure in turbo-generators;
5) loss of vacuum in turbo-generators;
6) loss of cooling water in turbo-generators;
7) final black out.

All these were accompanied by red lights, alarm bells, klaxons and the droning voice of the tape recorder. Clear thought was almost impossible and because of the noise-level, orders from the chief and second engineers could not be heard. The fact emerged that only the man who operated the remote oil fuel control knew what the fault was. The alarm system therefore did not point the finger of truth to the fault condition; the staff was only informed of the consequences resulting from that fault. Would the author agree that this was the danger from dependence on alarm systems?

MR. J. R. GILES commented on fire extinguisher media. He said that if a halogenated hydro-carbon, such as bromo-chloro-difluoro-methane, commonly know as BCF, were used, it was lighter in weight and less bulky than CO_2 so less media would be required to protect a particular space and obviously additional spare cylinders could be carried providing further protection once the initial discharge had been made. In fact, with BCF, the space taken up by these cylinders would be so relatively small as opposed to those of CO_2 that a back-up system could be provided and it would still take less space than the normal CO_2 cylinders. Other advantages in using BCF as against CO_2 were:

a) the distribution pipework would be of much smaller bore than for CO_2 systems;

b) there would be a greater degree of protection against re-ignition after initial discharge of these extinguishing media;

c) the media were less toxic, particularly with the ammonia additive, and personnel could operate in the affected machinery space immediately after discharge without suffering ill effects.

The compound was becoming more readily available in most parts of the world but sufficient spares could be carried on board to provide round trip protection.

Although it was desirable to have a "fail safe" wiring circuit on fire alarms, Mr. Giles pointed out that a straight forward closed circuit system would not differentiate between a broken wire or the operation of a detector under fire conditions. A wiring fault might develop at a time of navigational emergency and raise an alarm as for fire, thus creating further unnecessary strain at such a time of crisis.

Mr. Giles strongly recommended the use of a "monitored" circuit providing a fault signal for a break in a cable and preventing the occurrence of false alarms as a fire signal would only be given on actuation of a detector or alarm call point.

The cost of this type of system would compare favourably with that of the "closed" circuit system.

The author mentioned the use of infra-red detectors and some of their characteristics. The majority of infra-red detectors available on the market at present were of the fixed unidirectional type though a new detector designed to operate on the wave band frequencies described was now available and this had the added advantage of scanning through 360°.

MR. G. A. BOURCEAU (Member) in a contribution presented on his behalf by MR. I. J. DAY (Associate Member) agreed that the term "automated" at present covered widely differing installations and this had led to some ambiguity. These wide differences were however disappearing, apparently, in the future an automated ship would be one which was operated without permanent watchkeeping staff for main machinery and auxiliaries.

A step toward this had been the construction of ships in which the operation and supervision of the machinery had been carried out by a single watchkeeper from a centralized control point, either in the engine room or on the bridge as some owners had already arranged, e.g. The Socièté Maritime Shell turbine tanker *Dolabella.*

The design of a vessel with an unattended machinery space would differ from that of an orthodox ship and certain new arrangements should be made:

a) to ensure that the operation of the plant was at least as safe as it would be under direct human control;

b) consideration must be given to fire prevention and arrangements made for fire detection and fire fighting;

c) to replace either automatically or by remote control watchkeeping activities such as those required more frequently than every twenty four hours; e.g. emergency manœuvring when full away, repetitiously in the course of manoeuvring when passing from manoeuvring to full away conditions and *vice versa;*

d) to replace by remote or automatic controls those actions needed for the control and adjustment of the plant itself.

The arrangements made to satisfy these four points would have to be very carefully studied in order to ensure satisfactory reliability and a degree of availability, compatible with operational requirements.

At the end of 1966, Bureau Veritas had created a special classification notation, the AUT mark, which could be granted to vessels of which machinery spaces were to be unmanned for a period of 16 hours a day and which had been satisfactorily surveyed according to the 1967 Rules and in conjunction with the associated guidance note.

Since the beginning of 1967 when the various documents concerning this automation mark were issued, the Society had been requested to grant the mark to more than sixty ships at present under construction or just completed. Surveys had been carried out and three definitive attestations issued to date, whilst eleven other vessels had provisional attestations pending the completion of their regulation trial working period.

Requests so far received included vessels for various flags but in particular Finnish, French, Dutch, Norwegian and Yugoslavian. These had been built or were being built in France, Holland, Japan and Poland, tonnages ranged from 500 to 200 000, with both Diesel and steam turbine machinery.

In addition to fire detection and fighting, precautions for fire prevention were essential. It was preferable to limit the eventuality of a fire by studying, at the design stage, the machinery, piping methods, materials of construction etc., to ensure maximum safety. The guidance note previously referred to, set out the precautions to be taken.

It would seem useful on entirely automated ships to have two means of fighting fire, one of which should be high expansion foam.

It was considered that plant reliability could only be satisfactorily achieved when:

a) imminent failure in some part of the plant was known to be likely by use of suitable detection equipment, with or without reliability study;

b) false alarms and premature shut-downs due to failures in the automation equipment itself had been eliminated.

Ideally, staff would not be disturbed outside their normal working hours and, from information supplied by various owners, this could be achieved as the number of alarms occurring outside normal working hours on certain vessels was now very small. It would then be possible to reduce the staff necessary for operation to a minimum, not forgetting the staff needed to carry out important repairs which might be needed on voyage. At present, it would appear that the limit could be fixed at about 26 to 28 men for ships in the range 10 000 to 200 000 tons designed to operate with unmanned engine rooms.

Besides reduction in staff, the ultimate aim of automation was an important increase in availability, that is decreased outage for repairs and maintenance. This could only be obtained by fuller automation providing a precise knowledge of the condition of the plant, so that incipient failure trends might be known at any time. Only the really necessary maintenance would be carried out and that in good time. There was already a clear tendency towards this but technical studies and modification of present methods would take several years before new methods of operation based on total automation could be generally applied.

MR. P. M. LOW said that he did not agree with the author's implication that the unattended machinery space was but a step on the road to installing the machinery control position on the bridge. There were two quite separate approaches; either ship and machinery control from the bridge which required extensive control facilities for all personnel trained in their use and resulted in a machinery space which was unattended but not unwatched, or the unattended machinery space, as conceived by those owners currently operating a small number of ships in this way, which involved only control of the main engine from the bridge plus additional safety features to protect machinery automatically from damage due to fault conditions; here the only watchkeeping was carried out by the automatic alarm scanning system.

If this second approach were truly achieved, it would be a retrograde step to go from this to remote watchkeeping from the bridge.

A similar point arose when considering the choice of alarm system in Fig. 2 (a) or (b). Some national authorities were seeking to make (b) mandatory to route all alarms via the bridge watchkeeper who was awake. He suggested that this system resulted in a reduction in ship safety for the following reasons:

1) it imposed a time delay in calling the engineer;
2) it gave the bridge useless information in that they could not take an action to correct the fault;
3) it distracted the navigator's attention at the very time when machinery failures might be creating navigational dangers?
4) it gave the responsibility for ensuring the engineer's attendance to an officer who could not leave his post.

Mr. Low believed that only alarm system (a) was satisfactory—but it must be backed up by a feature to alert additional engineers should the duty engineer fail to acknowledge the alarm within a reasonable time. Only alarms, indicated in detail on the bridge should be those directly affecting navigation, e.g. steering gear failure or main engine speed reduction.

The author's example of the bridge officer reducing engine speed because of a low oil pressure alarm suggested that engineering decisions were to be made by personnel who at present were not trained in this field. He suggested that the reduction in speed should be automatic and the bridge informed only that it had taken place. These automatic shut-down and protection devices should be extended to cater for high bearing temperatures, loss of coolant pressure or flow, etc. The "fail safe" philosophy for alarm systems could be generally accepted but the safety of the ship must predominate over safety of individual items of machinery. A faulty electrical contact which stopped the main engine could create a hazardous situation for the ship. One possible solution was to adopt a normally deenergized shutdown system (i.e. not "fail safe") backed up by a normally energized alarm system which was truly "fail safe". Could the author give his views?

As a part of "good design" the paper suggested that mechanical linkages should continue to function correctly after wear had taken place. This was surely asking too much. Would the author not agree that the approach should be to protect the critical parts of the system including electrical and electronic equipment from dirt and other effects of the environment which resulted in accelerated wear and failure rather than risk incorrect functioning after wear had taken place?

Essential services in addition to the electrical supply discussed by the author must be conserved as far as possible, e.g. the steam supply from a motor ship exhaust gas boiler should be automatically supplemented by oil firing should the main engine be slowed or stopped. Essential auxiliaries must be arranged with an automatically-started standby unit to take over in the event of failure of the running unit.

The author's remarks on installation and pre-commissioning trials could not be too strongly emphasized. Even those enlightened shipbuilders having an excellent control engineering department still came to grief from lack of time and inadequate checkout procedures.

Instrument maintenance on ships was growing continuously and the author was right to stress the need for clean workshop conditions, test facilities and calibration equipment. Checking all alarm settings and functional checking of instruments *in situ* should be possible without any dismantling.

He could not agree with the author's suggestion for installing equipment in ships where there was no immediate intention of using it. Unnecessary equipment was neglected and deteriorated rapidly. It put an additional maintenance load on the ship without benefit of better working arrangements to cope with it. Antagonism from the ship's engineers would quickly be created and this should be avoided because in the last resort the success of any scheme relied upon the co-operation and enthusiasm of the engineering staff.

MR. P. J. G. MACK (Member) said that he would develop the author's reference to the current view that improvement in machinery reliability was necessary.

During the past year, in the course of normal survey duties in the London area, he had encountered a particular type of casualty impairing the safety of five ships operated by three different companies. In each case the main propulsion machinery was put out of action by failure of the lubricating oil resulting from system contamination. The principal contaminants involved were corrosion inhibited cooling water, sea water and fuel oil. In two of the cases an excessive rate of leakage of the soluble oil-inhibited coolant from the crankcase piston cooling pipework was followed by rapid emulsification of the lubricating oil. The first indication the ships' engineer officers had of this aspect of the trouble was sludging at the purifier discharge and a rapid increase in the lubricating oil pressure, conditions not generally catered for in unmanned machinery spaces.

Subsequent investigations indicated that in certain circumstances. Soluble oil could have a serious effect on the demulsibility of a crankcase oil and the introduction of sea water might produce water-insoluble soaps which could not be removed by the purifier so that their concentration would increase with time. The practice of adding soluble oils to cooling water until foaming occurred was an undesirable practice since if sea water or hardness salts were already present there was a risk of overdosing. The principal oil and chemical marketing companies involved were amending their instructions regarding simplified tests which should be carried out by ships' engineer officers to ensure that the appropriate inhibitor concentration was obtained, whether soluble oil or chemical, and the cooling water and lubricating oil systems were chloride free.

In the desired simplification of machinery design intended particularly for use in unmanned engine rooms, consideration should be given to the risks associated with the use of incompatible system fluids. If the engine design dictated that water must be used as the piston coolant and that the associated piping system must pass through the crankcase:

a) The design of lubricating oil drain tanks should aim at efficient transit and utilization of the whole of the system charge.

b) The present arrangement of lubricating oil and pumping systems did not provide any capacity for dealing with a sudden escape of a large quantity of cooling water into the lubricating oil system.

In the construction of lubricating oil drain tanks of new ships it seemed quite feasible to provide internal drain pipes leading from the crankcase into a weir or water/sludge collecting chamber of a suitable capacity constructed within the existing drain tank. The capacity of this weir could be consistent with the position of a low level alarm, fitted in the cooling water service tank. A second stage engine shut down alarm might also be fitted. In this way emulsification which occurred initially in the gear type lubricating oil pumps might be avoided simply by preventing mixing of oil and water. A suitable purifier and sludge pumping out connexion could be provided in the weir and a high level alarm might be fitted in the drain tank. This would be advantageous with engines having oil cooled pistons and in both cases the provision of internal pipes would be justified from the point of view of limiting the effect of a crankcase explosion.

Likewise combustion products, oil fuel supply and spill piping systems, scraper box drain pipes and sea water piping systems should be so positioned that the risk of lubricating oil contamination was reduced to a minimum. In crankcase and lubricating oil suction pipe arrangements bolted joints should be avoided where they might lie close to the inner bottom and to bilges.

In one of the casualties mentioned, engine failure occurred as a result of undetected leakage from a fractured sea water guide cooling pipe situated above a loose fitting crankcase door. The owners had subsequently fitted eyebrows above all crankcase doors.

Under seagoing conditions the sea water coolant should be arranged to be at a lower pressure than the system fluids and in port the heat exchanger should be isolated from the overboard connexions. In another of the casualties, involving a ship engaged on short international voyages and in estuarial waters, failure of the aluminium brass tubes in the lubricating oil cooler after only two years' service resulted in bearing damage and crankshaft pitting. The sea water leakage occurred while the ship was at the ferry terminals and the main engines shut down. In other cases it had been reported that ships operating on maiden voyages had experienced split tubes in way of supporting diaphragms due to machinery induced tube vibration. If the builders and owners were to specify the operating conditions, the heat exchanger manufacturer could select the appropriate material and method of construction so as to reduce the risk of such failures.

Mr. Mack then referred to the section of the paper on Bridge Control. Referring to (p), if rapid manœuvring response was a requirement (e.g. tugs and ferries), special attention might be required in design of cylinder cover gas joints since difficulties had been experienced in keeping them tight under such conditions.

Referring to (q), in many existing ships the engine speed transmitter functioned by utilizing a bleed connexion from the propeller hub hydraulic power system. In such cases failure of either the hydraulic power, i.e. the propeller servo pumps, as well as the pneumatic control power, in addition to causing loss of bridge control, would permit the speed transmitter to be displaced to the limit of its travel which was often the full speed condition of the engine and hardly a "fail safe" characteristic.

Manned or unmanned ships must have this rather tenuous type of bridge control, second stage audible alarms should be provided in the control stations to indicate both reduction of the hydraulic and pneumatic pressures, coupled with means of stopping the engines from the bridge or, alternatively, the foregoing alarms might suffice provided the engine came to rest when the relative pressure reached the lowest limit of effective control.

With regard to (r), unless full trials had been carried out to determine the effectiveness of the emergency propeller pitch locking arrangements, it might not be safe for the emergency hub springs to assume full ahead power following failure of the propeller pitch servo pumps. Recent trials indicated the inability of the hub springs alone to maintain maximum full ahead pitch when the engines were developing more than 16 per cent power. The effects of increasing the ahead propulsive power beyond this value coupled with pitching of the ship and the use of helm were known to create blade torques in excess of those which could safely be carried solely by the emergency hub mechanism.

As an ex ship's engineer, he would in principle take issue with the author concerning security of electrical supply. Another fundamental cause of electrical blackouts in ships having two running Diesel generators supplying the ship's load was that following rapid failure of one of the running generators, the remaining intact generator was unable to carry the total connected load sufficiently long to permit effective load shedding because it had not been designed with sufficient reserve. The problem was basically one of incompatibility of the designed setting of electrical overcurrent protective devices and the maximum overload which the Diesel generator was designed to withstand. He agreed that this feature should receive more attention and, additionally, that Diesel generator engines in particular might be specified to carry substantially greater transient overload than hitherto.

Finally, Mr. Mack endorsed the author's views that a careful assessment of the effect of the various fault conditions should be made at the design stage and that a full and effective simulation of all fault conditions and emergency procedures should be carried out during the pre-commissioning trials. To illustrate this point further, he referred to a boiler explosion recently investigated by one of their surveyors. The boiler ruptured violently through overheating caused by shortage of water despite the fact that the very latest automatic controls were fitted, including two independent magnetic type float switches for first and second degree low water alarm and shut down. These alarms were tested individually each day but unfortunately due to an original faulty cross wiring of the control panel when both floats were simultaneously in their bottom position, the feed pump was stopped and the combustion equipment started up automatically as for continuous operation.

MR. A. R. HINSON (Associate Member) commented on lubricating oil alarms for Diesel engines. It was a classification requirement that an alarm was fitted which would give warning of main engine lubricating oil failure. Many engine builders also fitted a cut-out which stopped the engine on lubricating oil failure but sometimes a device was fitted on the navigating bridge, enabling the cut-out to be overridden so that the bridge watchkeeper could keep the engine running without lubricating oil.

