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DESIGN AND COMMISSIONING OF STEAM TURBINE INSTALLATIONS

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Experience of past and presently operating turbine installations can provide valuable guide lines for future designs. Since the entire operational life of any installation will be influenced by the care taken in the design stages each forward step is carefully considered using this experience in a positive manner.

Even the best intentions and designs will founder if the commissioning and early days of the installation are not given adequate consideration and attention. The process of commissioning must be considered during the design stages so that it can be done efficiently. In this way the artificial barriers which are sometimes considered to exist between these two important functions are eliminated.

This paper is meant to illustrate the interdependence of one process on the other during the evolution of installations.

INTRODUCTION

The author assumes that the various methods of propulsion have been critically examined, that the vexatious question of steam versus Diesel has been solved and the decision has been taken to fit a steam turbine plant. In other words, he has no intention of stepping into the arena on that subject.

It is the intention of this paper to illustrate how efforts have been made to benefit from experience by applying some critical analyses of past installations and seeking remedies to their short-comings. It is also hoped to illustrate steps taken to enhance the chance of success when new features have been incorporated.

To achieve a successful turbine installation, the utmost care must be taken at every step and this care must start in the design stages. The success or failure of the design will be judged on the operating results and this must be kept in mind at all times. Following this theme, the sections of this paper are divided into two main parts—design considerations and commissioning.

CHOICE OF HEAT CYCLE

Following two classes of ships, one of which utilized multi-stage feed heating in split economizer layout and the other with multi-stage feed heaters and gas air heaters, the author's company decided to follow a simpler cycle route for the next series of ships of varying size and power.

There were several reasons for this decision, principally:

1) it was considered that greater overall economy would be achieved by reduced repair bills;
2) the complexity of multi-stage feed heating did not lend itself to engine room crew changes without prior duplication for familiarization purposes;
3) operation on optimum setting was rarely achieved due often to the complexity of the cycle;
4) operational problems with gas air heaters placed an undue burden on seagoing staff and proved costly on repairs;
5) reduction of the manning scale in future ships would have been precluded.

Reference to Fig. 1 illustrates the point made in item (1).

It will be noted that whereas the fuel cost has remained sensibly constant, the labour cost for repairs has shown a steady and continuous increase.

The cycle chosen for the simplified series consisted of de-aerator, economizers and steam air heaters. One bleed point only, at the cross-over, simplified the turbine design which at that time, was of the double-cased type. A further simplification was the omission of any form of nozzle control.

The fuel rates of ships following this basic cycle are shown on curve A of Fig. 2. The successful operation of these ships—and by successful is meant the realization in service of the design team's objectives—was encouragement to raise the steam temperature on the next class of ship (*Drupa*) to 950°F (510°C) with the reduction in fuel rate as shown on curve B of Fig. 2.

Extrapolations of both curves have been shown to include 28 000 shp which was the next size of plant to be considered.

Operating with superheat temperatures of 950°F (510°C) without resorting to exotic materials within the boiler, bearing in mind the degree of accuracy of controls and recording instruments, is close enough to the limit. Therefore, little more in the way of fuel economy can be sought by this means.

To increase pressures at constant inlet temperature will result in a decrease of turbine efficiency, and, if for erosion reasons, a limit of 11 per cent wetness of the exhaust steam is to be respected at the exhaust end of the turbine, further available gains are limited.

It would seem, therefore, that further reduced fuel rates can only be achieved by the increased complexity of multi-

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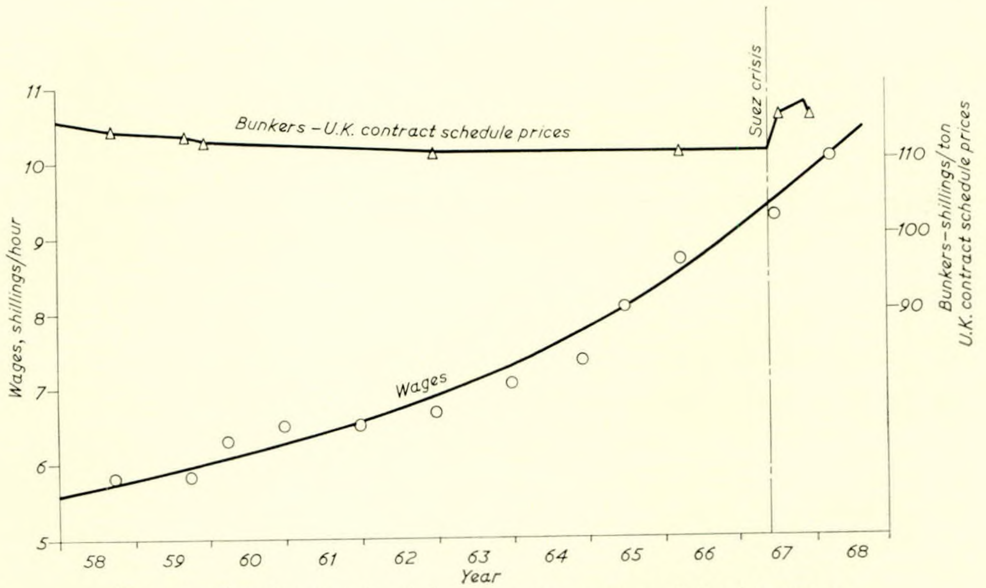


FIG. 1—*Showing trends of hourly wage rates and bunker prices*

stage feed heating with gas air heating, reheat or a combination of both reheat and multi-stage feed heating.

The selection of the cycle for the M class of ships with 28 000 shp installations was given careful consideration:

a) because a large number of ships was under consideration;
b) because the projected voyage would include long legs of steady steaming at full power.

Four cycles were closely examined:

i) Simplex cycle —A
ii) Complex cycle —B
iii) Simplex reheat cycle —C
iv) Complex reheat cycle—D

Table I gives the broad outline of each of these cycles.

TABLE I—OUTLINE OF HEAT CYCLES EXAMINED

Cycle	A Simplex	B Complex	C Simplex reheat	D Complex reheat
Boiler pressure, lb/in²	850	850	1150	1150
Superheater temperature, °F	950	950	932	932
Reheat temperature, °F	—	—	932	932
Boiler efficiency	88·5	88·5	88·5	88·5
Number of stages, feed heating	2	5	2	5
Economizers	fin tube	—	fin tube	—
Air heaters	steam	gas	steam	gas
Fuel rate, lb/shp h	0·476	0·464	0·440	0·420
Shp	28 000	28 000	28 000	28 000

It will be noted that for cycles using gas air heaters and those using economizers the same boiler efficiency was taken, i.e. the terminal gas outlet temperatures are the same. No doubt advocates of the Complex cycle will claim this is being unfair, since much of the economy normally claimed for cycles B and D would arise from reducing the gas outlet temperature. The author is unrepentant on this point, since experience has shown that the claims made for boiler efficiencies in the order of 90·5 per cent and more are paper figures rarely achieved in service for long periods and since

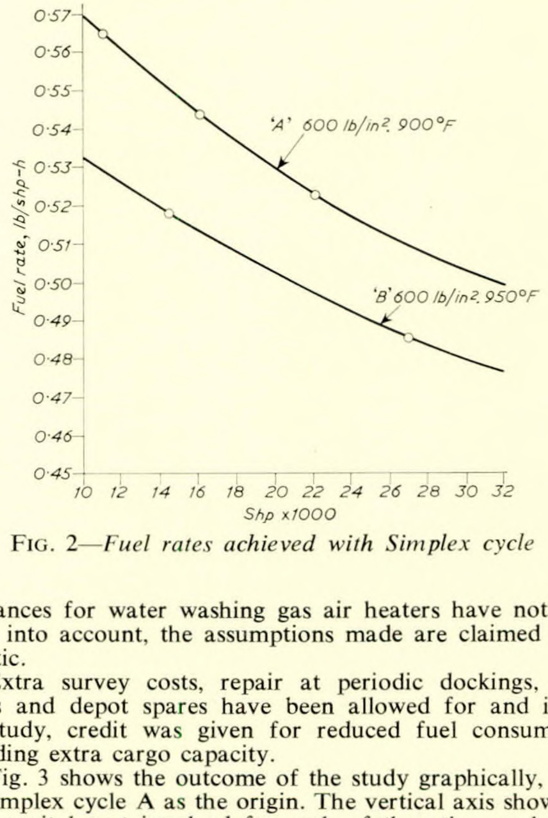


FIG. 2—*Fuel rates achieved with Simplex cycle*

allowances for water washing gas air heaters have not been taken into account, the assumptions made are claimed to be realistic.

Extra survey costs, repair at periodic dockings, extra spares and depot spares have been allowed for and in the full study, credit was given for reduced fuel consumption providing extra cargo capacity.

Fig. 3 shows the outcome of the study graphically, using the Simplex cycle A as the origin. The vertical axis shows the extra capital cost involved for each of the other cycles and the horizontal axis gives the yearly savings. On the basis of a 15 per cent annuity, the true saving is the figure vertically below the crossing point of the 15 per cent annuity line and the line of extra capital cost. The points for cycles B, C and D have been joined by curves for varying bunker prices to indicate the influence of fuel prices. Each radial line from the origin depicts equal rates of return.

For all bunker prices shown, cycle C shows the best rate of return and for this reason, the technical feasibility study concentrated on cycles A and C. The appraisal of reheat plant operation at elevated pressures indicated that as far as the turbine technology was concerned, most of the

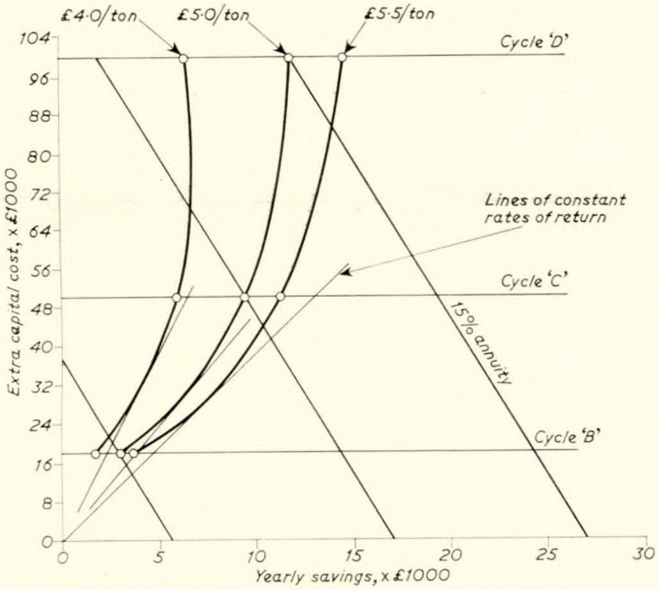


FIG. 3—*Yearly savings for capital expended*

foreseeable difficulties could be overcome. It still left, however, some doubts about the operation of boiler plant at the higher pressures. This is in no way a criticism of the boiler designers who have worked hard and achieved much in the way of producing attractive proposals and designs. Indeed, the author feels that the effort put into studying reheat by the boiler designers has resulted in major forward steps in conventional boiler design. Later, these advances are considered in further detail.

To summarize, the outcome of the technical feasibility study resulted in the decision to remain with the Simplex cycle without reheat, i.e. cycle A. Some of the reasons for this decision can be listed as:

1) limited knowledge of the feed water conditions existing on board during service which precluded the use of boiler pressures above 900 lb/in^2;
2) lack of time to allow detailed specifications to be drawn up;
3) lack of information on the capability of the various constructors; this problem arose from the world wide invitations to tender;
4) insufficient experience on controls and instrumentation.

On reflection and with some hindsight, the author still believes the decision taken at the time to remain with the simple and conventional cycle was the correct one. Some further experience and proof of reliability of plant and controls is needed before the possible savings, due to high steam conditions, evaluated previously in this section are sought.

A considerable part of the effort required will lie in the area of the steam generating plant and associated pre-boiler systems.

BOILER DESIGN

Boiler designs have, as already stated, advanced rapidly. These advances should result in increased reliability, availability and efficiency but the configuration, as far as internal cleaning and inspection is concerned, has to some extent been made more difficult. Indeed, mechanical cleaning has become almost impossible and large internal areas of heating surface cannot be inspected at all.

At the same time, steam conditions have increased, leaving the operator with the unenviable task of operating and maintaining this part of the plant for long periods, within more exacting operating limits than experienced or required ten years ago. The boiler designer should bear this in mind and cater for it by fitting adequate maintenance facilities for both the gas and water sides of the boiler.

The gas side maintenance does not end with the supply of soot blowers, although these are of paramount importance. The designer should provide adequate water washing facilities by way of inlet points for water lances and drains. These facilities should be so arranged as to allow cleaning to commence before the temperature in the gas spaces would normally allow entry.