Apparently this override was for emergencies when there was more at stake than the value of the engine and it was better to suffer damage there than pay a greater penalty. But Diesels were sensitive to lack of lubricating oil and could be quickly damaged to such an extent as to be virtually useless. If the ship were large and manœuvred slowly, the time the engine would run without lubricating oil might be too short to have any significant effect. There was also the risk of a crankcase explosion. It would seem that if there were any chance of lubricating oil failure at a time when stopping the engine was dangerous for navigation, extra safeguards should be provided, not a bridge override. For example, an extra lubricating oil pump should be put into service and the machinery space should be manned.

With reference to crankcase explosions, probably the best safeguard was given by an oil mist detector. He had recently seen that one owner had fitted a cut-out which would stop the engine if oil mist were detected in the crankcase had been fitted. Oil mist detectors had the advantage over temperature detectors in that they would detect oil mist from any source, including pistons and piston rods, whereas temperature alarms were usually fitted to bearings. A disadvantage was that by the time the oil mist had formed, the components might be damaged. The sequence of bearing failure was usually a rise in temperature followed by an increase in weardown, melting of the white metal and scoring of the journal. When a bearing thermometer and alarm were fitted, the records of operating temperature might be used to forestall failure. During recent acceptance trials a bearing temperature alarm sounded due to overheating caused by partial blockage of a lubricating oil pipe. No damage occurred. Temperature sensors were best fitted in contact with the bearing; if they monitored the temperature of the oil as it left the bearing the alarm might not sound if the oil stopped flowing. Temperatures of connecting rod bearings were more difficult to measure and transmit than those of main bearings and here a bearing wear down alarm was useful. In the Gotaverken alarm, contacts were fitted, operating if the crosshead shoe passed a pre-determined position below what was normally the bottom of its stroke. This provided a certain amount of safeguard against damage due to excessive weardown in top-end, bottom end and main bearings. In one case where spare top-ends had been fitted, the wear down alarm sounded when the bearings overheated sufficiently to wipe. They were scraped and re-adjusted and afterwards ran satisfactorily.

Should cut-out devices be normally energized and operate by switching off, or normally de-energized and operate by switching on? For main engines it would seem preferable that cut-outs should normally be de-energized so that failure of the power supply or, if the cut-out was electrical failure of the circuit would not stop the main engine inadvertently. However, since it was essential that the main engines could be stopped at all times, cut-outs should be provided with an emergency power source. In this, the main engine cut-out differed from those for ventilating fans, forced draught and induced draught fans, oil fuel unit pumps and pumps which discharged over the side. It was usual for the cut-outs on these items to be normally energized.

Lieutenant-Commander A. N. S. Burnett, R.N. (Member) queried Mr. Gray's statement about air conditioned and sound proofed control rooms being rightly insisted on by a large number of owners. In this context, he quoted a paragraph from his own paper "Choice and Layout of Display Instrumentation at the Machinery Control Centre in Ships", which was as true now as it was when it was presented in July, 1966: "It is the opinion of the author that the engineer should not be isolated from the machinery. Although the control room, with its controlled atmosphere, is more beneficial both for the man and the instrument (man is known to perform better away from noise and heat, and instrument performance is improved in a controlled atmosphere or a cheaper instrument can be used) as more emphasis is placed on bridge control with maintenance engineers performing a supervisory role in the engine room during the day, and a duty roving engineer and bridge watchkeeper dealing with plant malfunction during the silent hours, the additional cost of a controlled atmosphere control room cannot be justified for simple installations (unnecessary duplication of instrumentation and the cost of the room itself). This extra cost could well amount to £10 000-£15 000. A control centre, perhaps being an integral part of a maintenance area in a partially controlled environment, sited at camshaft or blower level in a motorship, or between turbines and boilers in a steamship, would appear to meet the need of the present as well as the immediate future." A room immediately in the path of the engineer approaching the machinery space, with a partially controlled atmosphere, where the man could work as well as watch, was the most cost effective way to meet the requirements of all shipowners, from cargo liners to the largest tankers.

How could the manufacturers design instruments for both the control room with its controlled atmosphere and the engine room environment? There must be one standard for the machinery space of a ship. This would give the manufacturers a chance to produce instruments which could be used adjacent to the boiler, in a control centre or anywhere in the ship. Money could be better spent on better and simpler instruments rather than on the control room.

Mr. Burnett stated that Scandinavian owners now used ejectors in their ships for bilge clearance, ballast pumping and a number of duties. He did not think any Scandinavian ship went to sea without water powered ejectors. They were simple instruments which did not get choked and could be operated remotely; the water flow could be controlled from outside the machinery space. This seemed to be ideal equipment to fit in the machinery space to deal with the bilge pumping for "unattended" engine rooms.

No mention had been made in the paper of machinery layout which should be as simple as possible to make fire detection easier. He quoted the case of a Scandinavian ship which had streamlined its engine room layout. This must be done in this country to achieve simplicity, reliability and ease of operation which were all part of the unattended machinery philosophy.

Mr. Burnett agreed with Mr. Gray about the Royal Navy procedure for testing and tuning. There was no doubt it was the best way to get a control system into operation in a ship. It had been found, by bitter and hard experience, that if the testing and tuning was done at the building stage, after the machinery had been installed, and all the power was available, that three or four days spent then saved the owner considerable time and trouble in the future. The commercial owner might say "four days" delay costing £2000 a day would amount to £8000 but he should take into account the time and trouble which ensued from breakdowns in service at a later date. Had a shipowner ever assessed what the total cost was to him of a breakdown after the commissioning date, compared with the cost of extra time taken to test and tune satisfactorily at the building stage?

When was the marine industry going to make some statement of common policy so that manufacturers could make the equipment which the marine industry required. There were so many conflicting ideas making it nearly impossible for any manufacturer to decide on proper design philosophy and planning. The C.E.G.B. was a good example of an organisation which had very comprehensive specifications for design and operation of equipment with which all suppliers had to comply. The marine industry should set down its requirements clearly so that the manufacturers could satisfy the shipowners and produce the good and cost-effective equipment which was required.

MR. N. MACLEOD (Member) said that the most difficult problem when considering new machinery installations was whether safety and reliability could be ensured with machinery unattended either all the time or overnight.

The detection and extinction of fire was the first thing that came to mind. Machinery space fires usually started small and prompt action with first aid apparatus dealt with the majority of them. The system proposed in the paper inevitably involved delay, the alarm in accommodation, proceeding to machinery space, recognition of alarm as a fire call, location of fire and that meant that the fire had grown beyond the use of first aid apparatus and the main extinguishing system must be used. With any of the extinguishing systems suggested, this meant shutting down all machinery for a shorter or longer period of time, thereby placing the ship in hazard. In accommodation spaces, a sprinkler system served the dual purpose of extinguishing the fire whilst initiating the alarm and indicating the location. It might be that something similar could be devised for machinery spaces where detectors would trigger local action and at least hold the fire in check. The primary consideration in planning an unattended engine room must be to avoid a large number of scattered potential fire risks and this involved a much higher standard of pipework and connexions. Of the detectors set out, the ionization detector seemed the most promising. Experience ashore had shown it to be very sensitive and reliable. Could it discriminate between Diesel exhaust gas and the products of combustion from an oil fire?

Whatever the source of main power, an electrical power failure put the ship out of control, as steering gear was almost invariably electrically powered. Preference tripping would only provide continuity of supply if non-essential load on system, which could be shed immediately without endangering the ship and/or machinery, was up to full load of one generator. On many ships during the hours when the engine room would be unmanned, this was not the case. This might be an argument for driving essential auxiliaries by the main engine and dividing the generating plant into a larger number of smaller capacity units.

Mr. Macleod had some misgivings about complicating the distribution network in search of continuity of supply, as circuit breakers did not always retain their trip values for current, voltage or time delay over long periods and the checking of settings with the ship in service might not be easy.

As one who was in close contact with seagoing engineer officers and their problems, he was tempted to ask: "Is it all worth while?" Did they believe that they were going to keep more engineers of the calibre required to understand and operate sophisticated equipment at sea by providing systems which would rouse them from sleep after a day's work, should any one of a large number of readings go beyond pre-set limits, rather than by providing them with centralized instrumentation and controls which would enable them to watch trends and make adjustments or corrections long before the limits were reached?

On many trades the periods for which unattended machinery spaces were likely to be acceptable as an asset to the value of a present day merchant ship, formed only a small percentage of a year's operation.

Every proposal for an unattended machinery space must start with the control system and the design of main machinery; auxiliaries and their arrangement must then be tailored to suit. The additional cost of control and alarm systems, higher standards of design, manufacture, installation, commissioning and maintenance must be balanced against any saving in operating cost and then compared with a central control system whereby a single watchkeeper could monitor and operate all machinery at all times, before the unattended concept could be justified.

MR. G. A. BRUCE (Associate) said that the paper referred to bridge and engine room control. This was really very old. Mr. Bruce had been on a ship, engined in 1931, which had this feature and on a number of modern and special purpose vessels this was standard practice.

He had had considerable experience in recent years of pre-commissioning trials on vessels where there was a lot of fairly complicated equipment and he endorsed what a number of speakers had said.

The owners wanted the ship quickly, the shipbuilder wanted it finished quickly, not only to meet his contractual obligations but also because he needed his money, and the sub-contractor supplying the engines was continually pressurized to shorten the pre-commissioning trials to allow for a quicker cash flow from the owners. This was partly due to archaic terms of payment prevalent in the industry and these could do with overhauling.

Mr. Whiteside had said that with bridge and engine room control, there must be overriding priority in the engine room. On Diesel/electric ships, this was almost always the case.

A speaker had mentioned that the number of alarms operating should be duplicated and this could be construed to mean that one had to have an alarm for monitoring an alarm. How complicted could they get?

In Mr. Bruce's experience the owners of small, rather specialized vessels invariably pressed for as much information as possible to be mounted on the bridge on consoles where the Captain or Mate could see it but this was often quite unnecessary information.

The discussion had underlined that what was loosely talked of as "automation" was in most ships just a rather complicated alarm system.

Correspondence

MR. J. E. CHURCH (Member) found himself in complete agreement with everything the author had written. Having experienced Diesel engine room fires due to oil leaks spraying onto hot pipes, he had always been very conscious of this danger and had never felt happy about unmanned engine rooms for this reason, among others. Before he would allow an unmanned engine room he would require that all oil fuel tanks, pumps and pipes would, wherever possible, have to be contained in separate compartments in which no hot pipes would be allowed and all fuel injection pipes on the engines would have to be encased in outer pipes to contain any sudden leakage to lead off to safe collection and alarm indicating points. All exhaust manifolds and hot pipes within range of any possible oil leak would have to be water cooled. Otherwise an uncomfortable number of casualties by fire were bound to happen sooner or later and it only needed one involving loss of life within our personal experience to make us very sorry that we ever agreed to an unmanned engine room at all. Mr. Gray had clearly shown the stringent requirements for early fire detectors but signs of danger would often be present before actual fire commenced. An oil leak might be seen by an engineer on watch and stopped before ignition took place, whereas auto detection of every such irregularity which might occur would be well nigh impossible. Assuming an unattended engine room was on fire, and an early alarm had been given. How easy or difficult might it be for those concerned to discover the seat or the cause of the fire—essential information if it were to be put out. A watchkeeper would almost certainly know how and where it started and this vital information could save the ship.

He appreciated that the author's concern was with safety precautions thought necessary, and not with the reasons whether or not an engine room should be left unattended. His recommendations were however, quite rightly very elaborate and far reaching and one could not help but wonder if it was all worth while. Basically the fact was that sufficient engineers and ratings must be on board:

1) to take over hand control of the machinery should the automatic controls fail;
2) to deal with all emergency breakdown repairs which might arise;
3) to deal with any foreseeable emergency which might arise such as fire, storm and tempest.

Items (2) and (3) required at least three engineers and three ratings. (1) involved continuous watches 24 hours each day and as regulations quite rightly said that a man might not be down below on watch by himself that also meant three watches of two men each, a six-man total. So, on any ocean-going ship, six men must be carried for any engine room, large or small, automated or not.

What was to be gained by spending a great deal of money on automated controls and safety devices which might or might not work, in order to enable the engine room staff to sleep at night, leaving the engine room deserted for sixteen hours a day so that there could be too many down there during the remaining eight hours.

Was it so desirable that the engine room crew should be on day work? Round the clock watchkeeping on the bridge must always remain. An unmanned engine room put most of the alarm systems and monitoring checks on the bridge and required the deck officers to watch these while the engineers slept and had off-duty weekends. This was hardly fair and not likely to improve human relationships on board.

In practice, no engineer worth his salt was going to enjoy his leisure and off-duty hours only a few yards away from his engines if he were to be told that he must not nip down and have a look that all was well. He was not likely to sleep very well at night either, knowing, as he alone would, what could go wrong and with what consequences whilst there was no one down in the engine room watching. So his guess was that, whether or not the powers that be said that an engine room should be unmanned, the engineers would pop down very frequently to check that all was well and as it often would not be, they would end up by being there even more than they would on properly organized watches.

Finally, the advocates of automation overplayed the hallowed word "productivity" and assumed that a ship's engineer was only "producing" if he was working with tools overhauling some piece of machinery while to be on "watch" was looked upon as a waste of time. Running machinery could not be worked on and it was not safely allowable to put out of use deliberately any standby machinery which was workable, merely to overhaul it, for standby machinery was there, to classification requirements, for use in emergency. Perhaps the author would like to include this as another essential safety feature?

He considered that a seagoing marine engineer could not be better employed than in watching, all the time the engines were working, for good watchkeeping could save the shipowner thousands of pounds a year. He was bringing to bear all his knowledge and experience through his own senses which conveyed instantly direct to his brain, safety signals which he felt sure the author would like to add to his list of essential precautions.

MR. O. W. DUMPLETON (Member) wrote that it was a good marine tradition to proceed by stages from the simple to the elaborate and from the small to the large. The paper referred to a progression to full automation by way of gradual reductions in attendance in engine rooms of large ships. Another approach was a progressive increase in the size of ship in which no watchkeeping engineer officer was required.

Mr. Dumpleton entered the field of marine automation by inventing an automatic helmsman originally intended for yachts. This equipment was soon adopted by coastal cargo vessels and had now been in commercial production for some ten years. In many of these ships it was normal practice to have bridge control of main engines and for the engine room to be manned only intermittently. Now that more sophisticated alarms were available it was possible not only to sail with unmanned engine rooms but with no engineer on board at all. In such ships were fitted not only engine alarms and remote gauges on the bridge, but also a course error alarm in the engine room so that the sole watchkeeper might leave the bridge to inspect the engines.

He would question the author's assertion for which no reason was given, that the engine room main controls should be disabled when the ship was on bridge control. Apart from the extra complication involved in having change-over gear it seemed much safer to leave available in the engine room at least the means to slow down or stop the engines, if not full control.

If both stations of the order transmitting device were to have control, both handles would have to move together but if, however, there were push buttons for ahead and astern and a continuously adjustable control for speed, there need be no mechanical connexion and corresponding buttons could simply be connected in parallel, with the speed set by whichever control was set lower. A somewhat analogous case was found in the local and remote controls for the oil burners of large power stations. No difficulty arose from having both sets of buttons operative at all times. An incidental advantage of a push button stop was that emergency automatic stop signals could be easily routed through the normal stopping channel rather than to some special shut-off device which had to be separately tested.

Instead of time delays being incorporated to safeguard the engine against over-rapid manœuvring, it would surely be preferable, and in line with good control engineering practice, to make the reversing action dependant upon the actual reduction of engine speed rather than on a pre-set time.

He could state from personal test that there is not normally a background radiation including ultra-violet, at least in small Diesel engine rooms lit by filament lamps and strongly suspected that it was not generally true in other engine rooms either. Detectors were readily available which could respond to the flame of a match at a distance of 20 feet or more whilst ignoring artificial lighting.

The need for regular operation of all parts of the system favoured bridge controls which were normally used for manœuvring, as against bridge stop controls only to be used in an emergency. Another example was a float type bilge alarm which could be tested simply by lifting the float as opposed to capacative or thermal types which needed real water or other liquid for testing. Again, an ultra-violet fire detector which could be set off by striking a match or cigarette lighter was much easier to test than a smoke detector or combustion-product type alarm. In realistic testing, some foolproof means should be fitted to distinguish between real alarms and routine tests.

One had to draw on experience from Dutch or German ships since this approach was not possible under British rules. Given the blessing of the Board of Trade, however, it should be quite possible, with present knowledge, for a relatively small team of shore-based engineers to look after a whole fleet of short sea traders.

MR. R. J. C. HARRIS (Associate) wrote that during the reply to the discussion, the author made reference to the problems experienced with basically industrial "data loggers" on ships. These problems were well understood by some manufacturers but the suggestion that no manufacturer would pay £500 000 for development of a marine equipment of this type should not pass without comment.

The Decca ISIS-300 equipment had been developed exclusively for the marine environment with which the company had had the benefit of many years experience. The development cost, some 50 per cent of the figure suggested by the author, was considered a justifiable investment in view of the worldwide market in which the company had always operated.

Substantial market research at the beginning of the development project immediately established the principal design parameters as reliability, simplicity and ease of installation. Concerning the operational facilities incorporated, the machinery protection function was considered of primary importance, while the "data logging" facility was a secondary function which could be included if required.

The classical approach to product development which included intensive market research, system design, environmental testing and quality control had achieved results consistent with expenditure in the past. Mr. Harris' company exported over 90 per cent of its marine radar production which was considered to bear witness to the effectiveness of this approach. There was no reason to suppose that ISIS-300 would prove an exception and a substantial world market was expected.

PROFESSOR G. H. CHAMBERS, D.S.C., M.Sc. (Vice-President) wrote that when the engine room was untenable through fire or its results it might be useful to operate remotely the main or some of the auxiliary machinery. This would not be possible with an open central control station or with a control room unless there was direct access to the control room from outside the engine room. Such direct access seemed to be an essential provision as did the provision of an airlock or similar safeguard at any door directly between the control room and the engine room. To rely on the lift for access under any emergency circumstances seemed unwise.

Further, the ability of control systems to withstand fire in the engine room would appear to direct the choice of medium towards a pneumatic rather than an electric or hydraulic system. The amount of air involved would not be enough seriously to feed the fire and a reservoir of control energy in blackout conditions could be simply provided.

The arrangements in Fig. 4 appeared to involve an appreciable risk that the emergency generator would be overloaded through connexion to the main busbars. Would it not be sound to keep the emergency supply quite separate from the main supply? The lubricating oil pump and other essential equipment could have individual change-over switches and a limited amount of secondary lighting could be fed only from the emergency generator. It would also be sound to provide for emergency ventilation of the control room since, under blackout conditions, control rooms could get very hot especially in steam ships.

The paper highlighted the more difficult circumstances under which marine machinery operated by comparison with land plant, particularly in emergency conditions, of which isolation from outside aid was the chief characteristic.

Author's Reply

In reply to the discussion, Mr. Gray said that the *definition of an unattended machinery space* had received comment from Messrs. Duncan, Bourceau, Low and Church. He would agree with Mr. Duncan that if the machinery spaces contained personnel or if a control station containing supervisory equipment contained personnel, then the machinery space could be considered as "attended". On this theory the *Dolabella*, referred to by Mr. Bourceau, had an attended engine room.

One feature, reported from ships operated in this manner, which might be of interest to Mr. Church, was that, with all engineers on day work, the chief engineer was able to call them together, say, after the evening meal, to review the day's work and to plan that for the next day. Reports from such ships were that this was of great value.

The necessity for arranging *fire prevention* had been mentioned by Messrs. Whiteside, Bourceau, Low, Macleod and Church and Professor Chambers. These comments were very valuable but regarding the view of Professor Chambers that this favoured a pneumatic control system, it must be pointed out that loss of electric supply alone would be sufficient to deprive the ship of propulsion. Consequently it was probably true that, provided the control system could withstand the same sort of temperature conditions as the electrical power network, this should be adequate. In other words, there was little to be gained by requiring greater fire resistance of the control system than was provided by the main machinery complex, including the electrical auxiliaries.

Fire detection in its various forms, was commented upon by Messrs. Whiteside, Munton, Giles, Macleod and Dumpleton. The author would agree that the ionization type of detector was indeed suitable for all types of fire likely to occur accidentally, also that there was a problem in ensuring that the combustion products actually reached the detector and for this reason the author heartily supported the view that the siting of detector heads needed to be based on actual tests, carried out with smoke, in the ship concerned, both with ventilation on and with ventilation off and, ideally, under engine running conditions also. It was probably a false economy to try to protect the machinery space with a very small number of detectors since this could lead to delay in the detection of fire. The probing of exhaust ducts for smoke also required care; if the air flow at the point of sampling were too great, the dilution which occurred before smoke reached the detector might be unacceptable. Where high flow rates were involved it was important, whenever possible, to probe the ducts before they married. The question put by Mr. Macleod had been answered by Mr. Giles. As regards the comment by Mr. Dumpleton concerning ultra-violet light in a machinery space, the author could only state that fluorescent lighting, of which there was plenty in modern ships, contained ultra-violet light.

Fire extinguishing systems were mentioned by Messrs. Whiteside, Duncan, Giles, Bourceau and Macleod. Regarding CO_2 flooding systems it was true that "as normally fitted" the gas quantity was sufficient for only one discharge so that its use deprived the vessel of further protection. However, this was not a criticism of CO_2 itself but only of the way in which it had been applied. There were a number of ships at sea today carrying a quantity of CO_2 sufficient for more than two discharges. Why Mr. Bourceau would insist on the fitting of a high expansion foam system was not fully understood. In the opinion of the author it was merely another available fire extinguishing medium; indeed, in spite of tests carried out ashore, experience with it in ships was very limited as yet. So far as the author was aware there were only two such systems at sea today and the ships concerned have been in service only a matter of months. It was known that other ships fitted with this system were being planned.

Mr. Duncan's plea for steam smothering was not completely understood. Such a system might have been adequate in the days of the Scotch boiler, with sufficient poundage of steam available, but with modern water-tube boilers, particularly if the feed pump was out of action due to the fire, it was doubtful if an adequate supply of steam would be available. Steam also had the disability that it has very little cooling action and so, if the steam was turned off, oil fires could re-ignite since they could be above the ignition temperature of the oil. Such a system could not be recommended.

Possible crew reductions, watchkeepers, alarm systems and facilities available on the bridge had brought comments from Messrs. Stobbs, Bourceau, Munton, Low, Mack, Hinson and Bruce. It was important to realize that the addition of control equipment and operation with unattended machinery spaces did not necessarily bring large crew reductions. The main purpose of these techniques was to enable men to be transferred from watchkeeping duties to daywork. Thus men were present in the machinery spaces at all times when the ship was in narrow waters and also during most of the daylight hours. At other times engineers were available to answer an alarm.

If the engineers' accommodation had easy access to the machinery space, or main control station, the fitting of a "stop" control only on the bridge, proposed by Mr. Munton sounded a very reasonable proposition. The time between this command being given on the bridge and a second manœuvre being possible on the main engine should be amply sufficient for the duty engineer to go below and take over control of the machinery. This was also illustrative of the author's view on questions posed by Mr. Stobbs. Most of the fault conditions in the engine room could be effectively dealt with by an alarm system, with the duty engineer answering the alarm and taking appropriate action. Fault rectification by the control system, e.g. by the use of automatic change-over to standby services, was surely not always necessary. Faults could thus be placed into two categories:

i) those which could be handled by an alarm and action by the duty engineer;
ii) the much smaller group where a fault required "shut-down" action, e.g. loss of lubricating oil causing shut-down of the main engine.

With this philosophy comparatively simple installations were suitable for unattended operation. In fact a number of the ships operating in this manner had simple installations with few automatic control loops (see also the reply to Mr. Munton on costs).

The bridge override control referred to by Mr. Hinson appeared to be a rather dangerous device. In some ships where this had been fitted it was arranged to be pulled instead of pushed to avoid any inadvertent operation.

The comments of Mr. Mack on controllable pitch propellers were fully agreed and, in fact, the type of installation he described was regarded as unacceptable by the author.

The location of control stations and their independence of action had raised questions from Messrs. Munton, Duncan, Low, Whiteside and Dumpleton. The view of the three first mentioned was that the main control station should be in the engine room/engineer accommodation area. This was valuable comment coming as it did from ship operators. Regarding independence of action, the expression used in the paper "other control positions should be ineffective" was perhaps an unfortunate choice of wording. Essentially this was both a disciplinary problem and one of communication between bridge and engine room. Unauthorized personnel should not be able to alter engine manœuvres from an alternative station. Indeed, some engineers advocated that the machinery spaces should be locked when they were unattended, the key being held by the duty engineer. This would deal with the first possibility.

The communications problems was another matter. Many engineers advocated that engine room staff must be able to take over control of the machinery at will, in order to safeguard it, but if such a take-over occurred during a critical manœuvre of the ship, then one could perhaps save the machinery and lose the ship.

The extent of the alarm system to be fitted on the bridge had been commented on by Mr. Munton and Mr. Low. The author would agree with Mr. Munton that this should be a minimum; Mr. Low had given the reasons for this view in a brief but compelling manner.

Details of alarm systems had produced comment from Messrs. Whiteside, Giles, Low and Hinson. The author would agree with Mr. Whiteside about separation of alarms and controls, but not with his suggestion that all alarms should be duplicated. Single point alarms still required two faults before a hazardous condition existed, viz. the original fault condition and the failure of the alarm. Thus it was a two fault philosophy. In addition duplication of alarms was not always practicable. In the author's view it was probably preferable to provide redundancy in the form of a back-up system. For example an exhaust gas system, a pressure charging system and a fuel oil system for a main Diesel engine could all be monitored and alarmed. However, a suitably alarmed exhaust gas system would also check on the main engine pressure charging system and the main engine oil fuel system, since malfunction in the pressure charging system or oil fuel system would probably affect the exhaust gas temperature. Such a philosophy, if carried out at the early stages of design planning, not only provided greater safety, but reduced the total number of alarms, a feature which apparently disturbed Mr. Whiteside.

Mr. Low had commented on the circuitry required for shut-down and alarm facilities. Mr. Hinson had put forward a very practical solution to this dilemma, i.e., for shut down facilities, normally de-energized but with an emergency source of power; for alarm facilities, normally energized.

Protection of the turbine on loss of lubricating oil pressure had been commented on by Mr. Whiteside. Positive stopping of the turbine suggested by Mr. Whiteside was one solution; another was to supply the turbine with lubricating oil whilst it was being driven by the propeller. This was described by the author under "Security of Electrical Supply".

Mr. Dumpleton had commented on the *time delays* which must be built in to the control system. The author had not intended that this should be interpreted as meaning finite in the time sense. It was normal good engineering practice to base these delays on engine speed. The important thing to realize was that such delays must be provided.

Reliability, instrument design and the desirability of a control room had evoked comments from Mr. Bourceau, Mr. Low and Lieutenant-Commander Burnett. The use of reliability studies had been suggested by Mr. Bourceau. These had been extensively used in the aircraft industry but to use them successfully they must be allied to a time scale. The aircraft industry was fortunate in this respect in that it was very well documented concerning failures. The marine industry was woefully short of such documentation. This lack of feed-back from the sea regarding failures of equipment probably meant that any exercises in reliability study were largely of academic interest. Mr. Low's view was that to ask control equipment to function satisfactorily after long service in the marine atmosphere was asking too much and that such equipment should be protected from the marine atmosphere. The author agreed with this statement and, indeed, it was for this reason that he would recommend the use of a control room to house the control equipment. By this means cool, clean ambient conditions could be provided. This was the reverse of the opinion of Lieutenant-Commander Burnett who would require all instrumentation to be capable of meeting the most severe conditions. This would, indeed, be a difficult task. An incidence of electrical blackout had been brought to the author's attention recently. This concerned self-regulating generators with the excitation equipment mounted in the cubicles of the main switchboard. Failure of the rectifiers in the excitation circuits had occurred. On investigation the ambient temperature inside the switchboard cubicles was measured as 70°C (158°F). The prime cause of failure was inadequate ventilation, of course.

However, to require that control equipment should be capable of operating in such ambient conditions was asking rather a lot. At figures such as these one might be reaching the limits of technical practicability.

One must realize that most of the control equipment available had been designed for the industrial user. Much of it was not suitable for marine use due to the difficult marine environment and, therefore, one had to be selective. It was rarely possible for the equipment which was not suitable to be "marinized". Usually redesign was required. This point was not always realized by the marine engineer.

Such re-design could be expensive and the figure of £250 000 as the price of the research and development work for a marine data logger given by Mr. Harris was illuminating. The figure of £500 000 suggested by the author in the verbal discussion was merely intended to illustrate the order of the sum involved. Both sums were in the order of "hundreds of thousands" of pounds. Marine engineers must realize that this research development work must be paid for and would be reflected in the price charged for marine instruments.

Bilge pumping had been commented upon by Mr. Whiteside, Mr. Duncan and Lieutenant-Commander Burnett. The author would agree entirely with Mr. Whiteside on his suggestion that extended spindles should be provided. Mr. Duncan's proposal for an alarm to indicate a choked suction might be difficult to achieve. Would it not be better to have, say, two level alarms, each at a different level. Lieutenant-Commander Burnett's comments were of great interest.

Reliability and design of main machinery had been commented on by Mr. Mack, Lieutenant-Commander Burnett and Mr. Macleod. The author was grateful for the valuable contribution from Mr. Mack.

Security of electrical supply had brought comments from Messrs. Munton, Low, Mack and Macleod and Professor Chambers. The author agreed with Mr. Munton that the system should be simple in design and auto-start main generators had not been suggested as necessary, in the paper.

In the case of the ship with more than one generator normally connected no additional safety measures had been suggested. With such a system two faults must occur before total loss of power could occur viz. failure of a running generating set and failure of the preference trip system.

In the case of the ship with only one generator normally connected, an automatic supply of power must be made available if this set should fail. However, in the opinion of the author this would be adequate if it could supply essential lighting, protect the turbine (in a turbine ship) and one or two other essential circuits such as navigation lights. This could be effected by an auto-start emergency generator or even a battery. With this system again, two faults must occur before total loss of power could occur viz. failure of the running generator and failure of the emergency auto-start generator (or battery).

Thus both schemes were based on a "two-fault" philosophy.

Regarding Professor Chambers comments on Fig. 4 and the possible overloading of generator III, this should not occur; circuit breaker F was normally open and generator III would not normally supply power to the main busbars. The exception mentioned in the paper was the possible use of generator III for starting under dead ship conditions when the machinery spaces would be manned.

The basic philosophy of operating a ship with unattended machinery spaces and the *economics* of this concept had been commented upon by Messrs. Munton, Low, Macleod and Church. As Mr. Stobbs had pointed out, of the eight safety features mentioned, items (iii), (vii) and (viii) were already fitted in conventional ships. Mr. Munton had pointed out that item (i) could be simplified considerably by suitable arrangement of the accommodation and machinery space. Similar considerations applied to item (vi). This left only a fire detection system, a bilge alarm and an alarm system for faults in the machinery space remaining.

A bilge alarm could be of the order of £30-£40 per point.

A central alarm system could be of the order of £25 per point for the alarm end; for the sensing end, say, £30-£40 per point; allowing, say, 80 points for a Diesel installation and taking the mean of these figures, produced a figure of about £5000. Installation was not included in this figure.

A fire detection system for the machinery space could be in the range £500 to £2000.

The foregoing illustrated the order of money involved and it seemed to be a very small percentage of the capital cost of the ship.

Actual operating experience, or the lack of it, with ships having unattended machinery spaces had been mentioned by Mr. Whiteside, Mr. Munton and Mr. Bourceau. Up to the present time a number of Danish flag ships had a total of some 22 ships with a total of over 6000 ship days of operating experience although very little had been published. The author agreed that feed-back of information on such experience would be of benefit to the industry as a whole.

The question of *Rules and/or Recommendations* had been comented upon by Mr. Munton and Mr. Bourceau. Since 1963 a number of documents containing recommendations for marine automation had been published. In more recent times these had become more detailed and in certain countries governmental regulations had been issued. Special notations of class had been devised by certain classification societies.