In the very large single boilers fitted to the latest series of ships, exposed refractory has been virtually eliminated with the exception of a few floor tiles. Exposed refractory has been a headache for years and elimination has certainly been the best cure.

The ways and means of minimizing damage due to hot spots on the water side of the heating surfaces by removing millscale, construction debris and guarding against transportation of metallic salts in suspension and solution by feedwater and filtration treatment will be dealt with in the section on commissioning. It is obviously equally desirable to check for hot spots in the design of the combustion spaces of the boiler.

In conjunction with the boiler designers, the elimination of flame impingement was attempted by the use of an air and water analogue model of the boiler.

Reference to Fig. 4 shows the predicted flame pattern within the furnace with the burner registers located dimensionally as they might have been. It will be noted that quite severe flame impingement is indicated by way of the screen wall. By adjustment to the register position and angle to the plane of the roof tubes, the flame pattern was changed to that shown in Fig. 5 which indicates a much more acceptable situation.

By using such a model, the boiler designer would hope to utilize the furnace volume more efficiently, which is important if the plant fuel rate is to be lowered by decreasing the excess air for combustion purposes. Reducing excess air

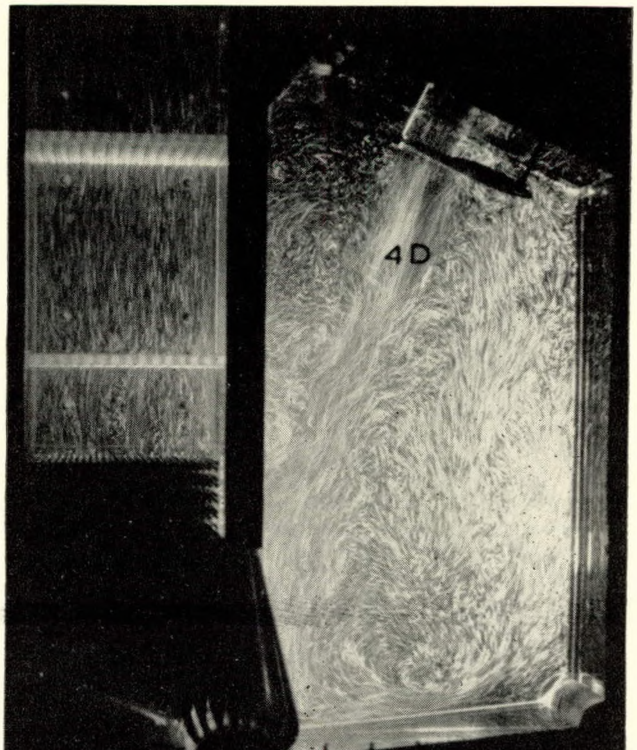


FIG. 4—*Burners located dimensionally—Predicted flame impingement*

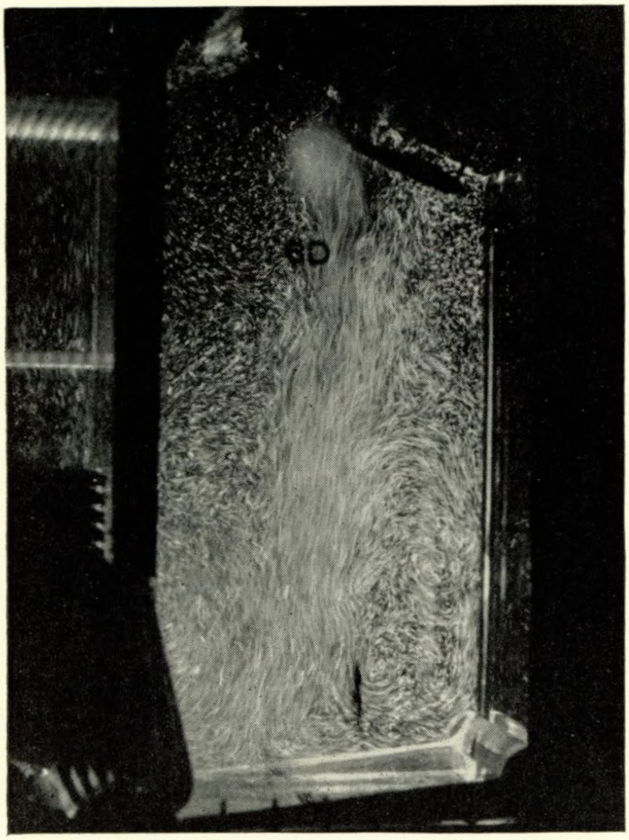


FIG. 5—*Modified burner location—Improved flame pattern*

without careful consideration being given to furnace design will only result in problems due to solids being deposited in the cold end of the boiler. The achievement of improved furnace conditions was one of the main considerations in deciding on a single boiler concept for the latest series of ships. The large furnace, relatively low thermal-ratings and increased "dwell period" to allow for complete combustion, will result in reduced shut-down time and higher combustion efficiency. The boilers, in practice, have shown that the designed CO_2 figure of 15 per cent can be easily and continuously achieved without approaching the smoke line of the burners.

As combustion approaches stoichiometric conditions, however, the more normal criterion of flame envelope becomes invalid since the flame will tend to fill the furnace as it searches for the small amount of free oxygen available to complete the combustion process. Other effects of flame configuration have been found to exist in practice with the type of boiler shown. Superheat temperatures, for instance, normally increase with increasing excess air. This remains true on this boiler but in addition increased superheat can occur due to reduction of excess air if the flame shape results in radiant pick-up in the lower rows of the superheater. Combustion control is therefore of increased importance in such boilers.

FEED WATER AND CONDENSATE SYSTEMS

Whilst boiler pressures for marine installations are modest by comparison with land practice, the trend is upward and therefore further consideration must be given to feed water conditions. Advice sought from various authorities on the subject indicated that feed water for boilers operating at pressures in the order of 900 lb/in^2 should have no more than 0·05 p.p.m. of iron and 0·02 p.p.m. of copper in solution.

To establish the conditions existing in typical feed and condensate systems, a series of tests was initiated. A ship called *Diala*, completed in August 1966, was chosen to be the test bed and fitted out with the following equipment:

a) amine and hydrazine injection pumps—injection point situated after the de-aerator;
b) *p*H meter fitted after the main condensate pump discharge;
c) O_2 meter with connexions before and after the de-aerator and at the drains tank pump discharge;
d) sampling points fitted at several places in the system.

After allowing the ship to settle down into service, tests were begun to establish the quality of water existing in the feed and condensate systems under different operating conditions. Particular note was made of the variations taking place when bringing into service those systems and auxiliaries which normally lie dormant for extended periods of time.

The findings of these tests proved to be extremely interesting and are summarized below:

De-aerator

This equipment worked well at all times, reducing the O_2 level below 0·005 ml/l at the outlet. The O_2 level at the inlet varied considerably, depending upon the ratio of the drains tank pump discharge to main condensate. Under normal conditions, the O_2 averaged 0·1 ml/l rising to 0·45 ml/l when using cargo pumps whose exhaust steam reaches the drains tank via an atmospheric condenser.

Evaporator

The evaporator, which is condensate cooled, produced excellent water at all times. The iron pick-up was 0·06 p.p.m., but the copper pick-up was high (0·2 p.p.m.), pick-up most certainly being from the distiller condenser tubes which are copper base material. The *p*H of the evaporator output was acidic (averaged about 5·4), but since on vessels of the author's company the domestic water comes from this source, the use of amines for *p*H improvement is precluded.

Feed Tank

The evaporator output is discharged to a feed tank formed within the ship's structure. Make up to the system is automatic and samples taken showed the same degree of copper content, but some further iron pick-up had occurred due to corrosion within the tank. Since the stored water is acidic, this is to be expected.

Drains Tank

This section of the system proved to be the source of a large proportion of the contamination. In earlier ships, the atmospheric condenser was a separate unit with a loop drain to ensure the lower tubes were always covered.

When cargo pumping, the steam demand approximates to that of the ship's normal full power requirement and this large under-cooled return to the de-aerator often resulted in fall-off in the efficiency of the de-aerator. This, on *Diala* and on later ships, has been overcome by building the atmospheric condenser into the drains tank allowing for regenerative heating, thus ensuring that the drains tank is always at a temperature close to saturation. This reduces the absorption of O_2 and CO_2 giving some improvement but as already stated, the discharge to the de-aerator is relatively rich in O_2.

Under normal steaming conditions, it was found that the iron in solution amounted to 0·04 p.p.m., copper 0·08 p.p.m., *p*H 9·6 and O_2 0·6 ml/l.

On starting up cargo pumps, however, the degree of contamination rose considerably for the first 15 minutes. Readings in this initial period were as high as total iron 4·16 p.p.m. of which almost 90 per cent was in suspension, copper 0·03 p.p.m., *p*H remaining at 9·3.

It was first thought that this high iron contamination was arising in the drains tank at the time the cargo system was brought into use due to the corrosion products being swept into the tank and consideration was given to the dumping of the condensate for the first 15 minutes. On the very large crude oil carriers, this could amount to 15 tons of water at a time when making water is impossible, due to the ship being in harbour. It is now considered that there is a gradual build-up of corrosion products in the drains tank due to precipitation over the weeks when the through-put is low. The sudden rise in contaminant in the drains tank discharge is then due to the increased agitation which takes place when the drain returns are suddenly increased. Some simple re-design of the drains tank bottom will retain the sludge build-up reducing the transportation out of the tank. The sludge can then be removed at regular intervals. To deal with the remaining contamination, the fact that such a large proportion is in suspension means that filtration can help to maintain an acceptable level.

To determine the grain size of the contamination in suspension, series of tests were carried out, using a specially designed measuring filter. This consisted of a container with a plastic membrane through which a measured quantity of condensate was passed. The membrane was then examined under a microscope and a grain size analysis carried out. The outcome of these tests showed that a 5-micron total cut-off filter would remove 98 per cent of the suspended matter.

In view of these findings, a 5-micron duplex filter, preferably of the depth type, is to be fitted on the very large crude oil carriers. Modifications to the drains tank bottom to reduce mechanical agitation of sludge build-up mentioned above will be made to increase the useful life of the filter cartridges which will be of the disposable type.

Main Condenser

The main condensate pump discharge gave a consistent figure of less than 0·02 p.p.m. of iron and 0·02 p.p.m. of copper. The *p*H value was 9·5, O_2 level 0·005 ml/l and total hardness of less than 1 p.p.m.

Other Contaminants

Other trace contaminants have been found in the feed system, of which silica is perhaps the most interesting. Silica concentrations of up to 8 p.p.m. have been found in the boiler water of a number of ships. It is not possible to state where this contamination is coming from. Some is undoubtedly present in the make-up feed water and some no doubt is being picked up in the feed system, possibly from silica inclusions in valve castings. Investigations into this are still proceeding.

The outcome of the tests indicated that approximately 100 lb of iron and 30 lb of copper are transported into the boiler every 1000 days of operation. Of the iron, almost 60 per cent is in suspension and of a median size capable of being removed by filtration.

PRECAUTIONS

Following the tests carried out and the researches made, it was decided that the step from 600 lb/in^2 to 900 lb/in^2 could be safely taken providing the necessary precautions indicated below were followed:

a) control pre-boiler system corrosion by using amine treatment;
b) fit ion exchange units for feed make up "polishing";
c) de-oxygenate boiler water using chemical injection as an insurance against de-aerator performance fall-off;
d) filter out the bulk of the suspended iron;
e) flush out precipitated solids from the system and boilers at regular intervals;
f) acid clean boilers and superheaters every two years to control magnetite film thickness and to remove deposited iron and copper;
g) "blow" boilers to keep the total dissolved solids at permissible levels, regardless of chloride readings;
h) maintain the specified phosphate reserve and alkalinity of the boiler;
j) ensure that ship's staff are fully aware of the precautions to be taken and the importance of seeing that boiler water purity is maintained.

Having drawn these conclusions for the steam conditions given, what of the future and possible further increases in steam conditions?

As previously indicated the next logical step is to the simplified reheat cycle taking advantage of even higher steam pressures. Before this can be done safely, however, feed water treatment and chemical control must be improved. To ensure the standard of such treatment is maintained, it may be necessary to consider automatic control of this part of boiler operation.

If the silica concentrations being found in existing boilers are allowed to exist in boilers operating at 1300–1500 lb/in^2, carry-over of silicates into the steam path of the turbines will certainly take place, resulting in deposition on the blades and severe fall-off in performance. To reduce the concentrations, much heavier "blow" than presently exercised will be essential and this should be taken into account in the economics of the exercise.

MAIN ENGINE

It may seem strange that so little has been said about the actual turbine. However, after considering the associated systems, only the steam path remains for comment, and the design of this is outside the scope of this paper.

Damage to the steam path by impingement of solids is mentioned later but purity of the steam deserves more attention than it gets.