The failure of any of the special facilities required by such regulations did not necessarily put the ship in hazard. In the final analysis the essential machinery could be operated by hand. It was within the ability of the ship's master, by reverting from an "unattended" engine room to an "attended" engine room to manœuvre the ship with safety, even if it became a matter of all hands turning-to. In other words the variable which determined unsafe or safe operation was the disposition of men.

The question might then very properly be asked, "What is the purpose of such a notation together with its accompanying regulations?"

To answer this question it was necessary to review the history of marine automation. The initial steps were taken by shipowners with competent technical staffs. Research and development work was carried out on the application of control equipment to marine machinery and in the marine environment; exercises in work study on board ship were carried out; courses of instruction for seagoing personnel were arranged. Based on the results of this work such owners could prepare comprehensive specifications to produce the best control arrangements for the ship in question. Such owners had no need for recommendations, regulations or a class notation.

The shipowners with little or no technical staff, and there were many of them, had no means of carrying out such research and development work, yet they were faced with the same staff problems and economic problems. These owners were not in a position to write a comprehensive specification. Consequently it was this type of owner who made use of the various documents containing recommendations and, if necessary, the class notation since this provided an easy method of specifying requirements to a shipbuilder.

However, since local hand controls for machinery were provided it was difficult for the author to see why notations of class should be proposed for the publication of regulations, other than the eight broad facilities mentioned in the paper.

The need for *adequate testing* prior to commissioning and *for reguar maintenance* had been commented upon by Mr. Low, Lieutenant-Commander Burnett, Mr. Bruce and Mr. Dumpleton. It was gratifying to know that in general their comments agreed with the views put forward by the author.

Marine Engineering and Shipbuilding Abstracts

No. 2, February 1968

Mammoth Tanker Considerations

The rapid escalation in the size of oil tankers—roughly a tenfold increase since the war—suggests that the limit in size has not yet been approached and that shipbuilders and naval architects are prepared to venture further despite the considerable technical and commercial problems posed. Indeed, it was stated last year by Sir John Hunter that the Swan Hunter Group was prepared to undertake the building of a 1 000 000 dwt ship, using techniques developed by the technical staff of the famous Tyneside yard. About the same time Lloyd's Register of Shipping reported that it had completed a feasibility study of the construction of a 500 000 dwt bulk oil carrier which indicated that, although design on conventional lines would require modification, no particular difficulties need be expected in the building of ships of such a capacity. The British Ship Research Association in its recently published Annual Report has recorded that it has studied design problems likely to be encountered in the building of tankers of 750 000 dwt; so it might be said that the way ahead is clearer for a further spectacular increase in the size of tankers.

With regard to structural design, since ships of 200 000 dwt have now been built in several countries, areas where structural troubles are likely to occur are fairly well known. Nevertheless, design is not purely dependent upon extrapolation although oil tankers, by reason of their standard design, do lend themselves to development in size by extrapolation. Other factors have to be taken into consideration and call for analytical research and model tests. An examination of the bending moments involved, which combine stillwater and wavebending moment components, is also necessary, the latter being determined by the energy spectrum concept. Structural efficiency calls for the optimum configuration of stiffeners and plating to produce minimum scantlings to ensure minimum steel weight and maximum deadweight as determined by an adopted minimum section modulus. Dynamic pressures in a cargo oil tank, due to ship motion, also play a part in determining scantlings since the maximum impulsive pressure can be many times the static fluid pressure. The deep draught of the latest generation of tankers means that should a tank be empty, a considerable water pressure will be exerted vertically upwards, varying with the length of tank and requiring to be taken by transverses and longitudinal bulkheads. Again, the shear forces have to be taken into account in arranging the longitudinal material while the thickness of plate imposes certain welding problems. It seems probable that high-tensile steels will play an important role in future tanker construction.—*Shipbuilding International, November 1967, Vol. 10, pp. 6—9.*

Dispersion-strengthened Alloys

Investigations have been carried out in recent years into the possibility of producing alloys with high strength at high temperature by dispersion hardening with constituents which can be dissolved in the matrix metal in the liquid state but which, once precipitated as a second phase to form a dispersion, are insoluble in the matrix in the solid state (SLIS: soluble in liquid, insoluble in solid). In these systems the necessary submicron particle size and dispersion is obtained by atomizing or 'splatcooling' the liquid. In the work now reported nickel was used as the matrix material, and experiments were conducted:

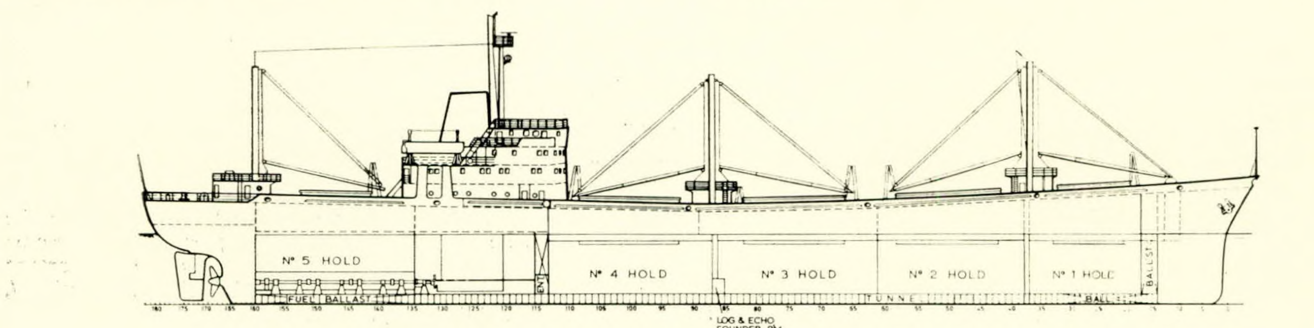
1) to relate the growth rate of second phase rare earth elements (lanthanum, gadolinium and erbium) to their solubility in the surrounding nickel matrix;
2) to determine growth rates in nickel/dispersed-phase systems where solid solubilities are low but where the chemical and physical stability of the second phase relative to nickel (as indicated by the melting point of the second phase and the solidus temperature of the alloy) varies (magnesium, uranium and yttrium in nickel);
3) to determine the solid solubility of lanthanum, gadolinium and erbium in nickel.

In reporting the solid solubility work the authors give details of alloying procedures, chemical analysis of the nickel/rare earth alloys, measurements of the ratio of electrical resistance at room temperature to that at low temperature, metallography, determination of the solid solubility of rare earths in nickel and types and compositions of the rare earth nickelides observed.

The second part of the paper is concerned with work conducted in connexion with the first two objectives. Melting and splatcooling procedures, and techniques for consolidating the splatted material, are described. Samples from compacted or as-splatted alloys were encapsulated in Vycor or quartz and heat treated. Light microscopy was used to determine the size and distribution of the precipitated phase in the splatcooled alloys. Details are given of particle size measurements. Observations on particle stability were confined to readily resolvable particle sizes. Each system is considered in turn.—*Kaufmann, A. R., Muller, W. C. and Russell, R. B., 4th June 1966. United States Department of the Navy Rep. NM1-8002; Nickel Bulletin, 1967, Vol. 40, No. 8, pp. 223-234.*

Russian Liberty Ship Replacement

A replacement for out-dated Liberty ship tonnage has been designed in Russia and is now available for export through V/O Sudoimport, Moscow. This new vessel, of about 13 800 dwt is suitable for the carriage of general cargo, industrial equipment and bulk cargo, excluding heavy ore and dangerously explosive cargoes. Propulsion can be either by Burmeister and Wain Diesel engine, built under licence in Russia, or by a Sulzer engine purchased from Switzerland.



Russian Liberty Ship Replacement

The design is for a single screw double deck vessel with five cargo holds, without a forecastle and with the engine room and accommodation arranged between Nos. 4 and 5 holds. The vessel will be built to the Rules and under the special survey of the Register of Shipping of the U.S.S.R. to their highest class; complying also with the SOLAS 1960 rules, and the Suez and Panama passage rules.

Low alloy and carbon steel will be used for the construction of the hull, which is to be of all-welded construction. A composite framing system will be used, with the upper deck, inner bottom and bottom framed longitudinally, with transverse framing for the sides, lower deck, fore part and afterpeak, deckhouses and platforms.

Principal particulars are:

Length, o.a.	459 ft 2⅜ in
Length, b.p.	426 ft 4¾ in
Breadth, moulded	67 ft 2⅞ in
Depth to upper deck, moulded	39 ft 8¼ in
Draught, summer	28 ft 10⅜ in
Tonnage draught	26 ft 3⅝ in
Deadweight at above	11 900 tons
Deadweight at 29 ft 0¾ in	13 800 tons
Deadweight at 30 ft 0⅛ in	14 500 tons
Gross tonnage (approx.)	9000
Cargo capacity	
Grain	689 056 ft^3
Bulk	633 282 ft^3
Machinery output	5500 bhp
Speed loaded	14 knots
Range at 14 knots	17 500 miles

The propelling machinery in the specification is given as a five-cylinder Diesel engine having an output of 5500 bhp at 135 rev/min, designed to run on fuel oil having a viscosity of up to 3000 sec Redwood No. 1 at 100° F (38°C) and a closed flashpoint on no lower than 65° C (149° F). The electricity supply will be obtained from two Diesel alternator sets, each of 300 kW output running at 500 rev/min, and from a 100-kW harbour service set. An automatically-started Diesel-alternator set of 100 kW output at 1000 rev/min will also be supplied.—*Shipping World and Shipbuilder, November 1967, Vol. 160, pp. 1893-1894.*

Marine Gas Turbines

Just as the lightweight simple-cycle gas turbine revolutionized the aircraft industry, it seems certain that the same power plant suitably modified will have far reaching effects in marine propulsion. The marine gas turbine has been the subject of much study, controversy and speculation since before 1939. The Royal Navy took the first realistic step by installing a 2500 hp gas turbine in the experimental vessel MGB.2009 in early 1947. Since then there has been a steady increase in the number of engines in naval service, and a widening of the field of application. This is well illustrated in a world-wide survey carried out by the United States Navy, which was published in April 1966, when the following facts were made known:

Year	No. of craft	No. of turbines	hp
1947 ...	1	1	2500
1958 ...	280	460	200 000
1965 ...	500	860	1 900 000

In the above study the marine turbine was considered in two major categories, namely, propulsion and auxiliary. The predominant use was propulsion, including boost and base-load engines and of the total 1 900 000 hp more than 80 per cent was represented by propulsion engines. Auxiliary applications include fire pumps, electrical on-board generating sets, boiler superchargers and hydraulic pump drives. Electric power generation was the predominant application in auxiliaries.

The main advantage which justifies the use of aero engines in the marine field is their low weight and volume characteristics. Specific engine weights are in the order of 0·7 lb/hp and specific volumes are less than 0·1 ft^3/hp. Large gas turbines above 10 000 hp have fuel rates at economical power of around 0·55 lb/hph. Engines of below 10 000 hp have specific consumptions generally in the region of 0·6-0·8 lb/hph.

Other advantages over conventional marine engines are:

1) more rapid starting and acceleration;
2) high torque at low rotational speed;
3) large horsepower sizes available;
4) simplicity of construction;
5) ease of, and reduction in maintenance;
6) lower installation costs.

The main disadvantage over conventional prime movers is high fuel consumption.

When considering aero gas turbines for use in the marine field, it is necessary to assess the effects which the changes in environment and load may have on the operation of the engine. Modifications to the unit which affect its power rating are usually necessary to meet the new requirements satisfactorily. When deciding the performance rating for marine use the following factors have to be considered:

a) More protracted periods of operation at the full marine rating will be required and the percentage of total operating time above the cruise rating may be in the region of five per cent.
b) The engine will operate at sea level.
c) Diesel fuel having a higher sulphur content than normal aircraft-turbine fuel will be used.
d) The engine will be subjected to salt ingestion from sea water which tends to foul the compressor blading and cause corrosion, notably of the turbine blades.
e) An overhaul life of 2000 hours is usually required.

The choice of marine rating is, therefore, a question of running an engine at as high a temperature as is consistent with achieving the required life between overhauls.

In order to combat corrosion, all magnesium components in the engines are replaced by aluminium alloy in the marine version and the blading of some of the compressor stages, which is of aluminium alloy in the aero engine, is replaced by blades of stainless steel.—*Connor G. G. "British Shipbuilding Today". Motor Ship, Special Survey, November 1967, pp. 70-76.*

Sea Water Corrosion of Nickel and Other Metals

The authors report some of the results obtained in initial studies at Digha, of the corrosion of the following materials by sea water under natural and laboratory conditions: mild steel, galvanized steel, copper, brass, nickel, Monel alloy 400, zinc and aluminium alloys. In the field tests, corrosion rates were determined for specimens subjected to alternate immersion and exposure at high tide and low tide or buried in the sea bed, for one month in each case. In the laboratory tests the specimens were totally immersed in natural sea water for one month and experiments were conducted to study the influence of temperature and *p*H on corrosion by sea water. Mild steel samples were used to determine the effect of inhibitors (potassium chromate, sodium nitrite, sodium arsenate) and of sea water velocity on corrosion rate and were also totally immersed for 24 hours in artificial sea water and in $0{\cdot}1N$ NaCl solution.

Under intermittent exposure, copper and brass had the lowest corrosion rates and nickel and Monel alloy 400 suffered least corrosion when buried in the sea bed. It was found that in general, the corrosion rate of specimens buried at half-tide level was greater than that of those buried in the sea bed. Rates of corrosion in laboratory tests were greater than under natural conditions and the velocity, temperature and *p*H of the test solutions are shown to have had a considerable influence on results.—*Khan, D. K., Mukherjee, K. P., and Bannerjee, T. N. M. L. Technical Journal, November 1966, Vol. 8, pp. 17-21; Nickel Bulletin, 1967, Vol. 40, No. 9, p. 253.*

Electromagnetic Controllable Slip Couplings

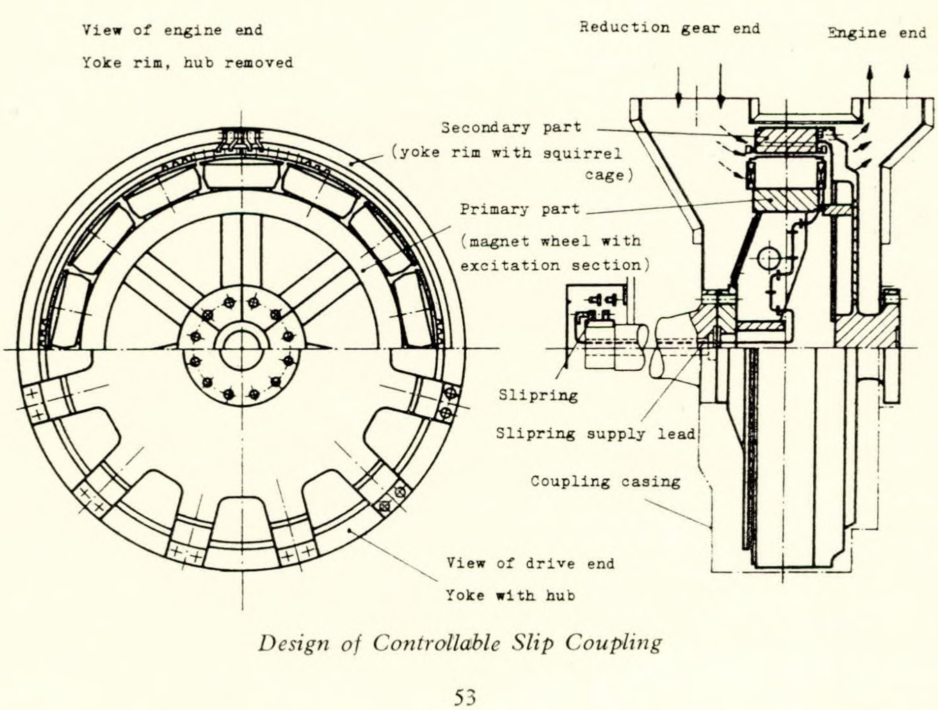
A new electromagnetic coupling suitable for geared or single Diesel engine propulsion has been developed by Siemens A.G. This coupling has variable speed control and offers maximum starting torque, is less expensive than the conventional slip coupling and has lower slip losses. Twelve of these new couplings are on order for installation in six twin Pielstick Diesel-engined refrigerated cargo vessels being built by Blohm and Voss in Hamburg, for the Hamburg-South America Line.

In recent years it has proved desirable to increase the speed range of propellers with medium speed Deisel engine drive. Since these engines do not run smoothly at less than approximately 35 per cent of their rated speed, still lower speeds have to be attained by letting the coupling slip. The Diesel engine then runs at its lowest operating speed, while the output speed of the coupling is considerably lower. This will produce relatively high slip losses in the secondary part which have to be dissipated without undue heating of the coupling.

Maximum starting torques are essential to permit rapid reversal and proper control of the propeller speed. The limited space available on board ship, the permissible bearing load of the Diesel engine and, last but not least, the costs involved have driven the use of conventional slip couplings to their very limits so that no additional demands can be placed on the types in use at present.

For that reason Siemens have recently developed a coupling with variable speed control which meets all the demands outlined above. The secondary part of this coupling consists of a steel ring of high magnetic but slight electric conductivity, in which a copper cage is fitted with the slots closed off towards the air gap by magnetic steel wedges.

Particular importance must be attached to the cooling of the coupling. An essential feature of this design lies in the fact that it is the first one which permits heat losses to be dissipated



Design of Controllable Slip Coupling

at all, this being a *sine qua non* for variable speed operation. The slip losses are thus not concentrated solely in the cage, but largely in the solid steel ring.

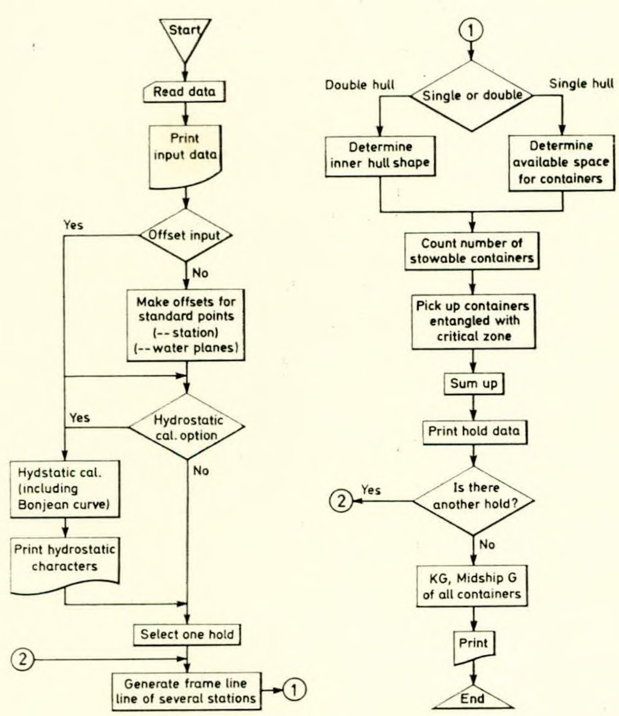
The couplings which Dynamo-Werk of Siemens A.G. are now building for Blohm and Voss, are the first of their kind to be used for ship propulsion. These couplings have a rating of 5500 kW at 500 rev/min and are also, as yet, the most powerful. The secondary part is arranged outside because of the cooling.

The minimum input speed of the coupling—or the mimimum operating speed of the Diesel engine—is 180 rev/min, whereas the lowest operative output speed is 115 rev/min. In the secondary part the value of the ensuring slip losses is approximately 110 kW, of which 70 kW are accounted for by solid iron and the remainder by the copper cage. The slip losses become less again at lower output speeds. The coupling thus enables the output speed to be varied right down to zero.—*Shipping World and Shipbuilder, November 1967, Vol. 160, pp. 1871-1874.*

Container Ship Design by Digital Computer

The design procedure of a high speed cellular container ship in the preliminary stage is to obtain the most economical ship size possessing the minimum main engine output, light weight and principal dimensions to satisfy the owner's requirements for number of containers, sea speed and cruising range. This research requires a tremendous volume of intensive work and to find the number of cubiform containers stowable in holds having curvatures in accordance with the ship's hull form from among the combinations of every conceivable principal dimension, is an impossible task by conventional manual computing methods. Through the employment of the digital computer it has become feasible to assume the number of containers stowable for every combination of principal dimensions and from these results it is possible to design an optimum form of economical ship.

A programme to find the number of containers stowable for a given combination of principal dimensions is composed of two main parts. The first is to prepare the precise hull lines complying with a given combination of principal dimensions suiting the required speed, range and propulsion power. The second is to determine geometrically the number of containers stowable in the holds for the prepared hull lines in accordance with the designated container stowage schedule.



Computer Programme Flow Chart

The flow chart of this programme is shown on the first half of the figure. The input data is the combination of length between perpendiculars, breadth, depth, draught and block coefficient and, if known, the position of centre of buoyancy. In this programme, prototype hull lines suiting the numerous speed ranges memorized in advance, and from these, hull lines best suiting the speed range are selected and developed by systematic modification against the given principal particulars. The hull lines thus produced possess ample precision for use in the preliminary design stage.

The flow chart for this programme is shown on the last half of the figure. The input data is the hold arrangement, container stowing schedule for each hold, sizes of hull structural members, container size etc. The inner hull shape of each hold is first obtained according to the information for either double or single hull construction. Next, the number of transverse rows of stowable containers for each tier is found. The critical zones along the inner hull, enabling the observation of the change in number of stowable containers which can be influenced by a slight modification of the hull structure or of the principal dimensions, can be specified. Subsequently, the programme is able to pick out the position and the true clearance of containers with regard to the specified critical zones. For the narrow hold near the ship's ends where the specified maximum transverse row at upper deck level cannot be complied with, the programme can function to examine whether odd or even number rows are to be favoured.

In this manner the most efficient method of container stowage can be obtained.—*Motor Ship, October 1967, Vol. 48, pp. 323-324.*

Medium-speed Engines for Liberty Replacements

The medium speed type of engine affords an advantageous solution to the propulsion problems posed by the Liberty replacement ships. In the first instance, the weight saving advantage is particularly important; the Piestick engine weighs only 9-10 kg/hp while the traditional slow-speed engines weigh in the order of 30-40 kg/hp. If the weight of a Pielstick engine installation is considered, e.g. the engine itself, the gearing and the couplings, a single-engine plant would represent a weight/power ratio in the order of about 15 kg/hp. In the case of a Freedom ship this represents a total weight saving of around 100 tons.

The advantages offered by medium-speed engines and covered briefly in the foregoing notes have for long been apparent but it is only in recent years that shipowners have accepted the readily available well-tried machine of this class — the S.E.M.T./Pielstick design. Some facts concerning this engine are of interest. The first ship powered by S.E.M.T./Pielstick engine of the PC type entered service in 1955. Today, 117 Pielstick-engined ships are in service and 113 vessels are on order, giving a total of 230 ships and 473 engines. The main reason for the increasing success of the S.E.M.T./Pielstick engine for marine propulsion is its ability to operate on heavy fuel. The fuels which may be utilized can be of from 200 to 3000 sec Redwood No. 1 at 100°F viscosity. They can be of any type, as test results and actual service results show that there need be no restriction concerning the sulphur content, Conradson value, ash content or, especially important, the vanadium content.

The establishment of a maintenance schedule for the S.E.M.T./Pielstick engine based on long service experience covers the following main points:

1) Inspection of fuel injectors after 1000-1500 h service.
2) Inspection of exhaust valves and eventual replacement after 5000-6000 h.

3) Inspection of pistons and replacement of rings after 10 000-12 000 h. Some owners have extended piston inspection periods to 16 000 h.

4) Inspection of main bearings after 20 000-24 000 h.

Cylinder liner wear measured on engines in service is less than 0·010 mm/1000 h (this measurement is taken at the top dead centre position of the firing ring, i.e. at the most worn point). This wear rate gives the liners a life of more than 60 000 hours.

The wear of the first ring groove is less than 0·015 mm/1000 h. These results represent a total operational life for the pistons, before eventual renewal of the first groove, of more than 30 000 hours.—*Gallois, J. Motor Ship, October 1967, Vol. 48, p. 298.*

Soot Blowers for Large Marine Boilers

One of the inevitable developments of marine steam engineering has been a considerable increase in boiler size, culminating—for the present, at least—in the very large Foster Wheeler watertube boilers now going into the liner *Queen Elizabeth II.*

Clyde Blowers Ltd. of Clydebank have supplied seventeen of their soot blowers for each of the three Foster Wheeler ESD II boilers, the largest that the firm has yet supplied for marine use. These blowers are fitted to the economizers as well as to the superheaters and boilers. Each blower is driven by a reversing electric motor which operates in a predetermined sequence as selected by skip/blow switches on the control panel. Contactless transducer-type limit switches are on the blower and valve units to control the operation and to signal completion of operation. The control panel for sequential operation of the automatic soot blowing system is an advanced static switching system using high speed transistor logic circuits made by Brookhirst Igranic Ltd.—*Marine Engineer and Naval Architect, October 1967, Vol. 90, p. 445.*

Queen Elizabeth II

The much discussed new dual purpose passenger liner of the Cunard Line was launched by the Queen from John Brown's Clydebank yard on 20th September, 1967, sixty years to the day after *Mauretania,* most famous Cunarder of all, slid down the ways at Wallsend.

In contrast to *France* and *United States,* which are of comparable size, although considerably faster, the new vessel will have twin-screw Brown/Pametrada geared turbines with a total maximum output of 110 000 shp at 174 rev/min. It is understood that no more than 85 000 shp will be needed to maintain the service speed. There will be three Brown Foster Wheeler ESDII boilers, each rated to deliver 231 000/310 000 lb/h of steam for normal/maximum output at 850 lb/in², 950°F. These will have Lucas oil-burning equipment and will give the greatest steam output of any boilers afloat. They are arranged two forward and one aft in a single compartment on the centre-line of the ship just aft of amidships.

The turbines are of cross-compound double-reduction Pametrada type and drive 19-ft diameter six-bladed Stone Manganese Marine propellers. The propeller shaft diameter is a nominal 32 in at the stern tube bearing. The H.P. turbines are of all-impulse design, with three controlled groups of first-stage nozzles. This will enable the highest nozzle-box pressures and turbine efficiencies to be maintained over the range of power needed for operating on the North Atlantic and also while cruising. The L.P. turbines are of double-flow impulse-reaction type and both lines are associated with double-reduction dual-tandem (locked-train) gearing. The valve chests containing the nozzle group valves are separate from and alongside the H.P. turbines.

There are to be two machinery control rooms. One is between the boiler room and turbine room for supervision of the propulsion machinery and will be manned only at sea. The other is an auxiliary control room which will be manned both at sea and in harbour for supervision of the auxiliaries.—*Marine Engineer and Naval Architect, September 1967, Vol. 90, pp. 374-377.*

Optical Smoke Detector

The demand for a reliable low voltage fire detection system able to initiate an alarm at the early smouldering stage, has resulted in the development of the Pyrotector Model 1030 24-volt d.c. smoke detector. It is claimed to be the first inherently stable detector of sufficient sensitivity to detect all types of smoke and is particularly suitable for the protection of computers, data processing equipment and other electrical risks. Although sensitive to all types of smoke, the detector remains unaffected by normal atmospheric contamination, e.g. dust or cigarette smoke. It is also unaffected by fluctuations in temperature, humidity or ambient light conditions. It can be wired into existing fire alarm circuits without the need for additional indicator panels or control equipment. It can be used to trigger-off fixed fire extinguishing systems, to shut down air-conditioning plant to prevent spread of fire, to control smoke door and shutter release devices and to operate audible and visual alarms. The detector may be used singly or in multiples to protect either individual pieces of equipment or whole factories, warehouses, office blocks and estates. The principle of operation is that of smoke particles reflecting light on to a photo-conductive cell. Two photo cells are used, one to detect faults and the other to actuate an alarm. When the unit is connected to a 24-volt d.c. supply, the beacon lamp incorporated in the smoke detection chamber is illuminated. This lamp irradiates the monitoring photo cell which causes a large decrease in cell resistance and energizes the fault relay. Loss of power or failure of the beacon lamp will cause the fault relay to become de-energized and the

CUNARD LINE'S THREE "QUEENS" COMPARED

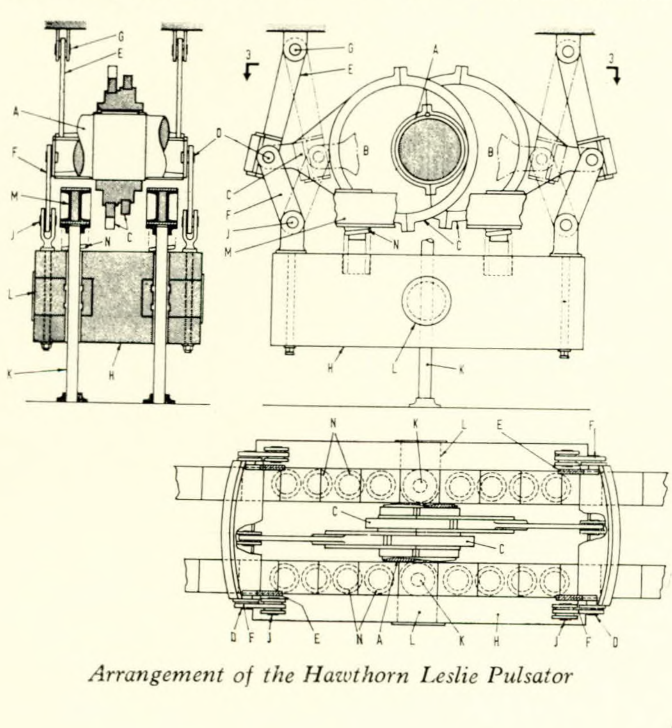
	Queen Elizabeth II	*Queen Mary*	*Queen Elizabeth*
Length, o.a.	963 ft	1019 ft 6 in	1031 ft
Beam	105 ft	118 ft	118 ft
Draught	32 ft 6 in	39 ft 4½ in	39 ft 6½ in
Gross tonnage	58 000 approx.	81 237	82 997
Keel to base of funnel	134 ft	125 ft	131 ft
Height of funnel	67 ft 3 in	59 ft	56 ft
Passenger capacity	2025	1948	2082
Machinery	Double reduction Pametrada type turbines	Single reduction Parsons type turbines	Single reduction Parsons type turbines
Power	110 000 shp	160 000 shp	160 000 shp
Service speed	28½ knots	28½ knots	28½ knots
No. of propellers	two six-bladed	four four-bladed	four four-bladed
No. and type of boilers	three Foster Wheeler	27 Yarrow	12 Yarrow
No. of decks	13	12	12

resultant contact transfer is used to intiate fault signals. When smoke enters the chamber, light is reflected on to the alarm photo cell which decreases its resistance until a point is reached when enough voltage is present within the circuit to energize an alarm relay via a transistorized amplifying circuit. This alarm relay, built into the detector, triggers off the appropriate warning. For local visual warning and detector identification purposes, an indicator lamp is built into the case. This lights under either fault or alarm conditions.—*Marine Engineer and Naval Architect, October 1967, Vol. 90, p. 461.*

Secondary Balancers—A New Approach

The principle features of the Hawthorn Leslie pulsator are shown below. It consists of a balancing mass (*H*) reciprocated vertically at a frequency equal to twice the rev/min of the mainshaft (*A*), by two toggle link mechanisms (*E*) and (*F*) arranged symmetrically at each side of (*H*) and driven by a pair of eccentrics (*B*) mounted on the mainshaft so that they operate exactly out of phase. Each eccentric (*B*) is connected to one of the toggle link mechanisms (*E*) and (*F*) at the pivot point (*D*), the other end of link (*E*) being connected to a stationary part of the surrounding structure at pivot point (*G*), while the other end of link (*F*) is connected to the balancing mass (*H*) at pivot point (*J*). The balancing mass (*H*) is constrained to reciprocate vertically by guide rods (*K*) operating in trunnions (*L*) which slide up and down the guide rods as the balancing mass is raised and lowered. The trunnions are provided to accommodate the small angular movements imparted to the balancing mass (*H*) by the toggle linkage. The pre-loaded compression springs (*N*) are inserted between the balancing mass (*H*) and a fixed beam abutment (*M*), rigidly secured to the surrounding structure, to ensure that the links (*F*) and pivot bearings (*D*), (*G*) and (*J*) experience only tension and uni-directional loadings. In this way buckling of the links and the development of backlash through wear is prevented.