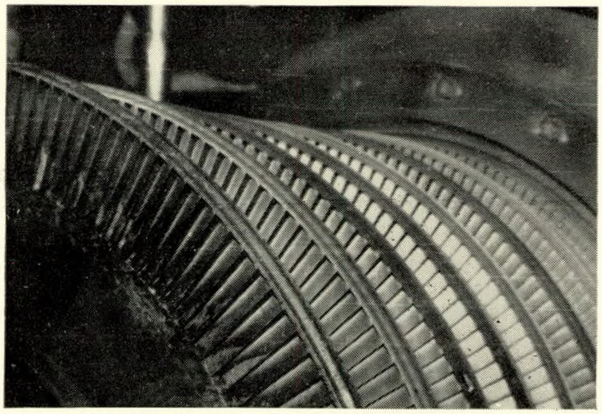


FIG. 6—*Deposits on H.P. turbine blading*

Fig. 6 shows an H.P. turbine opened up after 18 months service. The deposits seen were confined mainly to the fourth and fifth stages and consisted of a white powdery substance firmly adhering to the blading. Analysis showed this to be sodium salts and soluble in water. The selective nature of the deposit shows that it exists in solution in the steam, condensing in the stages which operate at the critical temperature for this chemical.

Clearly the turbine performance must fall off under such conditions due to the reduced steam path area and the roughness of the fouled surfaces.

Since this deposit is readily dissolved in water, it can be removed and the turbine performance restored by water washing. It is not necessary to open up the turbine for this and power station practice is to wash regularly using special water sprays in the steam piping while the turbine is turning slowly on no load.

Good results have been achieved by introducing water liberally through a relief valve or similar connexion to a cold turbine turning slowly on the turning gear. This deals with the effect rather than the cause and to prevent repetition steam purity must be improved by attention to boiler drum internals and to operating techniques related to the total solids in the boiler water.

MAIN CONDENSER

One obvious source of feed contamination is the main condenser and therefore to reduce the risk careful consideration should be given to the design.

Damage to the main condenser by erosion corrosion of the tube ends and tube plates, resulting in costly tube replacements, is only too familiar. The mechanics of this type of damage are now reasonably understood, turbulence due to change of direction or change of section within the flow being one of the chief factors involved. Local failure can often be traced to erosion of the protective oxide or hydrated oxide surface film upon which corrosion resistance depends. This is particularly so with modern condensers where the circulating water lines are of non-ferrous material and the water box ends constructed of neoprene lined mild steel. In these circumstances condenser tubes are completely denied the benefit that the presence of iron is known to contribute to the protective film formation. Added to this there is the problem of the initial filling of condensers which takes place at the fitting out berths. These berths are invariably situated in waters which are highly polluted resulting in the breakdown of the protective film before the condenser is commissioned.

To protect the condenser from erosion corrosion, careful attention to the flow conditions must be given at the design stages. Many modern steam turbine installations are being fitted with scoop circulation of the condenser in which pressure drops within the system are critical. This is an encouragement to the designer to give more thought to the flow conditions and therefore attention is being paid to the problem although for different reasons.

Provided excessive turbulence is avoided, the tube ends and tube plates can be protected cathodically by means of sacrificial anodes of iron or zinc. To provide the necessary degree of protection, over the period between drydockings, these anodes would have to be larger than could normally be tolerated as the volume would interfere with the good flow conditions which the designer is trying to achieve. Experiments with controlled impressed current cathodic protection using relatively small inert anodes of platinized titanium are presently being carried out. In addition to these inert anodes, one or more consumable iron anodes are included in the system to provide a supply of ferrous ions to help in maintaining, or reforming, the protective films. This is particularly advisable for the tube surface as the benefit of cathodic protection will not normally extend more than a few diameters into the tube ends.

As these experiments have only recently been started and a few teething troubles encountered, it is too soon to comment on the results.

The fitting of nylon or plastic sleeve ferrules in the tube inlet ends has been used on occasions to try and overcome the problem. Turbulence at the inner end of the sleeve is the main concern felt with this approach to the problem. A condenser recently examined after eighteen months service showed no damage and perfectly good protection had been given to the tube ends.

With regard to the continued efficiency in service of the condenser, the main reason for fall-off is the reduction in heat transfer due to growth within the condenser of various kinds of sea life and in this respect condenser capacity is normally specified with a cleanliness factor of 85 per cent. There exists, therefore, the possibility of a capital cost reduction if continued cleanliness of this piece of equipment can be ensured, and an improved overall efficiency. Some ships have been fitted with a poison injection system which is intended to prevent the settlement and growth of this marine life. It is unfortunate that the full benefits of this have rarely been seen due to either the failure of some small part of the equipment or lack of appreciation of the importance of the equipment. It is thought that most of the settlement of marine life and growth within the condenser takes place in coastal waters. In this respect, it is intended for future installations to start the poison injection cycle automatically with the starting of the main circulating pump when a scoop injection system is installed. It is hoped that this automatic starting of the equipment will improve the condenser performance allowing the position of margins on condenser surface area to be reconsidered. As already pointed out, this can constitute a considerable cost saving as well as a reduced number of tubes for maintenance in service.

LUBRICATING OIL SYSTEM

Failure of turbine thrust bearings and scoring of journals have in the past received ample publicity and many eloquent theories have been put forward to define the reasons. The author has no wish to detract from any of these and the following comments should therefore be considered as complementary to the work carried out by the various research bodies.

On numerous occasions bearing troubles have been experienced in turbine plants after months of trouble-free operation, without any apparent reason. The author believes that a fair proportion of these failures are due to the sudden shedding of rust concentrations from the vapour space of the lubricating oil drains tank. This conclusion is based on re-examination of several drain tanks which were without doubt passed as clean at the fitting out stage, prior to commencement of operations. However, immediately after commissioning, the humid atmosphere which exists in the vapour space initiates the corrosion processes, resulting in large sheets of millscale and rust just awaiting a little rough weather to bring it into circulation. Fig. 7 shows the vapour space of a lubricating oil drain tank in such a condition. The answer to this part of the problem has been to paint the tanks with epoxy paints after shot blasting. By comparison, a drain tank painted according to the specification developed by the author's company is shown in Fig. 8.

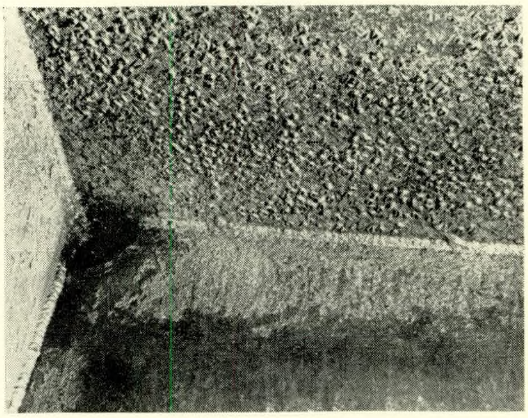


FIG. 7—*Rust concentrations—Vapour space of lubricating oil drain tank*

Turbine rotor thrust bearings are particularly susceptible to failure. The fine oil clearances of these bearings, usually in the order of 15 micron, calls for extremely clean lubricant. Fig. 9 shows graphically the degree of filtration achieved with disposable paper filters. It will be noted that 94 per cent of all particles of 15 micron or over are removed in a single pass through the element. After initial cleaning of systems, in the manner described under the heading of commissioning, paper elements have been used for periods exceeding one year in continuous use. The result has been journals and bearings free of score marks and elimination of bearing failures.

Lubricating oil pumps of the centrifugal submerged type have been specified to obviate the risk of bursting the paper elements should the pressure drop across them become exces-

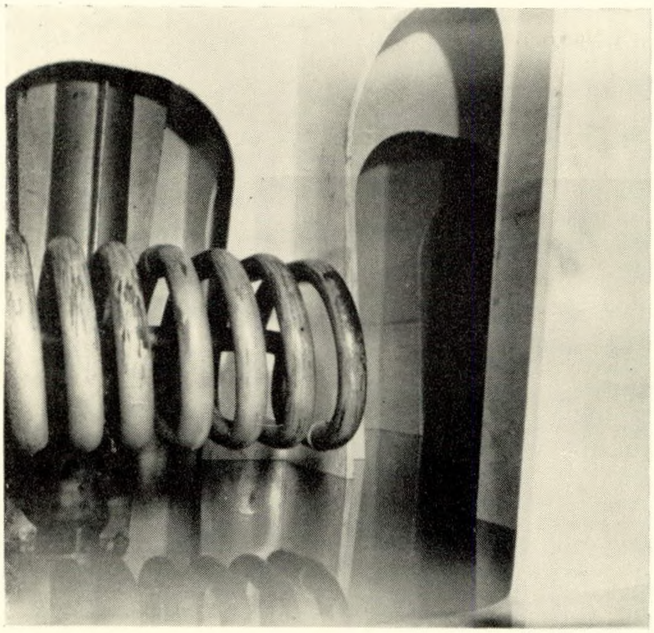


FIG. 8—*Epoxy painted lubricating oil drain tank*

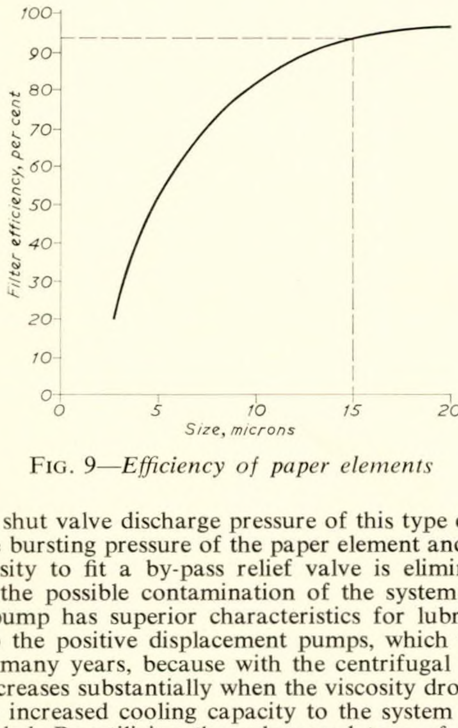


FIG. 9—*Efficiency of paper elements*

sive. The shut valve discharge pressure of this type of pump is below the bursting pressure of the paper element and therefore the necessity to fit a by-pass relief valve is eliminated thus avoiding the possible contamination of the system. The centrifugal pump has superior characteristics for lubricating oil service to the positive displacement pumps, which were standard for many years, because with the centrifugal pump, the output increases substantially when the viscosity drops thereby providing increased cooling capacity to the system when it is most needed. By utilizing the submerged type of pump, the suction pick-up of the stand-by pump is greatly improved should the working pump fail. Difficulty can be experienced in obtaining suction with pumps fitted outside the drain tank with extended suction lines, especially if the oil is heavily aerated.

Whilst tin corrosion still remains something of a mystery it has been fairly well established that the presence of water has been a contributory factor. Where precautions have been taken to prevent water inclusion in the oil available evidence indicates that the dire effects have been avoided. It is for this purpose that a coalescing filter has been included in a bypass arrangement. The attraction of such an arrangement is the simplicity and totally static nature of such equipment. It is true to say that only the free water will be extracted in this manner whilst water extraction using vacuum methods will reduce the water content below the saturation level in the oil, thus creating a buffer against sudden ingress of water. Both methods are presently in operation on ships in the author's company, but at this stage it is difficult to say whether or not the additional moving parts of the vacuum type are justified. All that can be said at the moment is that continuous water reduction in the system is a worthwhile feature.

Experience has shown that turbines have operated trouble-free as far as bearings are concerned since specifying the following precautions:

a) lubricating oil filtration to a total cut-off of 20 microns, full-flow;
b) all tanks, i.e. drains tanks, gravity tanks where fitted and storage tanks constructed of shot blasted primed steel coated with epoxy paint;
c) all pipes acid cleaned, passivated and phosphated to give protection against re-rusting during fitting-out;
d) water extraction on a continuous basis using a bypass coalescing filter;
e) a carefully specified flushing procedure adopted not only on board, but insistence on the application of the flushing procedure on the test beds of the manufacturers.

INSTRUMENTATION AND CONTROLS

The correct application of extended instrumentation and centralized control can help to improve considerably the overall plant operation. The economics of extended instrumentation has been dealt with in many papers and articles. A summary of conclusions drawn from these articles and experience indicates that the pay-off comes from:

a) optimization of plant operation;
b) better utilization of personnel and/or reduction of personnel;
c) personnel and machinery protection;
d) improvement of working conditions.

It also seems axiomatic that a plant operating close to design will require less maintenance. The following instances are quoted as some of the most obvious systems which will show a good rate of return on money invested.