In operation, rotation of shaft (*A*) and eccentrics (*B*) reciprocate pivot points (*D*) in the horizontal plane at a frequency equal to the rotational speed of the shaft. As pivot points (*D*) move away from their mid positions in either direction links (*E*) and (*F*) raise the pivot points (*J*) and therefore the balancing mass (*H*) until the pivot points (*D*) reach the extremities of their travel. Since the pivot points (*D*) reach two extremities, one at each end of their travel, during each revolution of shaft (*A*) it is evident that the frequency of reciprocation of the balancing mass (*H*) in the vertical plane is twice the rev/min of shaft (*A*).



Arrangement of the Hawthorn Leslie Pulsator

The magnitude of the vertical secondary force originated by the motion of the balancing mass is determined by the stroke of the linkage and the size of the mass so that by a suitable choice of these parameters, it is possible to accommodate the pulsator assembly in the comparatively narrow space available in aft end installations without interfering with accessibility. Furthermore, only the pivot pins securing the eccentric links need be dismantled to enable the gear to be swung aside to permit the intermediate shaft to be removed with a minimum of impediment. Similarly the gear can be readily uncoupled when not required, thus avoiding the wear that might occur with continuous operation. The circumstances in which uncoupling may be permissible depend on whether there is a significant resonance at or near the service speed and this will depend mainly on the loaded condition of the ship during a particular voyage.

The actual design envisages the use of ball and roller bearings throughout the linkage mechanism. In cases where the load on a bearing is substantially unidirectional and the relative movements are mainly oscillatory, there may be advantages such as reduced size and a corresponding reduction of inertia loading, in using a simple pin attachment with the pin rolling on a cylindrical surface of slightly larger radius so that there is a rolling rather than a sliding action. Provided the materials are carefully selected and are given a suitable surface treatment to minimize wear, such an arrangement is capable of giving long and trouble-free service as has been demonstrated by the suspension pin assemblies used in rotating pendulum vibration absorbers.—*Wilson, K. Marine Engineer and Naval Architect, October 1967, Vol. 90, pp. 431-433.*

75 350-dwt Vessel

With a deadweight capacity of 75 350 tons *Gallic Bridge* is the largest vessel yet to be built on the lower reaches of the Clyde. She is a bulk carrier with an overall length of 805 ft 0 in and is the largest vessel yet to be built by Lithgows Ltd. of Port Glasgow. She has been built for H. Clarkson and Co. Ltd. of London (Managers: J. and J. Denholm (Management) Ltd., Glasgow). Her principal dimensions are:

Length, o.a.	805 ft 0 in
Length, b.p.	775 ft 0 in
Breadth, moulded	105 ft 8 in
Depth, moulded to upper deck	61 ft 6 in
Draught	45 ft $4\frac{1}{2}$ in
Corresponding deadweight	75 350 tons
Total water ballast ...	41 100 tons
Total grain capacity ...	3 100 436 ft^3
Designed trial speed (loaded)	About $15\frac{1}{2}$ knots

Gallic Bridge has been built under special survey and to the highest classification of Lloyd's Register of Shipping for the notation ✠ 100 A.1 "Strengthened for ore cargoes Nos. 2 and 8 holds may be empty" with Notation C.C. (quench and tempered high-tensile steel fitted in top fibres). The vessel also meets the requirements of the Board of Trade, the Factory Act, the International Load Line Rules, British Tonnage Regulations, the Panama and Suez Canal Regulations and the International Conference on Safety of Life at Sea 1960.

She has a single deck with rounded sheerstrake in way of the holds, a raked stem and a cruiser stern, with a semi-balanced rudder of the Simplex type and a single four-bladed propeller. The engine room and accommodation are situated aft.

The main engine is a turbocharged two-stroke, single-acting, crosshead-type Diesel of Burmeister and Wain design, manufactured and installed by John G. Kincaid and Co. Ltd. It is an eight cylinder unit having a bore and stroke, respectively, of 840 mm and 1800 mm and developing 16 800 bhp (metric) at 110 rev/min with a maximum continuous rating of 18 400 bhp (metric) at 114 rev/min.

This engine is capable of operating on either Diesel fuel or heavy gravity type fuel having a viscosity of up to 3500 seconds Redwood No. 1 at 100°F. Each cylinder is fitted with three fuel valves and a single exhaust valve in the cylinder cover operated via a rocker arm and push rod, from the single chain-driven camshaft, which also operates the fuel pumps. Two turbochargers are fitted. Provision is made for cleaning the turbine blades while the engine is running by the injection of air and water into the exhaust gas at the inlet to each turbo-charger.

A centralized lubrication system serves the main engine rocker arms and exhaust valve spindles. The fuel injection valves are cooled by Diesel oil, thus avoiding contamination of the fuel oil in the event of leakage of the coolant. The main engine governor is of the Woodward type, and is designed so that the engine speed will remain constant, relative to the position of the fuel regulating lever and it also has an overspeed device which is incorporated in the bridge control system.—*Shipping World and Shipbuilder, October 1967, Vol. 160, pp. 1739-1740; p. 1743.*

Largest Tanker Built in Britain

The 115 250 dwt crude oil carrier *Narica* was delivered recently to Deutsche Shell A.G. by the Swan Hunter Group.

The accompanying table lists the main particulars of *Narica*:

Length, o.a.	870 ft 0 in
Length, b.p.	830 ft 0 in
Breadth	137 ft 10 in
Depth	64 ft 4 in
Draught	48 ft 10¾ in
Corresponding deadweight ...	115 250 tons
Horsepower	18 000
Trial speed	14·55 knots
Light draught	7 ft 4½ in (mean)
Light weight	18 100 tons

The ship has five cargo tanks longitudinally divided into three abreast to give a total of 15 cargo tanks. The wing tanks of No. 3 tank are used for ballast together with an athwartships tank forward and two wing tanks aft of No. 5 cargo tank.

The centre No. 5 cargo tank accommodates the slop tank which is used in the vessel's "load-on-top" tank cleaning system. The horizontal cross-sectional area of this tank has been kept to a minimum to facilitate the natural separation of oil and water during cleaning. This method of cleaning enables 99 per cent of the oil left in the ship after loading to be retained on board.

Cargo oil is handled by two Eureka horizontal single-stage centrifugal pumps each having a capacity of 159 000 ft^3/h against a head of 365 ft. Each pump is driven by a Stal-Laval turbine turning at 1100 rev/min and producing 2600 shp. For ballast pumping a Eureka pump of 77 600 ft^3/h capacity against a head of 80 ft is provided.

In the cargo pumping system, all valves except the stripping valves are operated by a 65-70 kg/cm^2 pressure hydraulic system supplied by Kracht Hydrauliek Werdohl, Germany. The operating levers are housed in 3-ft high circular steel coamings on the main deck, with similar levers located in the pump room entrance at deck level for the pump room valves.

A rather modest horsepower of 18 000, in comparison with other similarly dimensioned tankers, is provided by a Wallsend-Sulzer 9RD90 engine turning at 116 rev/min. This power enables a service speed of 14 knots to be maintained which, it is stated, is suited to the owners' operating requirements. Main engine equipment includes three Brown, Boveri turbo-chargers, one Woodward UG40 governor, three Serck air coolers and five 16 point, automatically replenished Ivo cylinder lubricators.

The main engine drives a Lips N.V. four-bladed, right-handed, Cunial bronze propeller of 6700-mm diameter. Intermediate and tail shafts run in Michell bearings, types M.T. and M.A. respectively. The thrust block is of the single collar, tilting pad type and the tailshaft runs in a cast steel stern bush fitted with Simplex type bronze oil seals and lined with centrifugally cast white metal.

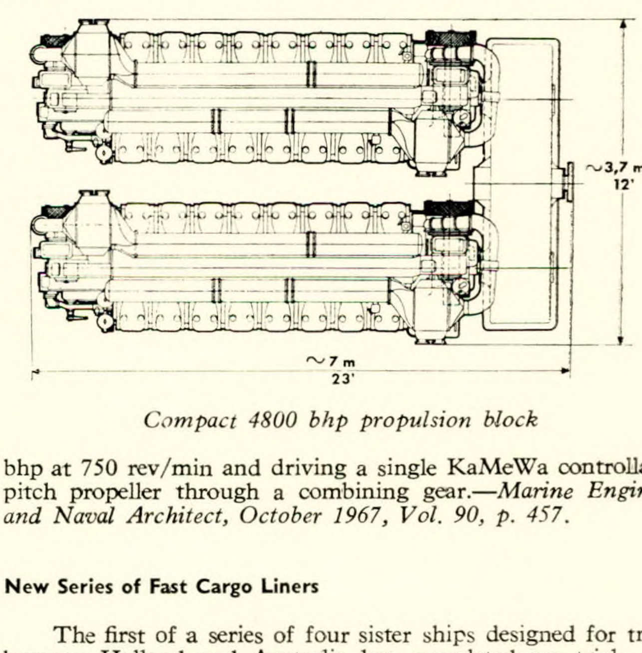
The machinery installation has been designed to operate with one engineer in the engine room during the day and an unmanned engine room at night, the intention being to release engineers for maintenance duties. This has been achieved by a comprehensively automated control system. The main engine can be operated either from a sound-proofed and air-conditioned control room in the machinery space or from the bridge. An engineer will be in the machinery space during cargo operations for starting up pumps.—*Motor Ship, October 1967, Vol. 48, pp. 286-290.*

Twin Gear 4800 hp Installation

The Transatlantic S.S. Co. of Gothenburg has ordered from Kalmar Varv a roll-on/roll-off motorship to perform a feeder service for their cargo liner and ACL operations based on the principal Swedish ports. This ship will have the following principal particulars:

Length, o.a.	248 ft 0 in
Length, b.p.	222 ft 0 in
Breadth, moulded	46 ft 0 in
Depth to shelter deck ...	34 ft 6 in
Depth to main deck	14 ft 6 in
Draught	13 ft 6 in
Deadweight	1325 tons

The machinery is to consist of two 16-cylinder Nohab Polar SF116VS-type four-stroke engines, each developing 2400



Compact 4800 bhp propulsion block

bhp at 750 rev/min and driving a single KaMeWa controllable pitch propeller through a combining gear.—*Marine Engineer and Naval Architect, October 1967, Vol. 90, p. 457.*

New Series of Fast Cargo Liners

The first of a series of four sister ships designed for trade between Holland and Australia has completed sea trials and is now in service. This vessel, *Wissekerk,* 13 290 dwt, has been built by the Maschinenfabriek en Scheepswerf van P. Smit Jr. N.V., Rotterdam, for N.V. Vereenigde Nederlansche Scheepvaartmaatschappij (United Netherlands Navigation Co.), The Hague.

The machinery is located well aft, deck cranes as well as a heavy lift derrick have been fitted and triple hatch covers are used.

The heavy lift gear consists of a 120-ton derrick suspended by means of two topping units over No. 2 hatch. The hoisting winch and the two topping winches have been neatly arranged below deck. As the wires belonging to the two topping units and the runner are always left on the winch, this gear is ready for use at any time. The blocks and other rotating parts of the heavy boom are self-lubricating.

Wissekerk has been fitted with a U-type roll stabilization system which has been designed by T.N.O. and, in order to minimize the loss in cargo space, has been arranged in the form of three tanks, one on top of the other, in way of frame No. 60. The fresh water tanks have been fitted between the uprights of the U-tanks. In order to reduce listing as much as possible during loading and discharging cargo, an automatically-operating transfer pump installation working on two wing fuel tanks in the double bottom has been fitted. The pump has a capacity of 100 tons/h.

Instead of steam heating *Wissekerk* has a thermal liquid heating installation for the bunkers, settling tanks and cargo oil. This installation consists of two oil-fired heat generators and two exhaust-gas heat exchangers. The oil-fired units are rated at 900 000 kcal/h each and the exhaust gas units, at 650 000 kcal/h each.

The circulating pumps for these systems have been supplied by Houttuin and consist of three pumps of 40 tons/h capacity and three of 20 tons/h, This system is new for use on board ship and is claimed to have certain advantages over the conventional steam heating installation. Smaller heating coils may be used, which reduces the initial cost, the system is fireproof and easier to control. The heating medium used is high flashpoint Monsanto Therminol TRO, which consists of chlorinated biphenyls.

The propelling machinery in *Wissekerk* consists of a six-cylinder Stork Diesel engine type 6 SW90/170 having a normal service output of 17 000 bhp at 115 rev/min and a maximum output of 20 000 bhp at 118 rev/min.—*Shipping World and Shipbuilder, November 1967, Vol. 160, pp. 1876-1883.*

Chain Cables

The Tayco type of steel stud-link cable came into being nearly 40 years ago as the first steel stud-link cable for marine purposes, replacing wrought iron. The advantages of steel anchor cable were immediately recognized and all classification societies allowed a reduction in diameter.

Shortly before the Second World War a new process of semi-automatic chain cable production, known as the inserted stud method, was evolved, and was adopted throughout many parts of the world due to its simplicity.

The principal differences between the two methods of manufacture are:

1) the Tayco link has a fully integral stud whereas the second method has an "inserted stud" which is secured in place by pressure of the link itself;
2) the inserted stud cable is produced from round bar material and the Tayco cable from drop forgings, which leads to the third main difference;
3) because it is produced from a solid billet of steel the diameter of the Tayco link is controlled and the crown is always slightly enlarged to allow for greater wear down. This cannot be carried out in the case of the round bar.

Despite the advantages of the fully integral stud method of manufacture, both types of chain cable have to conform to the very rigid specifications laid down by the classification societies and the various standards institutions, which govern testing, dimensions and material specifications.

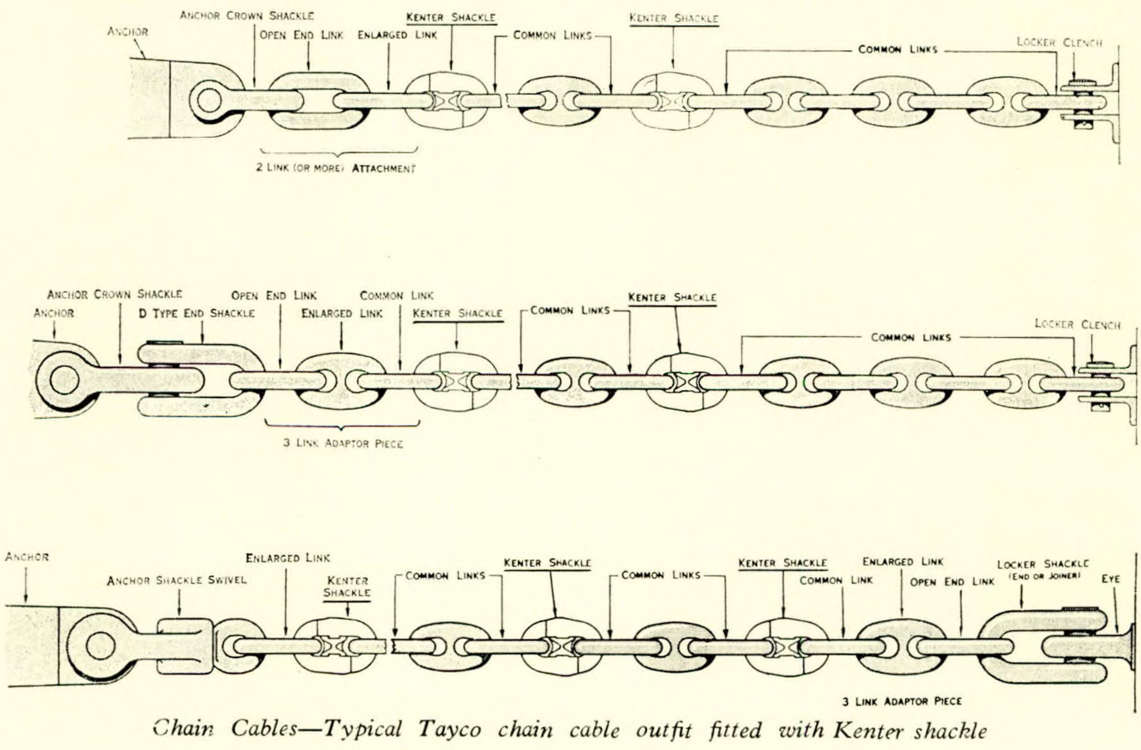
In the summer of 1965, a committee was set up by the seven principal classification societies, consisting of Lloyd's Register of Shipping, American Bureau of Shipping, Norske Veritas, Bureau Veritas, Italiano Navale Registro, Japanese Lloyd and Germanischer Lloyd. This committee looked into the possibility of producing very high strength stud link steel chain cable of a reduced diameter, in view of the vast tankers now being proposed.