The savings to be gained from steam temperature have been amply demonstrated in various plants and in this paper. When operating at the higher temperature, there is obviously less scope for error in the upward direction and most turbine designers quote the maximum time allowable for operation at temperature above design. Operators will sacrifice fuel for safety of operation if the temperature indication or recording apparatus is suspect or difficult to read. Here, therefore, is one loop which will show a pay-off and improve operating conditions by adoption of automatic control. Initial applications utilizing single element control proved troublesome due to temperature cycling. This was overcome by adding a second element related to boiler load using either gas flow or steam flow. Both have been used successfully but steam flow is considered the better choice.

Probably the next best loop from the point of view of return on money invested, is the combustion control. Achievement over long periods of time of the design CO_2 content in the flue gases will show a marked effect on the fuel rate and therefore, recording of this and accurate maintenance of the air to fuel ratio is an essential part of the control equipment. As already described in the boiler design section, close combustion control is essential to stabilize superheat temperature too.

The forced draught fan is a relatively large consumer of power whichever prime mover is used. Electric drive with vane control is popular, convenient and very often the automatic choice. When studying the requirements for the single boiler concept of a 28 000 shp installation it was calculated that losses across the vanes would be in the region of 60–70 kW under normal steaming conditions. This fact combined with the high starting loads and limited turn down range unless multi-speed motors were used led to the adoption of turbine driven fans. The control of this type of machine required careful design, not only to achieve economic operation, but also to give close control of the fan output to match the requirement for low excess air and good combustion. To overcome the time delay of the unit speed response on rev/min control, a dual control was developed to modulate fan suction vanes as well as the speed. Such an arrangement ensures close control of output and minimum power requirement for operation of the fan prime mover by meeting the initial load change with vane control, followed by rev/min modulation and vane trim to the optimum setting.

Lubricating oil temperature control is now fairly common in application, probably the major benefit derived being the correct temperature at the gearing spray nozzles contributing substantially to the elimination of scuffing of the gearing.

Cycle efficiency and plant stability is greatly affected by the correct use of bled and live steam within the various systems. System design and control engineering must therefore be given careful consideration at an early stage in the plant design if the optimum operation is to be achieved. Control valve and line sizes are critical, especially in relation to each other. If the pressure drop in the pipe line is disproportionally greater than that across the control valve, instability will be inherent in the system and no amount of adjustment of controllers will correct the situation.

A reliable protection system is a requirement for obvious reasons but it can also contribute to the efficient operation of the plant. By making a distinct separation between the alarm and the shut-down system, the operator will have time for corrective action, before the shut-down condition is reached, consequently reducing the offline time of the plant.

Improving the environmental conditions of the staff by providing centralized control in a well lit air-conditioned control room and automating those manual jobs which would not be attractive for the modern engineer, must bear fruit in keeping the well trained engineer interested in his work and in a seagoing career. Without remote control being applied in the cathedral-like machinery spaces of the very large ships presently being built, it is extremely doubtful if any effective attempt would be made to optimize plant operation.

The guide lines used in the application of extended instrumentation and controls, can be listed as follows:

1) standard system designs for all ships and rationalization of components to keep engineers' training and equipment spares to a minimum;
2) up-grading the quality of both instruments and controls to ensure fast and accurate response to all load variations;
3) all controllers related to the operation of the plant centralized in the control room with sufficient indication of valve position, desired and measured values, to enable the engineer to transfer the system from automatic to manual control and *vice-versa;*
4) control panels to be built in logical sections and standardized for all ships so that an engineer transferring from ship to ship will be immediately familiar with the controls, thus allowing him to handle any emergency conditions in his newly appointed job;
5) all components to be standard off the shelf units of proven reliability.

The achievement of the unmanned engine room concept is dependent upon controls maintaining stable conditions even when the load changes are made by bridge control, which is a necessary part of the concept. To assist in achieving a fully integrated control complex, a mathematical model of a ship and steam turbine plant has been built into a PACE analogue computer. It is interesting to relate that this model has been successfully used to check out a bridge control concept which was manufactured and fitted to a very large crude carrier, *Myrina,* as a prototype.

The behaviour of the control followed closely the predicted pattern and commissioning of the system was greatly facilitated by the checkouts made on the computer. Fig. 10 shows graphically the results of the interaction of the various control loops during a sample manoeuvre from 80 rev/min ahead to 70 rev/min astern and then to stop, executed from the bridge and without any intervention from within the machinery space.

It will be noted that the movement of the boiler water levels never exceeded ±1-in from the set position, the boiler pressure was contained between $\pm 2\frac{1}{2}$ per cent and the torque peak during reversing did not exceed the full ahead torque value.

This bridge control was built up of standard off the shelf components similar in nature, and from the same manufacturer, as the controls and instruments used for all other systems in the ship. It is based on rev/min feed-back and it

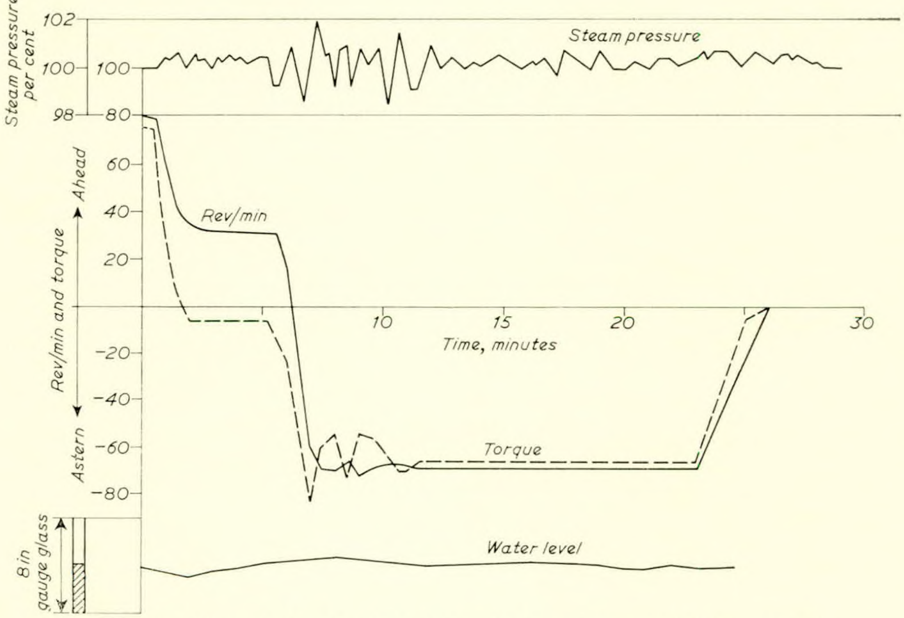


FIG. 10—*80 rev/min ahead to 70 rev/min astern on bridge control*

will be noted that these remained sensibly constant although the torque variation, due to cavitation of the propeller, was in the order of 30 per cent.

The system has built in safety devices to ensure that permissible limits are not exceeded regardless of the speed of load variation demand. After some further experience it is hoped that this system can be extended to give the optimum stopping capability for the ship. Experiments to date have indicated that this is not necessarily achieved by reversing the direction of the shaft rotation in the shortest possible time. The presence of cavitation in Fig. 10 would bear this out since little reverse thrust is being generated during that period

COMMISSIONING

Having thus considered some of the design aspects which will have considerable effect on the operation of turbine installations, few will dispute that all this will be of little avail if comissioning procedures are ignored or neglected.

The following comments on commissioning precedures, which have been developed and specified on the basis of experience gained, are given in the hope that some problems may be avoided in the future.

Commissioning Boilers and Associated Systems

In previous sections of this paper, necessity for cleaning boilers internally prior to commissioning and during service has been highlighted. The difficulty of doing this mechanically has also been touched upon, and the author's company has specified for the past ten years and carried out chemical cleaning of the boilers, pre-boiler, condensate and steam systems.

Steam conditions have increased during this period and later ships are now following the single boiler concept. The pre-commissioning of the boiler plant is therefore becoming increasingly important and the days when a "boil-out" was sufficient, are well past. At the time of commissioning, it is highly desirable that the surfaces are completely clean and the millscale removed as well as any grease, oil and general debris occasioned during the construction period. It is also desirable to have the heating surfaces protected from the outset by a continuous and well established film of magnetite.

The choice of chemical for the process normally lies between hydrochloric acid or citric acid for although other acids would do the job, they are rarely offered in tenders for the work. Hydrochloric acid is probably the best for dissolving millscale, is certainly the cheapest and requires the minimum of time. The disadvantages of this fluid however, are the rather onerous precautions required in handling, the more difficult control due to the rapid action and the more aggressive attack of the base metal, should the inhibitor fail to fulfil its purpose. For these reasons citric acid has been specified using a circulation technique with an acid strength of three per cent.

The normal process is:

1) normal boil-out with alkali solutions;
2) empty and refill with distilled water, stabilize the temperature at 185°F (85°C) by firing with a lighting up burner or gas flame, circulation from a tank with a heating coil through the boiler, returns being brought back from various vents, drains, etc., this can include the economizer and superheater in the circuit;
3) add inhibitor to specified strength;
4) add citric acid compounds until required strength is reached and continue to circulate maintaining effluent temperature as far as possible, tests of circulating fluid should be taken by a qualified chemist for iron content and acid strength, Fig. 11 shows graphically the increasing ferrous iron content of the effluent during treatment, it will be noted that the iron content stabilizes as the process is completed.
5) the contents of the boiler should be pumped and run out as quickly as possible, being neutralized in the process to prevent pollution of the harbour;

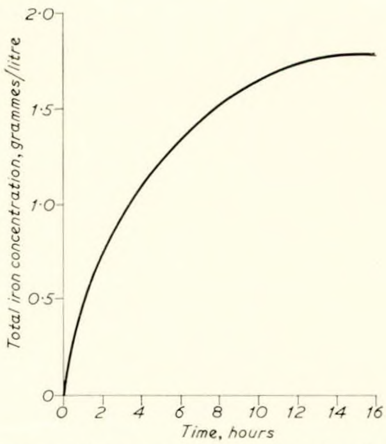


FIG. 11—*Progress of acid cleaning*

6) refill with water, adding inhibitor and citric acid to one per cent strength to scour any deposits left from the main cleaning;
7) empty and flush until all returns show clear;
8) refill to working level, adding 300 p.p.m. of hydrazine and raise the temperature by firing to about 370°F (188°C) adding hydrazine to try to retain a reserve during the process; this pressure passivation will form a protective magnetite film on the surface and prevent rapid re-rusting;
9) dump the contents under pressure to help dry out the boiler, open up for inspection and final flush-out of any isolated pockets of scale build-up.

Drum internal fittings should be removed prior to the process, since they tend to interfere with the circulation. These fittings should be dealt with separately, possibly in the circulating tank. At no time when acid is present in the boiler should firing take place. Inhibitors are sensitive to temperature and if local heating exceeds the critical temperature, attack of the base metal will result. Where evidence has been found of acid attack, it is invariably in way of tube expansions. The author is convinced that this is often due to local heat being retained at the heavier boiler sections which are in way of the tube ends. Should this take place when hydrochloric acid is being used, the attack will be severe. With hydrochloric acid, one wise precaution would be to have thermocouples peened into the boiler material close to the tube expansions to ensure that the temperature in that locality is not in excess of the inhibitor critical temperature.

The cleaning of the condensate system in a similar manner to that for boilers, becomes a logical follow-on and requirement. As already discussed, it is necessary to reduce as far as possible, the transportation of metal salts into the boiler and the best method of ensuring this from the new condition is to remove the millscale by dissolution, using chemical cleaning. The author's company normally specifies the use of citric acid, using a circulation technique. Care must be taken to ensure that flushing out and pressure passivation is carried out to prevent re-rusting on completion of the process.

On several occasions when turbines were opened up immediately after sea trials, severe damage to the nozzle plates and first stages of the turbine was found. This was due to shot blasting by scale and debris left in the system. Fig. 12 shows the extent of damage which can occur if efficient cleaning and removal of millscale is not carried out on the steam lines. In the light of such evidence, there is no point in specifying fine clearances and surface finish to achieve good performance, if fundamental procedures of protection are to be ignored resulting in damage within the first few hours of operation to the extent shown in Fig. 12.

The main source of the damage was found to be millscale from the formed bends of the superheater. Blasting through

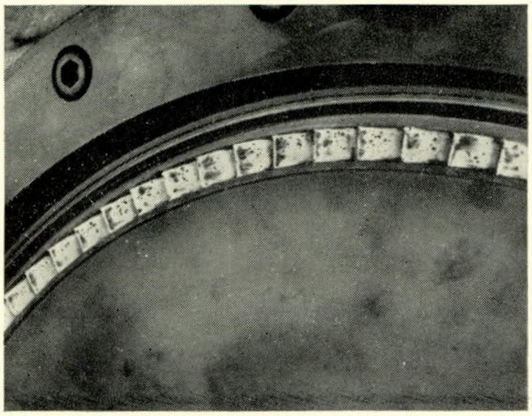


FIG. 12—*H.P. turbine diaphragm—Damage from scale*

FIG. 14—*Debris removed from turbine lubricating oil system*

of steam systems using target plates in an attempt to clean and prove systems ready for connecting to the turbine did not prove to be the cure since the scale only exfoliates after some hours of operation.

Fig. 13 shows a typical superheater close bend which has been sectioned. The millscale in the upper half is obvious. The lower half illustrates the cleaning results after being submerged in acid at ambient temperature for a period of approximately two hours. Cleaning of the material in the previously described manner would have removed the remaining scale leaving it in a first class and clean condition.

It is interesting to record that on a 28 000 shp plant recently brought into service, the debris removed from the boiler including economizer and superheaters amounted to 135 g in the course of the normal alkali boil-out procedure. The ferrous iron removed by chemical cleaning afterwards amounted to some 296 lb. Had the millscale been left to exfoliate in the normal course of events, considerable damage to the nozzle plates and first stages of the turbine would have occurred.

Main Condenser Commissioning

As already mentioned in the design section of this paper, the protective films on tubes and tube ends are of extreme importance and their establishment in the early stages is worthy of effort.

To try to overcome the problem of protective film damage by polluted water during fitting-out periods condensers which may lie for more than four days with water in them are drained off and dried out as far as possible. One of the leading turbine manufacturers advises circulation of the main condenser during the fitting out period with clean sea water or if necessary with fresh mains water to which has been added the compounds normally found in sea water. Into this water is injected ferrous sulphate to provide a source of iron and the circulation is carried out for a period of some three weeks before commissioning. This is done by a small circulating pump which is run continuously and the iron sulphate content checked at intervals of approximately two days. By so doing, it is hoped that the condenser will build up the necessary protective films before the introduction of harbour water and therefore will start its life in a much healthier and corrosion resistant condition.

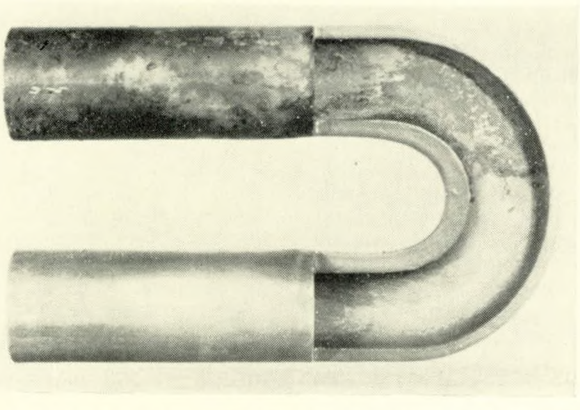


FIG. 13—*Superheater close bend—Showing millscale in upper portion*

Commissioning Lubricating Oil Systems

The preparation of this system for operation has in the past left much to be desired. Fig. 14 shows the debris removed from a system after one year's operation; the system having been certified as cleaned and flushed at the time of acceptance.

The usual method of flushing the system using gauzes at the inlets to bearings does not help the operation and may, in fact, constitute a hazardous and dangerous practice. Such restrictions in the pipework, reduce the velocity of the flushing oil thus allowing any debris in suspension to settle out in the pipeline system. The finer the gauze used or the more choked it becomes, the lower the velocity and greater the tendency to leave debris in the system. It is not unusual to see the gauzes slipped out from between flanges leaving the bulk of the dirt collected on the surface behind in the pipeline.

A stationary rotor or journal in a bearing constitutes an excellent filter, trapping any particles in the oil between the shaft and the bearing resulting in scoring on turning the engine. The main flushing should be carried out with all bearing and gearing sprayers disconnected, the circuit being completed with temporary "jumper" pipes. The oil should then be circulated at high speed, flushing any debris present into the drains tank. The main 20-micron filters should be brought into the circuit after some hours and the flushing carried on until it can be safely assumed that all pipes have been cleaned with filtered oil. Only then should the bearings and gearing sprayers be connected and further circulation carried out with the engine preferably turning at a speed which gives film lubrication.

After flushing in this manner for some days, the oil is pumped into the renovating tank and the drains tank opened up for cleaning. The painted tank contributes much to this phase of the operation since it is so easy to clean. Trying to clean an unpainted tank using so-called "lint free' rags is a time consuming pointless exercise resulting in filter chokage with lint when the system is brought back into service. Passing the oil back to the system via the purifier completes the commissioning.

Experience has shown that using this method takes no longer than the time normally allotted to this task but the end result is immeasurably better.

Commissioning and Testing of Instrumentation and Controls

The care required during commissioning of plant has been stressed throughout this paper but no section of the plant requires more thorough attention and meticulous checking than instrumentation and controls. Whilst this is agreed upon generally it is this section that suffers most from corner cutting and programme squeezing when time is short.

The early stages of commissioning plant is the time when alarms and safety cut out equipment can serve the engineer best. It is therefore doubly important that the necessary time and effort be devoted to this subject.

The policy should therefore be to see that the following steps are covered:

1) all instruments inspected, shop tested and calibrated prior to installation; records taken of the calibrations for future check-outs;
2) all instruments and control equipment tested, calibrations checked, records being made of any re-calibration required after installation;
3) all pneumatic loops and electric circuits checked for leakage on completion;
4) all control loops checked out on completion;
5) all alarm circuits checked out and set to correct values.

These steps should be completed prior to any testing or commissioning of plant. Before this can be achieved however, a lot of thought and time must be devoted to the operation, with the necessary facilities available, some considerable time before the first plant tests are due. Some important points are listed below:

a) where pneumatics are used the control air compressors and driers must be operational, the air lines purged of dirt and moisture before equipment is connected; generally instrument failure is due to lack of care on this point;
b) the control room should be completed ·nd all trades other than those related to the instruments removed from the area; the room should be made a "clean space" with access restricted to those only directly involved;
c) the test and calibration equipment should be the first installed so that check out facilities are available.

The reward for this effort is immediately obvious when plant commissioning begins. Tests and trials are carried out with a fraction of the effort previously required and the build up of the morale of the ship's engineers who will eventually have to operate the plant can be seen to mount daily.

SEA TRIALS

Sea trials must to some extent be part of the commissioning processes. They should, however, be primarily concerned with the proving of plant which has already been commissioned and tested to the maximum extent possible alongside before they commence.

Sea trials and procedures are in themselves a subject worthy of more space than is available in this paper and have been well covered in published papers and codes. For these reasons the author has not devoted any space on this important aspect.

CONCLUSIONS

The success of any machinery installation is only won after a lot of effort is made in all stages of the construction and operation. The author has tried to show some part of the care and attention to detail required in the design and commissioning of modern steam turbine installations. The extent to which this is exercised will without doubt have a direct and critical effect on the ship throughout its life.

Since the ship and its machinery represents a large investment and the assured earning capacity, which is the prime object of its creation, is an economic necessity, any money spent and effort made to ensure trouble free entry into service constitutes good insurance.

Continued effort to improve on design and commissioning techniques is essential to the industry in general and to the owners in particular. Experience has shown that in the process of seeking perfection, disappointments will never be in short supply, but there is also a lot of satisfaction to be had. All the shortcomings are not due to mechanical or technical difficulties, many are due to the mental approach to the subject and in this respect the author hopes that the industry generally will make increasing efforts to equal those of the designers by commissioning installations with the care and attention they deserve.

ACKNOWLEDGEMENTS

The author wishes to thank the management of Shell International Marine for their kind permission to publish this paper. Thanks are also due to colleagues and friends in the industry for suggestions made and help given during the preparation of the paper.

Discussion

Professor I. K. E. Jung (Member) said that Mr. Preston's paper had four postulates:

1) simplicity of plant and simple maintenance;
2) cleanliness of water;
3) cleanliness of steam;
4) cleanliness of oil.

Professor Jung had given talks on how to use steam at sea in the right way for many years and in many parts of the world. Mr. Preston's address would help manufacturers greatly. When they competed for an order, there were usually only two factors discussed, price and fuel consumption.

Mr. Preston mentioned many other factors of fundamental economic influence, such as simplicity and availability. When shipyards were told of the importance of sufficient preparation before trials and commissionings, they did not take it seriously. With Mr. Preston's background, the message would be heard and would result in great improvements.

He took up the following points:

a) reheat or non-reheat plants;
b) cleanliness of steam;
c) optimization of propeller rev/min;
d) turbine machineries for interlocking or overlapping propellers.

Fig. 15 showed the pay-off times of Mr. Preston's two reheat cycles, C and D, as well as comparable figures calculated for a Swedish 30 000 shp project with 1450 lb/in^2/950°F/950°F "R-FPP" with normal propeller and "R-CPP" with propeller with adjustable blades. The consumptions were 0·452 for the basic cycle and 0·412 and 0·405 lb/shp-h for the two reheat cycles. The values were well in accordance and showed that

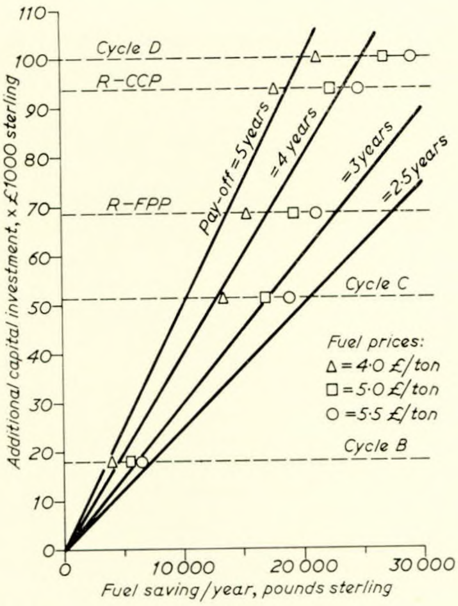


FIG. 15—*Evaluation of marginal costs of reheat steam turbine plants*

reheat units must have availability comparable with non-reheat units in order to pay. The next generation of reheat boilers might prove this possible. The higher the power, the more favourable would the pay-off time be for reheat.

Fig. 16 described why the nozzles in Fig. 12 had been damaged on the convex outlet side. The impact craters caused by the steel particles were much more severe on the nozzles than on the blades. It was obvious that the turbine efficiency would deteriorate quickly when exposed to shots of steel particles from the steam piping. With finer mesh strainers and harder material in the nozzles, the damage could be reduced—but not avoided—if the steam was not kept free from hard particles.

Fig. 17 was a result of an optimization propeller rev/min calculation for a 28 000 shp, 200 000 dwt tanker machinery. With reduced rev/min, the power demand decreased by about three per cent/ten rev/min. The costs for propeller, shafting and gear increased but the fuel cost and the capital cost for turbine auxiliaries and boilers decreased with the power. The optimum rev/min for different pay-off rates could be calculated. From the standard 105 rev/min, the pay-off times were favourable down to 75 rev/min and were good even at lower speeds.

Fig. 18 showed a turbine arrangement for overlapping propellers with one H.P. turbine and two parallel L.P. + astern turbines. Considerable gains had been measured with this unconventional propeller arrangement, see Fig. 19. However, if the test results were applied for the same propeller rev/min, the single screw drive would give about four per cent higher efficiency than the twin screw arrangement and the outward turning overlapping propellers would give about eight per cent

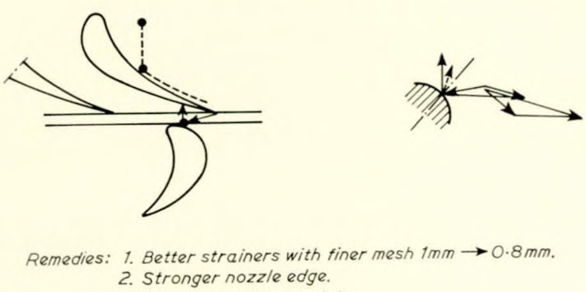


FIG. 16—*Damage to nozzle by solid particles in steam flow*

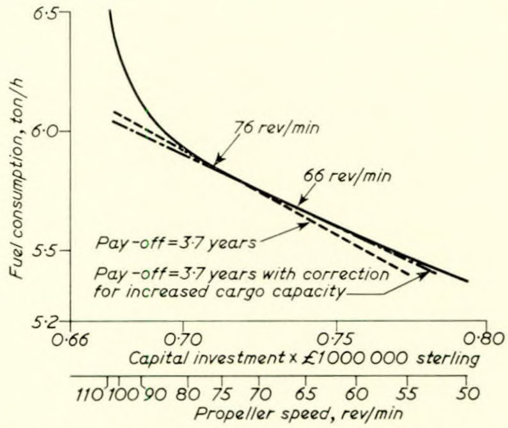


FIG. 17—*Optimum propeller speed—200 000 dwt tankers*

improvement. For large tankers, this propulsion system would be of great interest.