These tankers would have a problem handling chain cable of the required size. For example, a single link of 5 in (127 mm) stud link cable would weigh one fifth of a ton.

The proposals set out by this committee were officially adopted by all classification societies late in 1965 and the following notation was laid down for the different types of anchor chain now available:

"U" (Unified) 1. Mild steel.
"U" 2. Normal strength steel.
"U" 3. Extra high strength steel.

An example of the diameter variations and the consequent



Chain Cables—Typical Tayco chain cable outfit fitted with Kenter shackle overall weight reductions on a typical cargo ship, trading to the Far East is given below:

U. 1. 2½ in diameter cable. Outfit weight = 44·1 tons.
U. 2. 2 3/16 in. diameter cable. Outfit weight = 33·8 tons.
U. 3. 2 in diameter cable Outfit weight = 28·3 tons.
Shipbuilding International, October 1967, Vol. 10, pp. 24-27.

Gas Turbine for Large Vehicle Transport

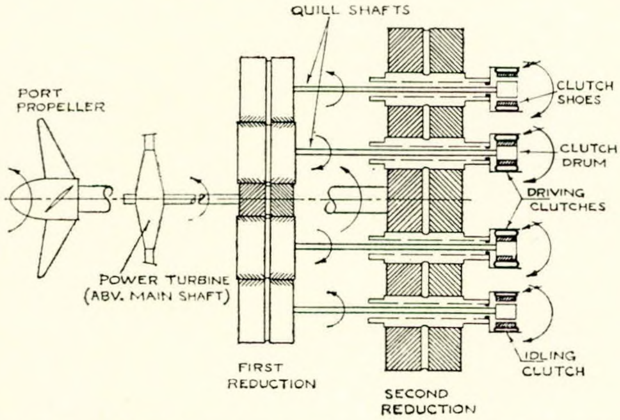
The U.S. Military Sea Transport Service's roll-on/roll-off ship *Admiral William M. Callaghan,* is the first large commercial vessel designed from the outset for gas turbine propulsion. The power plant represents a reasonable and economic combination of existing, proven components, all designed for continuous, full-power operation.

The basic ship requirements are essentially military, being high sea speed, rapid port turn-round and maximum cargo deck area. These requirements are the prime factors in achieving a high transport rate per ship/year. The conflicting requirements of deck area and sea speed have produced a long, fine-lined ship. Rapid port turn-round requirement has been satisfied by roll-on/roll-off capability for military vehicles from all cargo decks. In addition, all six hatches are served by booms and conventional cargo-handling gear.

Proposals were invited and of the six received, three proposed a gas turbine-electric drive, one either a reversible pitch propeller or alternatively an electric drive and two proposed a reverse reduction drive of the type which was finally selected. The evaluation of the offers received was difficult as each bidder was quoting on a different proposal. The selection was made after weighing three criteria:

1) cargo transport ability of the ship, assessed as its revenue-generating ability versus its cost to the Government; (60 per cent significant)
2) ability to handle roll-on/roll-off cargo in a rapid and effective manner; (30 per cent significant)
3) ability to handle general cargo in an expeditious manner; (10 per cent significant)

The main propulsion power of *Callaghan* is provided by two Pratt and Whitney FT4A-2 gas turbine engines, each driving a Falk reverse reduction gear unit. The shafting which connects to the twin, four-bladed, fixed pitch propellers has long outboard sections owing to the transom stern of the hull and each is supported by a vee strut at the propeller bearing. In order to place the lateral frequency of the shafting above the maximum propeller blade frequency without involving the hydrodynamic drag of a second set of shaft struts, the outboard shaft sections have been designed as torque tubes with high lateral stiffness and a smooth flow surface from the hull to the propeller hub. Although this shaft design is not a direct consequence of gas turbine propulsion, it exemplifies a design innovation appropriate to high speed ships where the gas turbine has the greatest potential advantage.



Power transmitted from the turbines to the fixed pitched propellers through pneumatic clutches and true reversing gear-boxes

The reduction gear units are of the locked train type, similar to naval gears used for high power ratings, in which the power from the high speed gears is divided by the use of quill shafts to the low speed pinions. The reversing arrangement is of an existing concept wherein the input pinion, connected to the power turbine, rotates one set of clutch assemblies in the ahead direction and another set of clutch assemblies in the reverse direction. Output shaft rotation depends upon which set of clutch assemblies is engaged to drive the low speed pinions which drive the output gear.

The input power is divided between the high speed gears which mesh with the engine pinion. When operating ahead, power is transmitted by the two quill shafts to the drums of the ahead clutches. By inflation, the clutch shoes are placed in contact with the clutch drum and thus transmit torque to the second reduction pinions.

The outer set of high speed gears are thus driven, unloaded, in the reverse direction. The connected clutch drums also spin in reverse; however, as the reverse clutches are disengaged the clutch shoes are spinning in the opposite direction, being driven by the pinions in mesh with the low speed gear.

To reverse the rotation of the main shaft, the engine output power is reduced to the idle condition, the ahead clutches are disengaged and the reverse clutches are pressurized. Initially, the reverse clutch drums are turning counter to the output glands and slipping occurs until the clutch torque dissipates the inertia of the system and the windmilling torque of the propeller. When relative rotation in the clutch reaches zero, the shaft rotation has been reversed and engine power is increased to accelerate the ship astern. The proper sequence of engine throttle control and clutch control is performed automatically by a single throttle lever for each engine.

The clutches are of the Airflex pneumatic type with asbestos-faced shoes mounted on a torus gland, with a relatively flat oval radial section. A small cubic inflation of the gland moves the shoe radially inward to contact the clutch drum. The shoes are expected to last the life of the unit with normal, commercial ship operation. Each clutch assembly is made up of three glands, all supplied from a common air manifold. These assemblies have been proven with many years of heavy-duty service in other marine applications at comparable heat/absorption rates.—*Marine Engineer and Naval Architect, November 1967, Vol. 90, pp. 479-485.*

Unattended Machinery Spaces

Probably the main factor which deters a shipowner from adopting an unattended machinery space is the fire risk. Machinery space fires are the most dangerous of all for the following reasons. They involve flammable liquids; there is plenty of air and often plenty of fuel, sometimes under pressure, so that development and spread can be very rapid. Furthermore such a fire may put essential services, such as pumps and lighting, out of action. The principal characteristics of machinery space fires is speed, the time scale being measured in seconds instead of hours.

Hitherto, machinery spaces have been occupied by watch-keepers and automatic fire detectors and alarms have not been considered necessary except for special risk areas such as scavenge belts and oil purifier flats. In unattended machinery spaces it will be obvious that there must be an automatic fire detection and alarm system and that the detection system must be capable of responding very rapidly.

The most common causes of fire are blowbacks or leaks from boiler fronts and overflows, leaks of fuel oil, or lubricating oil falling or spraying on to ignition sources. Such fires involve flame from the beginning and, therefore, heat and other electro-magnetic radiation. Lubricating oil is often regarded as being fairly safe. However, investigations into crankcase explosions have made it more widely known that when such oil is finely divided, as for example, by vaporization from a hot surface, spontaneous ignition can occur at temperatures as low as 270°C (515°F).

Detectors which respond to visible light have been produced but, in order to prevent natural or artificial light from giving false alarms, the amplifiers are d.c. coupled and, therefore, do not respond to a steady output. Instead they have a band-pass characteristic which means that they accept only fluctuations in a particular frequency band. It has been found by experiment that the band which is characteristic of flame flicker is 5-35 c/s.

In a machinery space there is a normal background of infra red, visible light and ultra violet. The detectors must distinquish between this background and the greater radiation levels associated with fire. Probably the main reason why radiation detectors have not been widely used is the difficulty of making the above distinction with adequate safety margin and, at the same time, achieving high sensitivity.—*Gray, D., Motor Ship, December 1967. Special Survey Marine Automation and Remote Control, pp. 20-22.*

Heat Generation and Residual Stress Development in Resistance Spot Welding

A description is given of the resistance spot welding process in terms of the internal behaviour of the weld as the process takes place. Experimental measurements and computer analysis of the heating, cooling and stress development provide the data. Temperature profiles from the thermal analysis programme are fed into a stress analysis programme and a complete picture of the stress development is obtained. The computed stresses are correlated with residual stresses determined experimentally. —*Lindh, D. V., Tocher, J. L. Welding Journal, August 1967, Vol. 46, pp. 351s-360s.*

A Method of Investigating Low Cycle Thermal Fatigue

A method of investigating low cycle thermal fatigue under large uni-axial constraint is presented. The specimen clamping device, time/temperature controller and programmer are described. From the preliminary test results on several steels, particularly on Incoloy, the type and significance of data obtainable by this method are discussed.—*Nippes, E. F., Uy, J. C. Welding Journal, August 1967, Vol. 46, pp. 371s-379s.*

Welding Brass to High Strength Low Alloy Steel

The author describes a welding technique for the efficient joining of naval brass to high strength low alloy steel (U.S. Steel Cor-Ten). The technique applies the gas tungsten arc welding process using a phosphor bronze filler metal. Weldments are of the butt and lap fillet types. Sound, porosity-free bronze weldments are obtained. They can be guaranteed to meet the 40 000 lb/in^2 minimum tensile strength requirement for the phosphor bronze filler metal. Metallurgical bonds are developed at the filler metal deposit to base metal interfaces.—*McGowan, M. T. Welding Journal, July 1967, Vol. 46, pp. 587-591.*

Fatigue Strength of a Weldable High Strength Martensitic Stainless Steel

A new stainless steel has been introduced which has higher strength than the annealed austenitic steels but still retains their excellent forming and welding properties. The static strength of this new material can be matched by several low alloy constructional steels. However, the dynamic properties of this steel exceed those of many constructional steels, particularly when welded. An extensive investigation of this new alloy has been executed.—*Kaltenhauser, R. H. and Lovejoy., P. T., Welding Journal, September 1967, Vol. 46, pp. 391s-398s.*

Heat Transfer from Fuel Gas Flames

Acetylene, propane and stabilized methylacetylene propadiene are evaluated as fuel gases. The heat transfer intensity profiles of the fuel gas flames are compared for a range of oxygen/ fuel ratios. The performance of each fuel gas is related to its heat transfer intensity profile. — *Fay, R. H. Welding Journal, August 1967, Vol. 46, pp. 380s-383s.*

New Ultrasonic Plastic Welding Technique

With the use of ultrasonic techniques, thermoplastic, and in some cases thermoplastic to metal, parts can be joined economically. The finished joint is strong, clean and is made considerably faster than is possible with solvent joining or spin welding techniques. Ultrasonic joining processes available at this time include: plastic welding, inserting metal in plastic, staking metal to plastic (lock-seal) and reactivation of adhesives. In each application, ultrasonic vibrations above the audible range are employed to generate localized heat by causing one surface to vibrate against the other.—*Schechter, M. C. Welding Journal, July 1967, Vol. 46, pp. 592-598.*

Midship Bending Stresses on Two Dry-cargo Ships

Tabulated stress data from unattended instrumentation systems are presented for two ships covering a total of 6528 h at sea. One ship has her machinery amidships while the other has hers aft.

The data indicate that the trend of maximum peak-to-peak stress, versus set state for the two ships is similar. The maximum peak-to-peak stress recorded in this data is approximately 6900 lb/in^2 for a sea state 11.—*Fritch, D. J. and Wheaton, J. W. March 1967. Ship Structure Committee Publication SSC-181.*

Current Penetration Seam Welding

Current penetration welding is a new technique for producing high speed seam welds. It uses high frequency current in the range from 10 000 to 500 000 c/s and will produce seam welds in two or more layers of metal at speeds in the range of 25-200 ft/min. The new technique has the advantage of many times the speed of conventional seam welding plus the production of a high quality continuous weld without stitches or nuggets. Continuous welds have been made in mild steel at rates of 25-150 ft/min between two layers from 0·002-0·006 in thick and in three layers 0·032 in thick.—*Rudd, W. C. Welding Journal, September 1967. Vol. 46, pp. 762-766.*

Recent Developments in the Employment of Ultrasonic Testing Equipment for the Dimensional Evaluation of Defects

After pointing out the criteria for the quantitative evaluation of defects by means of ultrasonic testing equipment, the author describes methods employed for checking crankshafts and thick-walled pipes.—*Bordoni, C. Fiat Technical Bulletin, October/December 1966, Vol. 19, pp. 127-136.*

Radiographic Sensitivity

Radiographic sensitivity is defined and a mathematical expression describing it is derived. Evidence is presented to show that radiographic sensitivity, contrary to popular opinion, is independent of specimen thickness *per se,* and that modern penetrameter design is based on invalid assumptions. Designs for penetrameters which provide a more realistic measure of the quality of a radiographer's techniques are offered.—*Stevens, A. J. Materials Evaluation, July 1967, Vol. 25, pp. 169-172.*

Use of Numerical Methods for the Investigation of Flow in Water Pump Impellers

This paper describes the development of a digital computer method for predicting the streamlines and vane surface velocities in mixed flow impellers. The flow is assumed to be axisymmetrical and reversible. However, even with these simplified assumptions, it is shown by examples that valuable information can be obtained for design purposes. No attempt is made to describe computer flow diagrams or to list machine orders.—*Wood, M. D. and Marlow, A. V. 1967. Paper submitted to the Institution of Mechanical Engineers for written discussion. Paper P29/67.*

Developments of, and Experience with, a Tube Cleaning Method for Condensers and Heat Exchangers

A new cleaning method has been developed for condensers and heat exchangers consisting of a brush, a receiving bush at each tube and valves automatically controlled by a timing device to reverse the flow in the tubes at predetermined intervals. Various reversing methods are described for tubes to be fitted originally or subsequently with the device. Brushes for elliptical tubes and special brushes for removing scale have also been developed.—*Heeren, H. Energie, München, March 1967, Vol. 19, pp. 97-102; Fuel Abstracts and Current Titles, August 1967, Vol. 8, p. 59.*

Boiling Heat Transfer Data at Low Heat Flux

Data are presented for natural and forced convection heat transfer from the outside of a single $\frac{3}{4}$-in diameter tube to saturated water in the pressure range from 535 to 1550 lb/in^2 area. Nonboiling and nucleate boiling at low heat flux are considered for vertical and horizontal tubes. Water chemistry is shown to be important in obtaining reproducible data. A new factor, suspended solid material in the boiling medium, is found to influence the nucleate boiling data in a manner similar to that of a dissolved gas.—*Elrod, W. C., Clark, J. A., Lady, E. R. and Merte, H. Trans. A.S.M.S. Journal of Heat Transfer, August 1967, Vol. 89, pp. 235-243.*

Motions and Propulsion of Single Screw Models in Head Seas

The paper presents the results of experiments in waves with 34 models of practical ship designs with block coefficients from 0·55 to 0·88, in the form of estimates of significant pitch and heave and mean power increases in irregular head waves, for ranges of Beaufort numbers from five to eight and ship lengths from 400 to 1000 ft. These results are analysed to evaluate the variation of pitch, heave and power increase with the principal dimensions (length, breadth and draught), two form factors, weight distribution and speed.—*Moor, D. I., and Murdey, D. C. 24th May 1967. Paper read at the Joint Meeting of Koninklijk Instituut van Ingenieurs and the Royal Institution of Naval Architects, The Hague.*

Application of Self-lubricated Materials

In a continuing programme to exploit the unusual properties and potential advantages of solid composite lubricants, a sleeve-type seal based on reinforced polytetrafluoroethylene was developed as a piston seal for high-pressure air compressors. The status of the material development for maximizing the effectiveness and life of this seal is reported. The use of an organized metallic filament winding technique to provide a superior reinforcing matrix is compared to the randomly dispersed particles and fibres used heretofore. — *Halliwell, H., Thomas, G. L., Ward, J. R. and Skruch, H. J. Lubrication Engineering, July 1967, Vol. 23, pp. 278-287.*