MR. D. J. GIBBONS, B.Sc. (Member) agreed with much of what the author had said. Some of the illustrations showing contaminants in systems and the damage caused thereby, were most salutary and accorded with his own and, he believed, with general experience. However, his experience with lubricating oil systems would indicate a higher proportion of steel turnings and fewer washers than illustrated. On a serious note, the times one found severe contamination of lubricating oil systems in ships—particularly in steam ships—were too numerous and could only be related to inadequate shipyard practices. Unfortunately, it was still frequently regarded as the duty of the owner to specify an improved cleaning routine. This could only hope to remove contamination already present in the system; the onus of avoid-

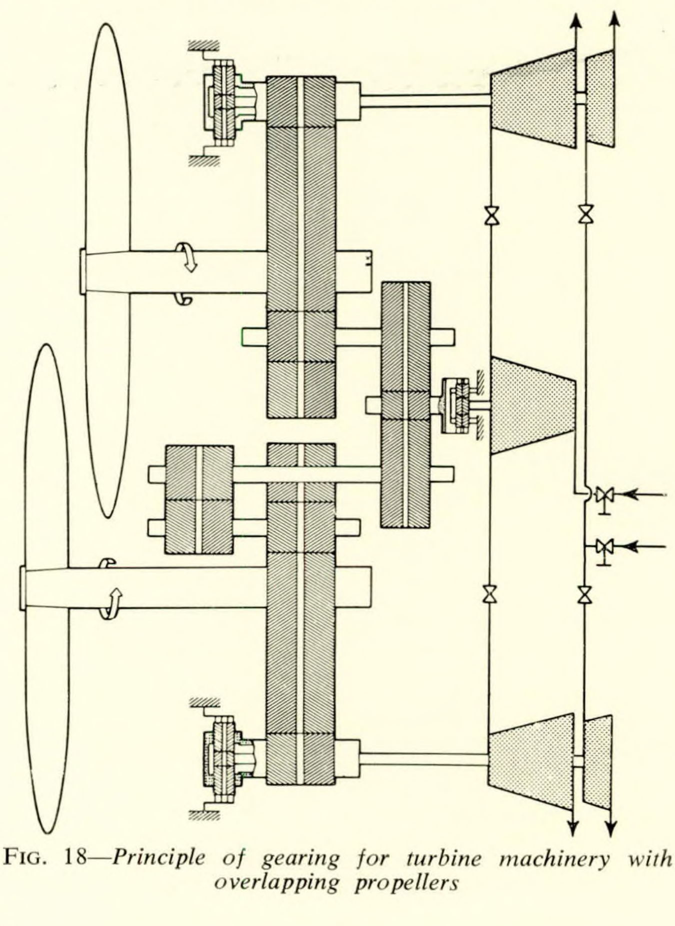


FIG. 18—*Principle of gearing for turbine machinery with overlapping propellers*

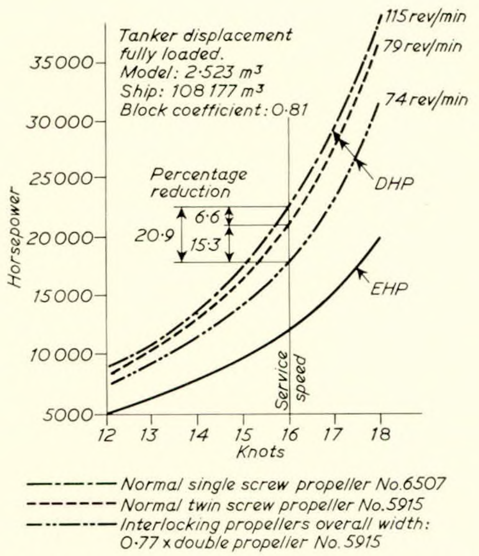


FIG. 19—*Comparison of required propeller horsepowers for different propeller arrangements, according to Mr. T. Munk and Professor C. W. Prohaska, August 1968*

ing contamination by sound manufacturing and installation practice must always rest with the shipbuilder and his sub-contractors.

The author's comments on boiler feed water quality and the study that had been made of the contaminant source had particularly interested him. The high oxygen concentration in the atmospheric condenser condensate would appear to be severe and liable to lead to corrosion problems in the boiler. Could the author advise as to the level of contamination to which the de-aerator was able to reduce the oxygen content when operating with this highly contaminated feed, and also give his views on the effectiveness of a low vacuum condenser for the cargo pump exhaust as a means of achieving de-aeration of this condensed steam? Alternatively, had the author considered using the main turbine condenser for cargo pump exhaust duty, keeping this unit at a high vacuum during cargo handling operations? It would appear that, with the axial exhaust arrangement adopted on a number of the ships operated by the author's company, such a practice could be quite satisfactory. With regard to the other metallic contaminants, it was noted that an ion exchange system was recommended for the make-up feed. What precautions did the author recommend, other than a five micron filter for removing iron from the drains tank returns, for removing ionic contamination and silica from the main feed system, which would include, perhaps, the make-up feed and drain returns? This would apply particularly to the copper mentioned by the author. He had also mentioned the possibility of using hydrazine. Was this intended as a means of reducing copper pick-up or to provide protection for the iron parts in the condensate system? Had the author considered a main feed ion exchange system, either in full flow or bypass, as a means of reducing contamination from this source?

MR. K. BROWNLIE, B.Sc. (Associate Member) said that in the section on the choice of heat cycle he noted that cycle "C" showed the best return on the additional capital cost and that study was therefore concentrated on the basic Simplex cycle "A" and cycle "C".

It was readily understood why reheat cycle "C" was not adopted at the time, as it would have involved a move into a region where there was little operating experience.

However, adoption of cycle "B" would not have involved any increase in boiler conditions, the only changes from the basic cycle "A" being the addition of high pressure feed heaters and the use of a gas air heater.

Despite a return on the extra capital cost of between 10 and 20 per cent per annum (from Fig. 3), depending on the bunker price assumed, it was decided for the reasons stated not to adopt cycle "B". Could the author give more details of the problems which were experienced with multi-stage feed heaters and gas air heaters and the extent of the extra repair cost incurred?

Had experience shown that the Simplex cycle "A" was normally operated more nearly at the optimum setting than would be achieved with a system such as cycle "B"?

The author had stated that the clearances in turbine rotor thrust bearings were very fine, being of the order of 15 micron (0·0006 in). The thrust bearings in his company's propulsion turbines did not operate with such fine oil clearances.

The minimum oil film thickness in the thrust bearings was in no case less than 45 micron (0·0018 in) and in many cases was much greater. However, it was doubtful whether degree of oil filtration should be equated with minimum oil film thickness.

It was his company's policy to specify 40 micron oil filters and he did not know of a single thrust bearing failure occurring in any of the turbines. Incidentally, use was made of thrust collars with hardened faces. This eliminated "machining" or "wire wool" type failures.

There was, of course, no objection to a finer degree of filtration than 40 micron being provided, but this was not necessary to safeguard their machinery.

Damage had on one or two occasions occurred in journal bearings due to relatively large particles of dirt entering the bearings, but these had occurred immediately after installation, or after opening up the lubricating system pipework. The dirt had entered the system on the downstream side of the filters and had not been removed by adequate flushing before running up.

Consequently he entirely supported the author's remarks on the importance of an adequate and mandatory oil flushing procedure which involved circulating oil at high velocity through the system.

MR. A. ROSE, B.Sc. (Associate Member) said that the author had pointed out the risk of bearing failure due to dirt in the lubrication system. In his company's experience, dirt was the cause of the majority of reported failures and the author's description of the method of commissioning lubricating oil systems was particularly useful.

As to the degree of filtration necessary, it was worth while looking at the tests carried out by Pametrada some years ago. On the bearing test machine there, a fairly typical turbine thrust bearing was installed with a separate 40 gallon capacity lubricating oil system. To this lubricating system quantities of graded abrasive were added and the machine was run at about 6500 rev/min with a specific load on the pads of 210 lb/in². This resulted in an estimated minimum oil film thickness of 25 micron. In each test $\frac{1}{2}$ lb of aluminium oxide was added to the oil but an analysis of the outlet showed an abrasive concentration of only 0·0053 per cent by weight. Presumably much of the added abrasive was trapped in the pipework or filtered out by the bearing.

After 24 hours' running with an abrasive of $4\frac{1}{2}$ micron mean particle size ($7\frac{1}{2}$ micron maximum) 0·0015 in wear had taken place on the trailing edge of the pads.

After 48 hours with 9 micron mean size abrasive (14 micron maximum) 0·005 in wear had taken place.

A test using 21 micron mean size abrasive (35 micron maximum) had to be stopped after one hour when white metal temperatures rose to 310°F (154°C). It was found that up to 0·012 in wear had taken place, some on the trailing and some on the leading edge.

From the successful use of 20 micron total cut-off filters there seemed to be comparatively little abrasive of less than 10 micron size in practical lubricating oil systems. Some comment from the author on this would be appreciated. He felt that the finer the filtration the better.

Had the author any experience of the adhesives used in paper element filters softening under the effect of certain hot oils leading to the bursting of the elements?

Another reason for failure of turbine thrusts seemed to be excessive overloads. On certain classes of turbine vessels the measured turbine thrusts had been two to three times the design figure. With designed loads of 200–300 lb/in^2 the measured thrusts had resulted in specific loads of 500–600 lb/in^2, which, although normally acceptable, had not had the same ability to withstand misalignment or momentary overload due to, say, boiler priming.

In the thrusts of these vessels after satisfactory service the white metal was heavily lacquered with the products of overheated oil, the white metal had been deformed and spread over the trailing edge and the pivots heavily indented.

Wherever possible, pads found in this condition had been replaced by oversized pads. Unfortunately, not all bearings had been examined in time and the deterioration of the white metal surface had led to premature failure.

Had the author found that turbine thrust overloading was a fairly commonplace occurrence? Mr. Rose's company had been troubled by this recently on their bearings.

Another aspect of overload had been damage to equalizing segments when these had been fitted. It was not common British practice to fit equalizing segments unless service experience had shown the turbine to be suffering large thermal distortions. However, when exporting to the United States it had been found that equalizing segments were almost invariably specified. His company felt that with good machining, cold misalignment was not a problem and that under normal loadings thermal distortions could be accommodated.

However, it would be most interesting to hear the author's views as to the desirability of fitting equalizing segments, particularly in the case of the higher powered turbines that were coming along.

Mr. A. F. Hodgkin (Associate Member) said it was true that a Complex feed cycle with gas air heater usually had a lower uptake gas temperature than could be obtained from a Simplex cycle using economizers. Attempts to achieve low funnel gas temperatures with air heaters had resulted in high air heater maintenance and significant performance deterioration in service. Advances attributed to steam generating plant designers were not confined to the boilers, so that modern examples of the Complex cycle, utilizing mainly rotary air heaters and uptake temperatures ranging from 240°–280°F (116°–138°C) offered increased availability owing to improvements made in combustion equipment and protective coatings for heating surfaces. Modern combustion equipment, within the more ample furnace dimensions now currently popular, was capable of operation at near stoichiometric conditions, ensuring the maximum practicable depression of the dew point and elimination of unburnt solids. This, coupled to the use of protective coatings, mainly of vitreous enamel, was calculated to give very much improved life for those parts which previously became unserviceable after only a few months' operation. Evidence to support this was now available.

In an uptake gas temperature range of 240°–280°F (116°–138°C) the lower limit was usually achieved (undiluted) by a rotary air heater, whilst in the upper half of the range the tubular air heater was a feasible proposition. Owners not satisfied with the relatively closely packed heating surface of the rotary air heater with its attendant leakage and gas carry-over problems could, with only slightly reduced boiler plant efficiency, confidently accept a tubular air heater with enamelled tubes. Although somewhat more bulky than the rotary air heater, the tubular had much larger gas passages, no moving parts, and sufficed with 15 per cent less fan capacity. The boiler efficiency using the tubular air heater was about ¾ per cent less but was still better than the simplex cycle by a similar amount.

Modern boiler designs now offered improved facilities for gas side maintenance by means of effective soot blowers, water washing arrangements and many ample access spaces. In addition, the author had suggested there should be adequate facilities for maintenance of the water side of the boiler.

Care should be taken to see that provision of good maintenance facilities did not tend to increase the frequency at which it was necessary to use them. Good access to the water spaces could, for example, be obtained through a large number of gasketed handhole fittings. Fittings of this type were a well known source of leakage and required frequent maintenance. The proper course was to reduce the need for access and to remove the maintenance problem of gasketed joints by eliminating them from the boiler design. The boiler should be completely welded to enhance the tightness of the whole system, reducing, to an absolute minimum, loss of the working fluid. This reduced make-up quantities, the risk of introducing impurities into the system and limited the quantity of treatment chemicals required. Once satisfactory water conditions were achieved in practice, the need for water side inspection arose only infrequently and the all-welded boiler was then seen to encourage those conditions which made it acceptable. It would be interesting to hear more of the author's philosophy on this aspect of boiler design.

It might be that, with certain configurations of furnace and combustion equipment, model tests were required to ensure the elimination of undesirable characteristics such as flame impingement. The improvement to be made to Fig. 4 by aligning the burner axis mainly parallel to the vertical sides of the furnace chamber must have been obvious, even without a model test The main advantage of a large roof-fired furnace was to provide a long flame path before the products of combustion impinged upon relatively cool surfaces. It would seem highly desirable, therefore, to maintain a degree of symmetry and aim the burner straight down the furnace, giving the greatest residence time.

At the boiler pressure levels currently in marine use, high steam purity was an obvious necessity, imposing a need for a high standard of performance from drum internals. When the purest steam was required, cyclone type separators were always used, and typical of the performance of such a system were the figures obtained from *Esso Malaysia.* Using sodium flame photometry the sodium content of the saturated steam from the drum was found to be 0·08 ppm and at the boiler water conditions prevailing this corresponded to a carry-over of less than 0·05 per cent.

No matter how careful the designers were in introducing new equipment aimed at giving improved performance in service, all their efforts would be devalued if proper care in the commissioning routine was not observed. Any boiler plant was prone to more than average rates of gas side fouling when being steamed intermittently at very low outputs and when, at the same time such steaming was being carried out without the benefit of a fully commissioned system of interlocks and safety devices, and sometimes even without the benefit of sootblowers to keep the soot build-up under control, the plant became very much more vulnerable to accidental damage. At these times it was absolutely essential that proper and adequate supervision was given to those entrusted with the operation of the equipment.

Mr. D. Cochrane (Member) said that Mr. Preston's investigation and conclusions on water treatment and chemical cleaning gave much needed attention to their increasing importance.

Chemical cleaning was regarded as a nuisance and was usually reluctantly sandwiched between gas freeing and voyage repairs, or in new ships carried out at drydocking following sea trials. The paper should help in accelerating the marked change in attitude now apparent and help in planning a better service.

The recent revision of BS1170 gave some general guidance on pre-commission cleaning, and dealt with the use of amines and hydrazine.

The observations on *Diala*, regarding copper and iron pick-up endorsed the view that the greatest corrosion and wastage in feed systems and boilers occurred at shut-down and slow running. A paper to the Institution of Mechanical Engineers* also drew attention to this and showed considerable reduction of corrosion using nitrogen gas blanketing for vacuum break and sealing. This might be worth consideration as an alternative to the very fine 5 micron Duplex filter which was to be used. It would be interesting to know the results from this filtration, although it

* Sherry, A. and Gill, R.1964–65. "Chemical Commissioning at West Thurrock Power Station". *Proc. I. Mech. E.* Vol. 179, Part 1, Paper No. 22.

was presumed that it would cope with only a proportion of the feed water throughput prior to start-up.

The author's figure of 100 lb iron and 40 lb copper over 1000 hours' running pinpointed the continuous wastage and transport of corrosion products to the boiler which went on in most units.

Copper deposits in marine boilers, which Mr. Preston had mentioned, until recently were not regarded as warranting a special removal process. This was more frequently carried out in land practice where higher pressures were used. Recently, however, copper removal processes had been recommended and carried out in marine boilers. The standard process consisted of the use of 1·0 per cent citric acid raised to *p*H 9·5 to *p*H 10 with ammonia, followed by the addition of an oxidant such as sodium bromate, sodium nitrite, hydrogen peroxide, or, in some cases, compressed air. An iron removal process using hydrochloric acid or citric was sandwiched in between two copper removal processes, as the copper in a heavily scaled boiler may be partly masked by iron, hence the two-step process.

One of the more promising cleaning processes now being introduced into this country from the U.S.A. was an alkali complexing agent for iron, copper and hardness salts. It was based on E.D.T.A. with special alkaline buffering agents and inhibitors, and could be injected whilst the boiler was under low pressure; this should offer considerable time saving.

The possibility of heat retention at the heavier boiler sections mentioned by Mr. Preston was noted; one or two precautions were normally taken to cope with this. First of all, in tests the inhibitors themselves gave very low corrosion rates of the order of 0·005 to 0·002 g/cm^2–day at a temperature of 90°C (194°F) on normal boiler steels with inhibited hydrochloric acid, and figures of 0·0012 to 0·003 on 3 per cent citric acid at 90°C. (194°F). In addition, it was usual to have a time lag of one to two hours after locking off burners and a check that there was a temperature drop in the boiler water before adding inhibited acid. To cover the surface effectively with thermocouples as suggested by Mr. Preston might present practical difficulties, but most chemical cleaning contractors would be only too willing to co-operate if this were deemed necessary.

It was noted that in pre-commission cleaning the removal of drum internals was recommended. This was ideal, but delayed the process. Provided there was reasonable access for hosing out of trapped residues—this could often be accomplished by part removal of baffles—it was best to have the internals assembled rather than have a break in the process and men moving out and in part way through the process, with the attendant risks of further débris etc. The passivation process was probably best carried out with all the internals fitted.

At one time it was considered best to fit in with the building programme and clean new boilers, then steam lines, then feed lines, or some other order suited to the builders. He would, however, make a strong plea for an effort to be made to clean all items in the cleaning programme at the same time, as this caused least interference in the long run.

Recently three boilers with the associated economizers, superheaters, feed system and steam lines in a large passenger vessel soon to be commissioned, were cleaned in a process time of four days. This could only be achieved with careful co-operation and planning between all concerned. It seemed logical that the contract for cleaning should be placed three to four months before completion of the ship; then a worth-while joint planning exercise could be carried out by the shipyard and chemical cleaning contractor, who would require the following facilities:

1) access to unit section and pipework layout drawings covering the equipment to be cleaned and a list of materials in the circuit;
2) completion of boilers ready for firing and heating; facilities to maintain the required temperature over the period of the process;
3) completion as far as possible of insulation in order to retain the heat for the process over the period required;
4) adequate supplies of good quality water and normally sufficient distilled water to supply the water for final passivation;
5) provision of power for circulating pumps;
6) disposal point for effluent.

Some idea of the results obtained from a recent pre-commissioning cleaning contract could be gathered from the following figures. With a capacity of 103 tons, there was a percentage total Fe in solution of 0·3 per cent weight/volume, and the estimated weight Fe was 700 lb. This figure did not include iron in suspension which was always present, and some remained in the bottom drum after emptying—a layer of about 1 in to 2 in of sludge which on analysis proved to contain 70 per cent iron oxide.

Commander K. B. Birkett, R.N., said that in the Royal Navy there were some parallel problems.

There were exactly the same difficulties in commissioning as in the commercial field: dirt in steam and oil systems. The Navy was involved in a very complicated pre-commissioning flushing routine for lubricating oil systems and, in general, while this removed dirt from the pipe systems, the equipment suppliers quite often provided, within the limits of the unit, certain foreign materials which were apt to find their way through bearings and leave their trademarks.

In steam and feed systems the problem was not quite so acute, but even in his short experience he had removed a baulk of timber, a wire scrubber and a yard square sheet of permanite from the feed system. It was incredible that this sort of thing could find its way into ships in this day and age. It was obvious that greater attention to quality control in the shipyards was required.

In the Navy, the steam and feed cycles were necessarily slightly more simple, but it would be interesting to know for what feed temperatures the author designed, how the feed heaters were disposed in the cycle and how the various auxiliaries were driven to get the fuel rates claimed in the paper. He assumed that a single boiler and single turbine plant were involved.

Whilst in the Navy there were not normally the higher steam conditions used commercially, there was a fairly arbitrary division point for the use of de-aerators. This was usually at over 600 lb/in^2 boiler pressures. Experience was that although the de-aerator met its specified duty at sea, which was 0·02 ml/litre of oxygen, in general it did not meet it in harbour. Taken by and large, these high oxygen excursions had no deleterious effect on the inside of the boiler and so far as he was aware. there was no serious incidence of oxygen pitting in economizers.

Unacceptable fireside wastage of economizer elements had however been experienced. This had been attributable to the comparatively low uptake and feed inlet temperatures existing in naval boilers. To obviate this problem cermet coated elements were now being introduced into service.

Acid cleaning was not favoured except in new boilers which were cleaned using citric acid only. Thereafter in the ship's life the more conventional methods of internal cleaning were used, except in the rare event of very hard scab pitting which no other process would remove.

Again a rather more simple approach to boiler water treatment was taken, using the Navy compound which kept the *p*H value between 10·5 and 11·5. Generally a very satisfactory result was obtained.

The total dissolved solids level of 1000 ppm was not exceeded by the regular use of pumping up and running down, and in his experience there had been no occasions of turbine deep deposits on opening up. In fact, opening up turbines, except for carrying out essential modifications or repairs, was now becoming more and more infrequent, in spite of fairly rigorous handling of the boiler. He could only put this down to good drill, good cyclone separators or good boiler water treatment. However, the results appeared to be satisfactory so far as the turbine was concerned.

Whilst the Navy went through the same processes of external cleaning of boilers by water washing, a recent decision to change over to distillate fuels had reduced the incidence of external cleaning considerably.

With regard to condensers, Mr. Lewis had reported elsewhere that in the Navy they had now abandoned "sacrificial" anodes and corrosion pieces completely in salt water systems, in the belief that in their size of heat exchangers these things formed a greater potential source of danger than of good.

They had endeavoured to use rubber-lined doors on main condensers on one occasion but this was not successful because micro cracking took place, and corrosion began beneath the surface.

The Navy was committed to remote and automatic control of machinery for reasons of ship defence against environmental warfare and reduction in manpower. There were also the obvious benefits of consistency in operating standards and rapid response, not to mention easing of the operator's task. In the current generation of COSAG ships, cruisers and modernized carriers, the wedding of automation to combustion control made possible the use of a high pressure spill system which would have been impractical in a purely manual system. Very satisfactory results were obtained.

He supported the author on commissioning, cleanliness of systems, etc. These remarks were completely borne out by Naval experience.

The condition of gearing on opening had been mentioned by the author. The Navy had found it an advantage to fit dehumidifiers on gear-cases, both open and closed circuit, and these had produced gratifying results so far.

MR. R. L. J. HAYDEN (Member) agreed with most of the conclusions and statements made by Mr. Preston.

The author had reached similar conclusions to those reached on previous occasions concerning the complexity of feed cycles. The *Orcades* and *Himalaya* class of ships started out with economizers and gas air heaters. Subsequent to heavy maintenance costs connected with gas air heaters on the original ships, the last ship, *Orsova*, was fitted with economizers only in the gas stream and with bled steam air heaters. The overall results of the ship were an improvement on the earlier vessels.

Whilst appreciating that the balance between higher theoretical efficiency and higher maintenance costs must be largely a matter of judgement on the part of the purchaser, any factual maintenance costs which the author had available would be welcome, especially those on which his judgements had been based.

One of the problems of a commercial company was judging the best offer to a customer without having factual maintenance costs available. Having submitted a proposal with the designers' best judgement one was frequently disappointed to find that the customer had accepted a lower offer, which might be cheaper initially but more expensive in the long run.

In the particular design of boiler illustrated, increased superheat could occur due to reduction of excess air if the flame shape resulted in radiant pick-up in the lower rows of the superheater. This phenomenon applied to any design of boiler. The superheater must be kept as far away from the burners as possible. One possible cause of long flames could not only be low excess air but could be due to individual burner flames not burning right back at the burner tip. For this reason each burner should be fitted with an individual ignitor and not flashed off burners already in use.

Boiler designers were continually striving to improve the efficiency of drum internals. With any given set the amount of carry-over of solids was at least proportional to the total dissolved solids in the boiler water and the suggestions the author made for controlling total dissolved solids were well worth attention.

The need to limit silica in steam was well founded at higher pressures, as this silica could go over in solution in steam and there was no way of separating it.

Boiler designs of the dual circulation type could be produced, whereby total dissolved solids in the water in the drum were lower than the total dissolved solids in the blow-down sections. It was doubtful whether these designs were necessary for marine service but they could be considered if silica became a problem at higher pressures.

He had always thought that insufficient attention had been paid to the presence of suspended iron in boilers, as compared with some of the dissolved solids in feed water, and the effect of the suspended iron on "on load" corrosion in boiler tubes. Mr. Preston was right in saying that where this type of corrosion occurred, the deposits showed on analysis a large proportion of iron and copper. If one could get rid of some of the iron, an improvement could be expected. It would be interesting to hear of any progress Mr. Preston made with the removal of copper, which seemed to be the next stage in preventing this type of corrosion.

The cause of selective corrosion of tube expansions during acid cleaning might be related to the exposure of grain at the tube ends, where the tube had been cropped, and to the high stress remaining as a result of the expanding operation. This seemed more likely than the author's suggestion of differential temperatures.