Universal Propeller Charts for Ship Design

When designing a ship it is necessary first to settle the efficiency of the screw propeller, its number of revolutions and its diameter, The decision about the other details of the screw will follow later. Two propeller charts which may easily serve all design purposes are offered. An example of a full-power thrust curve for a tug is given taking into consideration fixed and variabe pitch propellers. The problem of shallow immersion of screws is touched upon.—*Volker, International Shipbuilding Progress, August 1967, Vol. 14, pp. 338-344.*

Gas Shielding Test Methods

A literature survey and experiments have been performed in the area of gas shielding apparatus design and testing techniques. Gas tungsten arc tests show that static gas shielding tests predict weld performance within experimental limits of accuracy. They do not predict discoloration or partial oxidation of the weld surface which may be important to the user, nor do they predict weld performance at low shielding gas flows.—*Reiter, S. H. Welding Journal, August 1967, Vol. 46, pp. 676-682.*

Protecting Standby Equipment

The author discusses the problems of corrosion in standby power plant equipment. The peculiar problems of heaters, boilers, and turbines are examined. Traditional as well as new corrosion control devices are considered. Attention is given to difficulties encountered with peaking operations.—*Reid, W. T. Materials Protection, July 1967, Vol. 6, pp. 42-44.*

Gears and Their Lubrication

Metal as well as the lubricant undergoes changes in service. Metal deforms, expands, contracts, bends and twists under load while lubricants change in volume and physical properties. These changes are caused primarily by pressure and temperature changes. Since pressure is the results of applying load, but it is impractical to reduce load, attention is directed to temperature which can be controlled. Therefore the use of the lubricant as a heat transfer medium is just as important as preventing metal-to-metal contact.—*Reynolds, E. S. Lubrication Engineering, May 1967, Vol. 23, pp. 187-192.*

Pressure Measurements on Flapped Hydrofoils in Cavity Flows and Wake Flows

The purpose of the experiments is to obtain detailed information about the flow field, such as the pressure distribution at the surface of a flapped hydrofoil in full cavity or wake flows. The experimental results obtained have been compared with the theoretical predictions, for investigating the tunnel wall effect and estimating the viscous effect of a sharp corner. An empirical method for correcting the tunnel wall effect is developed.—*Meijer, M. C. Journal of Ship Research, September 1967, Vol. 11, pp. 170-189.*

Experiments on Slamming of Wedge-shaped Bodies

A series of experimental investigations of rigid body slamming was performed at the U.S. Naval Ship Research and Development Centre by dropping one flat bottom steel model and five wedge shaped steel models with small deadrise angles (up to 15°) from various elevated positions above a calm water surface. The test results were used to provide a set of charts for estimating the maximum impact pressure due to rigid body slamming of wedges.—*Chuang, Sheng-Lun, Journal of Ship Research, September 1967, Vol. 11, pp. 190-198.*

Residual Strains and Displacements Within the Plastic Zone Ahead of a Crack

Strains and displacements in the plastically yielded region generated ahead of a machined notch and a crack were detected with an interferometric technique. The measurements were performed on Fe-3 Si steel sheets after unloading and reflect local yielding under plane stress conditions. The results show that notch acuity within the limits examined has little effect on the strain distribution.—*Cammett, J., Rosenfield, A. R. and Hahn, G. T. November 1966. Ship Structure Committee Publication SSC-179.*

Marine Reheat Turbine Plant

Basic problems to be solved in the planning of an actual marine reheat cycle steam plant are discussed. Optimum reheat pressure ratio is given as 15-25 per cent of the initial pressure. Initial steam conditions of 100 atm and 520°C temperature are proposed as optimum conditions, reheating to be carried out to the same steam temperature. A feed pump driving turbine system is discussed where the turbine is driven by steam bled from the main turbine before reheating and the feed pump turbine bleeding and exhaust are used for feedwater heating.—*Takeda, Y. Japan Shipbuilding and Marine Engineering, July 1967, Vol. 2, pp. 23-32.*

Explosive Forming of Tube Joints

A new method of expanding tubes after welding developed and being used by Foster Wheeler in the manufacture of feedwater heaters is called "Detnaforming". The process involves a type of kinetic expansion which is accomplished by the detonation of a selected charge of explosives in a plastic insert. The latter is so located as to expand the tube in the tube hole beyond the tube-joint weld area. The expansion extends to within ⅛ in of the shell side of the tube sheet.—*Heat Engineering, 1967, Vol. 42, No. 3, pp. 37-40.*

Measurements on Fully Wetted and Ventilated Ring Wing Hydrofoils

Force measurements and visual observations were made in a water tunnel on fully wetted and ventilated flows past a family of conical ring wings having a flat plate section geometry. The fully wetted flows exhibited separation from the leading edge except for the largest diameter/chord ratio, a result which has been attributed to excessive cone angle. The effect of ventilation is to reduce markedly the lift curve slope. Pressure distribution measurements were also made under ventilating conditions for one member of the series tested.—*Acosta, A. J., Kiceniuk, T. and Bate, E. R. Trans. A.S.M.E. Journal of Engineering for Industry, August 1967, Vol. 89, pp. 445-455.*

Applications of Plastic Theory of Bending

Over the past two decades, plastic theories of bending have been used quite extensively in the design of civil enginering structures and a very large number of publications have appeared as a result. These publications are quite useful for designing some parts of a ship's structure, but there are quite a number of the structural components of a ship which cannot be tackled so readily. This is due to the fact that most civil engineering structures are designed to withstand uniformly distributed and concentrated loads whereas most ship structures have to withstand hydrostatic loads in addition to concentrated and uniformly distributed loads.

This article shows how the plastic theory method can be applied to certain components of a ship's structure. The kinematical approach of Horne is used. — *Shipping World and Shipbuilder, September 1967, Vol. 160, pp. 1533-1535.*

Analysis of the Modified Strip Theory for the Calculation of Ship Motions and Wave Bending Moments

A detailed comparison is made of calculated and measured ship responses to regular head waves. The comparison includes an analysis of the hydrodynamic force distribution along the length of an oscillating ship model in still water, the wave force distribution on a restrained model in waves and the wave bending moment distribution in regular head waves. The analysis shows that the calculations are sufficiently accurate for practical purposes, at least in the frequency range which is of interest.—*Gerritsma, J. and Beukelman, W. International Shipbuilding Progress, August 1967, Vol. 14, pp. 319-337.*

Australian Supply Vessel for Rough Seas

A specially designed, high-powered vessel capable of withstanding the roughest weather and sea will be built in Australia for the Esso/BAP offshore natural gas and oil exploration in Bass Strait, between the Australian mainland and Tasmania. This twin-screw boat now under construction by Adelaide Ship Construction Pty., Ltd., will be the first vessel of her kind to be built in Australia. She was designed to operate safely in the offshore waters of the exploration area which is known for its rough weather and choppy seas. The vessel will transport personnel and supplies between the mainland and the giant derrick barge to be used. The supply boat will be powered by two General Motors Diesel engines of 445 bhp.—*Shipbuilding and Shipping Record, 14th September 1967, Vol. 110, p. 369.*

Stress Investigations on Large Diesel Engines

An account is given of stress investigations carried out on models of certain components of the Sulzer RD marine engine series. The model tests were supplemented by measurements on engines in operation and strength tests on welded joints.—*Borgeaud, P. Sulzer Technical Review, 1966, Research Number, pp. 58-69.*

Thermal and Oxidation Stability of Heavy Duty Industrial Gear Oils

Formulation of gear oils with E.P. additives for continuous operation at high bulk oil temperatures was studied by the authors with particular attention to oil properties and additive characteristics. Sulphur phosphorized gear oils containing depletion additives appeared to be excellent products according to laboratory and limited field tests. The depletion inhibitor described reduces additive depletion, inhibits sludge formation, improves demulsification potential and inhibits corrosion. It may, however, slightly reduce initial load carrying ability and increase friction.—*Norton, J. H. and Dickey, J. R. Lubrication Engineering, August 1967, Vol. 23, pp. 314-324.*

Orthogonal Panoramic X-ray Unit

The radiographic examination of circular welds has been carried out for many years by means of panoramic X-ray equipments which emit a circular radiation beam and thus enable the whole 360° of the weld to be radiographed by means of a single exposure. These equipments, however, had the disadvantage of emitting an X-ray beam having an oblique angle of incidence which was due to the geometry of the tubes with flat anticathodes.

A panoramic equipment emitting a radiation beam whose median plane is perpendicular to the axis of the equipment with a new type of tube having a conical anti-cathode, is now available.—*Masson, P. British Journal of Non-destructive Testing, September 1967, Vol. 9, pp. 86-87.*

Ships' Gear for Oceanographical Research

This paper discusses types of research vessel, routine and experimental, common to many nations. Fixed deck gear, including winches and wires, together with instrumentation and apparatus are reviewed. Standard and experimental "free" equipment used for research vessels is described. Comment is made on additions and alternations to meet the ever increasing demand for space in these specialized ships.—*Herdman, H. F. P. 1966. Paper presented at the Technical Symposium of Ship's Gear International. Paper No. 12/2.*

Airborne Infra-red Detection Set Provides Sea Surface Temperature Indication

The infra-red detecting set is a valuable instrument for remotely recording sea surface temperature. Surveillance with this device allows the collection of large quantities of data over broad areas within a relatively short time. Equipment of this type is planned for installation aboard American aircraft in 1968 for supporting the Antisubmarine Warfare Environmental Prediction Services ((ASWEPS).—*Pickett, R. L., and Beckner, C. F. Undersea Technology, July 1967, Vol. 8, p. 19; p. 22.*

Nondestructive Testing of Composite Structures with the Sonic Resonator

An instrument called the sonic resonator has been developed for nondestructive testing throughout the depth of a composite structure while operating from only one accessible surface. Successful test results have ben obtained for a variety of honeycomb, laminar and corrugated (truss-core) materials. Defects detected include disbonds, voids, crushed core and fracture core.—*Botsco, R. J., Materials Evaluation, November 1966, Vol. 24, pp. 617-623.*

Floating Power Plant

The General Electric Co. in America is building a power plant capable of generating enough electricity to supply a community of 25 000 and will later tow it halfway around the world. This 240 × 101 ft floating power plant is scheduled to go into operation as part of the development work in the U.S. Nike-X antimissile system. The plant is powered by two G.E.C. packaged LM1500 jet gas turbines which will supply the peak power demands of the radar system, with Diesels supplying the continuous base load. — *Gas Turbine International, July/August 1967, Vol. 8, p. 23.*

Foam-in-Salvage

Aside from economics, quality and efficiency of foam formation, the feasibility of generating urethane foam underwater to a simulated depth of 375 ft in 30°F water (without exploding the foam upon decompression) has been demonstrated with a carbon dioxide blown foam in the laboratory. To date, service applications for the foam-in-salvage system have been limited to two stranding type salvage operations involving a destroyer and an LST. Two near surface recovery operations involved a sunken barge and a dredge.—*Winer, A. and Munger, M. Naval Engineers' Journal, June 1967, Vol. 79, pp. 465-474.*

Corrosion and Heat Transfer

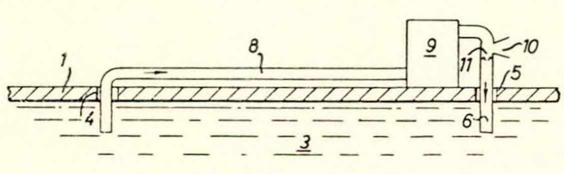
The general features of heat exchange phenomena are reviewed and their influence upon corrosion processes in liquids is outlined. A survey of experimental techniques previously used by others has been made and new ones based upon an analysis of the problem are suggested. The presentation of data obtained by these methods is illustrated with some results obtained on mild steel, copper and aluminium.—*Ross, T. K. British Corrosion Journal, July 1967, Vol. 2, pp. 131-142.*

Patent Specifications

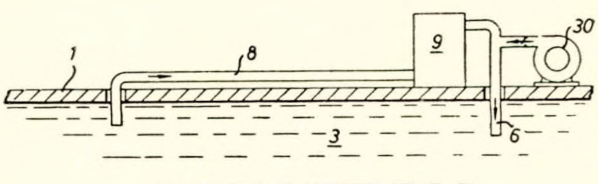
Breaking of Sheet Ice

This patent relates to the breaking of sheet ice as for example in estuaries or between an island and its mainland. According to the invention water is drawn from the body of water at one locality beneath the ice and is discharged into the body of water at a second locality beneath the ice horizontally spaced from the first locality and air is mixed with the water drawn before it is discharged.

Referring to Fig. 1, the numeral (1) indicates a sheet of ice on a body of water (3) having two holes (4) and (5) at localities



—FIG. 1.—



—FIG. 2.—

which are spaced apart. The left-hand end of a suction pipe (8) enters the body of water (3) through the hole (4) and is connected at its right-hand end to a pump (9), whose discharge pipe (6) enters the body of water (3) through hole (5). The pipe (6) is provided with an air inlet (10) and an injector (11) shown diagrammatically.

Fig. 2 shows an alternative mode of carrying the invention into effect in which air is dispersed into the water flowing downwardly through the pipe (6) by means of a pump (30) which forces air under pressure into the pipe (6) near its upper end. The pump (30) may deliver air at say 60 lb/in^2 gauge to the water inlet member.—*British Patent No. 1 072 370 issued to Horlicks Ltd. Complete specification published 14th June 1967.*

Securing-means Against Turning of the Rudder Motor Carried by the Rudder Head of a Ship

This invention provides a connexion which secures a ship's rudder motor carried on a rudder head against turning in relation to the hull of the ship. This connexion comprises a peg fixed at one end and engaging a recess in a bearing member so that up to a certain value the force between the two due to a turning moment of the rudder relative to the hull is taken by the peg at a particular point along its length, while any force greater in magnitude than this certain value is taken by the peg at a different point in its length nearer to its end.

The accompanying Figs 1 and 2 show an example of a connexion for a hydraulic ship's rudder motor in the form of a rotary vane drive mounted on the rudder shaft.

As shown in Fig. 1, the horizontal platform (2) mounted on the housing of the rotary vane drive (1) has rectangular cutouts

Fig.1

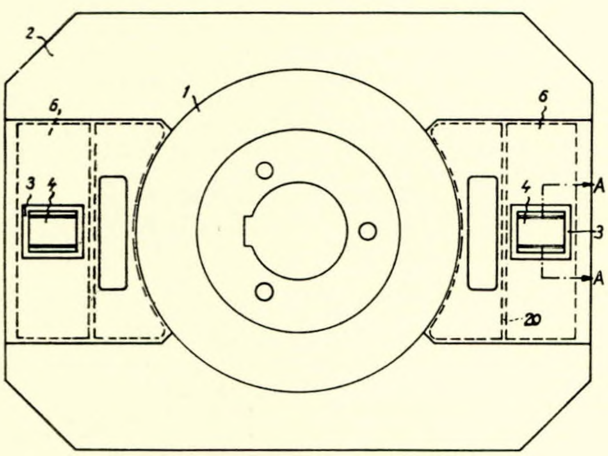
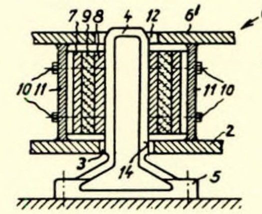


Fig.2



(3), through which extend pegs (4) which are rectangular in cross section. Each peg projecting from a base (5) (Fig. 2) is surrounded by a box shaped stop bearing (6) formed from webs which are welded onto the platform (2) and connected to one another by a cover plate (6). During normal operation of the rotary-vane drives, the torques exerted are transmitted to the ship in a resiliently flexible manner through one of the three-layer plate assemblies (7), (8) and (9) of each peg (4). If damage occurs to the propeller, then the transmission of torque in the connexion takes place through the corresponding side faces (14) of the peg (4) and the hard stops associated in the cut out (3).—*British Patent No. 1 078 938 issued to Licentia Patent-Verwaltungs-G.m.b.H. Complete specification published 9th August 1967.*

These abridgements are reproduced by permission of the Controller of H.M. Stationery Office. Full specifications are obtainable from the Patent Office, (Sale Branch), 25 Southampton Buildings, Chancery Lane, London, W.C.2, price 4s. 6d. each.

Corrigendum

On page 204 of the December 1967 abstracts, in the article entitled "Trailing Suction Dredger for Columbia" the words Columbia and Columbian should read Colombia and Colombian, wherever they appear.