He endorsed the author's remarks on the commissioning and testing of instruments and controls, and agreed with him in the main. However, Mr. Hayden had been connected more with the land side of the business than the marine side in recent years, and suggested that the marine industry should endeavour to avoid the problems at the moment besetting the power station industry, where commissioning had taken much longer than was originally anticipated. He hesitated to quote figures but it was many times longer than marine machinery was taking. Even taking into account the increased complexity of the land equipment, something here required to be remedied. Part of this delay was undoubtedly caused by the complication of the instrumentation and the advent of specialists which it brought in its train. This made more difficult the provision of an individual on the part of the contractor and an individual on the part of the customer who could, within a reasonable time, be familiar with every problem occurring during the commissioning phases. There was a tendency now on the land side to have commissioning committees and he respectfully suggested that the marine industry would do well to avoid them.

MR. P. R. OWEN (Associate Member) referred to the interlocking overlapping propeller arrangement mentioned by Professor Jung.

When a normal twin screw vessel made a turn, the inboard screw of that vessel slowed down because of the increased load on that screw.

With the interlocking arrangements shown, both shafts were forced to run at the same rev/min, therefore during a turn the increased load on the inboard shaft would result, not in a reduction of shaft rev/min but in the redistribution of torque from the outboard to the inboard shaft. This could result in the inboard shaft being overstressed due to excessive torque.

In a recent naval vessel built by Yarrow, it was found that for such an arrangement, the pitch of the inboard c.p. propeller had to be trimmed during a turn in proportion to the rudder angle to prevent overstressing due to excessive torque.

With the arrangements suggested by Professor Jung, it would appear necessary to fit some protective device. He suggested that for vessels with f.p. propellers this could take the form of reducing the power output of the propulsion machinery in proportion to the rudder angle. Had the author considered this problem?

Correspondence

Mr. R. W. Jakeman, M.Sc. (Associate Member) wrote that the author had stated that the filter bypass relief valve might be obviated by the use of a centrifugal pump rather than a positive displacement pump. Whilst his experience of centrifugal pumps had been favourable, he did not agree with this particular claim because, bearings of the type concerned would run rather longer on contaminated oil than on no oil at all. The latter situation could clearly arise very quickly if a filter without a bypass relief valve became fully blocked.

Also operation of a centrifugal pump against a blocked discharge line could cause cavitation, leading to damage to the pump. Operation of the pump under such conditions could not be tolerated for more than a few minutes.

A filter differential pressure alarm should be fitted, but the bypass relief valve should not be dispensed with in view of the possibility that the bearings might be starved of oil, if operation of the alarm did not result in immediate remedial action.

Mr. P. Lawrie, B.Sc., C.Eng. wrote that the author had commented on possible increase of superheat temperature due to flame penetration through the furnace exit into the region below the superheater and two possible reasons had been advanced.

The first, by the author, was elongation of flame due to low excess air operation, and the second, by Mr. Hayden, was that flame fronts might not be correctly established, particularly if contact ignition between flames (cross-flashing) was attempted. It was agreed that both conditions could give the result mentioned, but it must be said that on two commissioning trials recently attended and involving the type of boiler described by the author, the excess air/superheat relationship obeyed the normal rules, even at very low oxygen readings in the gas outlet from the economizer.

The following comments applied to the two ships examined:

a) on one it was not possible to see the burner flame roots, due to the absence of appropriately placed sight holes; on the second, the presence of sight holes on boiler roof level enabled the flame roots to be clearly observed;
b) on both ships, the gas sampling points left much to be desired, bearing in mind the requirement to operate at approximately five per cent excess air;
c) excess air entered the system, after the combustion zone, from air-cooled sootblowers, and to a lesser extent through sight ports.

Due to (b) and (c), it was therefore impossible to analyse accurately the combustion performance.

It was suggested that for future installations, consideration should be given to:

i) provision of sight ports, to enable all flame roots to be observed;
ii) installation of a more sophisticated system of gas sampling points, enabling samples to be taken from various parts of the outlet duct;
iii) installation, if practicable, of shut off dampers to air-cooled sootblowers and sight ports, so that these could be isolated for short periods while gas samples were being taken.

Returning to the subject of burner ignition, Mr. Lawrie's company had consistently recommended that remotely operated burners should each be equipped with an ignitor to ensure the establishment of correctly positioned flame fronts under all the varied conditions which might be met in service.

This recommendation had been accepted and recent investigations had shown that when the ignitors were used, flames were always correctly established. On the other hand, it was demonstrated that contact ignition (cross-flashing) did not always result in the establishment of a correctly positioned flame front. However, when the flame fronts were correctly established, the burners tolerated extremely high air/fuel ratios, without the flames becoming detached.

Dr. P. T. Gilbert (Member), in a written contribution, agreed with Mr. Preston that the increased use of non-ferrous or completely coated ferrous water boxes was one of the factors leading to an increase in recent years in the number of cases of trouble due to inlet end impingement attack of condenser tubes. He also agreed that attack could be avoided by operating an appropriate system of applied current cathodic protection, supplemented if necessary by ferrous sulphate treatment of the cooling water to assist in the build-up of good protective films along the length of the tubes. The fitting of tube inserts should not also be necessary, though inserts were, of course, useful as a temporary remedial measure when inlet end attack was experienced.

Applied current cathodic protection was not the only way of achieving the desired result and it was usually possible, in main condensers, to fit, without creating additional turbulence, sufficient sacrificial anodes of a suitable grade of soft iron or mild steel to give complete protection against inlet end attack. There had been many cases in practice where this measure had been entirely effective in preventing or arresting trouble. The use of zinc sacrificial anodes, on the other hand, had on occasion, given rise to difficulties and he did not recommend their use.

With smaller condensers and heat exchangers there was a much greater risk of creating excessive turbulence if attempts were made to fit sacrificial anodes into existing units. The method could still be advantageous, however, if the water boxes of the units concerned were designed from the outset with the appropriate requirements in mind. The Ministry of Defence (Navy) decision to dispense with the use of soft iron sacrificial anodes was coupled with a decision to standardize on 70/30 cupro-nickel tubes for all condensers and heat exchangers with sea water cooling. The cupro-nickel alloy had a greater margin of safety against the occurrence of inlet end impingement attack than had aluminium brass, which was the standard tube material for marine service. The practices in H.M. ships in this matter might not, therefore, be appropriate also to condensers and heat exchangers containing aluminium brass tubes in merchant ships.

On the question of copper pick-up, there appeared to be ample evidence that the copper content of condensates could be significantly reduced by hydrazine treatment, despite the resulting increase in ammonia content in the system. Ammonia was without action on copper and copper alloys in the absence of dissolved oxygen and the beneficial effects of hydrazine were no doubt due to the fact that the reduction in the dissolved oxygen content more than counterbalanced any effects from an increase in the ammonia content of the condensate.

Author's Reply

The author thanked all present for their careful attention and kind reception. The contributions to the discussion added much to the paper for which he was duly grateful.

The author was particularly grateful to Professor Jung for opening the discussion and for contributing so much by looking into the future and describing various alternative arrangements for steam turbine installations. There was much food for thought in Professor Jung's comments which would bear careful consideration.

Mr. Gibbons had asked about de-aerator performance. Tests had proven that mechanical de-aeration had been adequate under all operational conditions reducing the O_2 to 0·005 ml/litre even with the highest degree of O_2 enrichment. Under these conditions one could feel quite confident that corrosion was under control in systems after the de-aerator but nevertheless the author's company still took the precaution of continuous hydrazine injection after the de-aerator, to scavenge the last trace and to guard against any fall-off in de-aerator performance. With regard to corrosion in the systems prior to the de-aerator this could be minimized even with relatively high O_2 content by *p*H control at about 9·0.

Since favourable conditions could be achieved on a continuous basis the added complexity of vacuum cargo pump condensers did not appear to be justified. The use of the main condenser as a receptacle for auxiliary exhaust steam seemed to be gaining favour in some quarters but once again the extension of vacuum systems did not appear to be justified. The danger of hot spots and expansion difficulties due to a rapid variation of exhaust returns was still a deterrent and therefore his company preferred to remain with the auxiliary atmospheric condenser usually of the "U" tube type to accommodate these high load and temperature swings.

The feed treatment described, plus CO_2 scavenging and *p*H improvement by the use of monocyclohexalamine together with removal of suspended iron from the drains tank return by 5 micron filtration ensured that acceptable feed water was presented to the de-aerator. The next problem to be tackled before increasing boiler pressures was that of copper transportation. It was hoped to start work on this in the near future, the first attempt being the introduction of hydrazine at the crossover pipe on the assumption that copper attack would be reduced in the main condenser if hydrazine was present.

Ion exchange units were incorporated in the make-up feed system to improve the water quality by sodium and copper elimination. There was no doubt that a full flow mixed bed demineralizing plant would improve the condensate condition but the cost, size and maintenance of such plant rules out the application.

Mr. Brownlie had asked why cycle B was not adopted since the higher steam condition limitation did not apply in this instance. Whilst agreeing that the rate of return on money invested was acceptable the actual profit figure could be seen from the diagram to be quite small, a figure which could be very easily lost if the ship should lose one day due to the extended pipework and increased number of feed heaters. On the point of maintaining design fuel rates, where the Simplex cycle was used, the design fuel rate had been maintained and even one half per cent better had been achieved over extended periods, whereas with the Complex cycle it was not unusual to find that the actual fuel rate returned was in the order of 3½ to 4 per cent higher than design. With regard to the maintenance cost of gas air heaters, it must be remembered that his company's experience was based on ships in the order of 7500–8000 shp using tubular gas air heaters. On these particular ships the repair cost was about £1000 per year for the maintenance of this heating surface. The diagram showing the comparison of cycles had not taken into account this kind of repair cost since later cycles would have the benefits of better materials and possibly better design in the air heaters.

Whilst respecting Mr. Brownlie's experience and specification for 40 micron filtration of lubricating oil and noting with interest the advantages claimed for hardened thrust collars, experience had shown this degree of filtration to be insufficient. Where this degree of filtration had been used, scored journals and marked thrust pads had invariably resulted. Other turbine designers had demonstrated finer clearances than those quoted by Mr. Brownlie and since the author's company operated turbines from various sources, they were happier with finer filtration.

The life expectancy with paper disposable elements after proper cleaning of the system had shown that the finer filtration could be obtained without any cost burden.

Mr. Brownlie's comments on the occasional failures immediately after installation certainly underlined the main point being made about the initial cleaning of the lubricating oil system. Turbine designers should also look to pedestal designs to ensure that oil pockets, etc., could be efficiently cleaned and inspected before commissioning.

The author was most grateful to Mr. Rose for the information contained in his contribution.

Whilst it was agreed that a new filter would eliminate a large proportion of the 20 micron contamination, a filter was one of the few pieces of equipment which improved its efficiency with time. It could be noted from Fig. 9 that the filter specification would eliminate 80 per cent of particles above 10 micron size when new and after some time this efficiency would increase. Probably this fact explained why further problems had not been experienced.

On the question of paper element adhesives, no failures had been reported during the five years or so when these had been in use.

On the question of overloaded thrust bearings there had been evidence on one or two turbines where the pivots had been heavily indented, but in general there had been no requirement for the fitting of equalizing segments. There seemed to be a need to ensure an adequate oil feed into the centre of the thrust collar to avoid the pumping action of the thrust collar depressing the pressure within the pad area. There had in fact been statements made that reduction of the number of pads to allow for better entry of oil into the bearing surfaces resulted in reduced thrust failures.

Mr. Hodgkin pointed out that care should be taken to see that provision of good maintenance facilities did not tend to increase the frequency with which it was necessary to use them. The author agreed with this. The reference in the paper was a plea to improve facilities for the efficient and quick acid cleaning of boilers prior to commissioning, and in operation. Also, there was little point in providing access to the waterside if it only meant viewing the tube ends.

Mr. Hodgkin's comments on commissioning of boilers with regard to the fouling of gas surfaces when the sootblowers were not available, and also the operation without fully commissioned interlocks, were extremely prudent. Equipment was undoubtedly damaged on occasions during the early stages due to lack of attention to this detail. The author recommended shipbuilders to use lighter fuels during the commissioning procedures to facilitate easy lighting and reduction of fouling of the gas sides thus reducing the hazardous period when soot fires could occur.

Commander Birkett had enquired about the cycle used to achieve the fuel rates stated in the paper. The most effective way of explaining this was to include the diagram shown in Fig. 20.

The author was surprised that plants operating without de-aeration in the Royal Navy had avoided corrosion problems. This had not been his experience. The fall-off in efficiency of de-aerating plant in port had been experienced but had been overcome by arranging auxiliary condensers with regenerative heating, sizing live steam valves supplying heating steam to meet the port conditions and ensuring that condensate sprays in the de-aerator were effective under light load conditions.

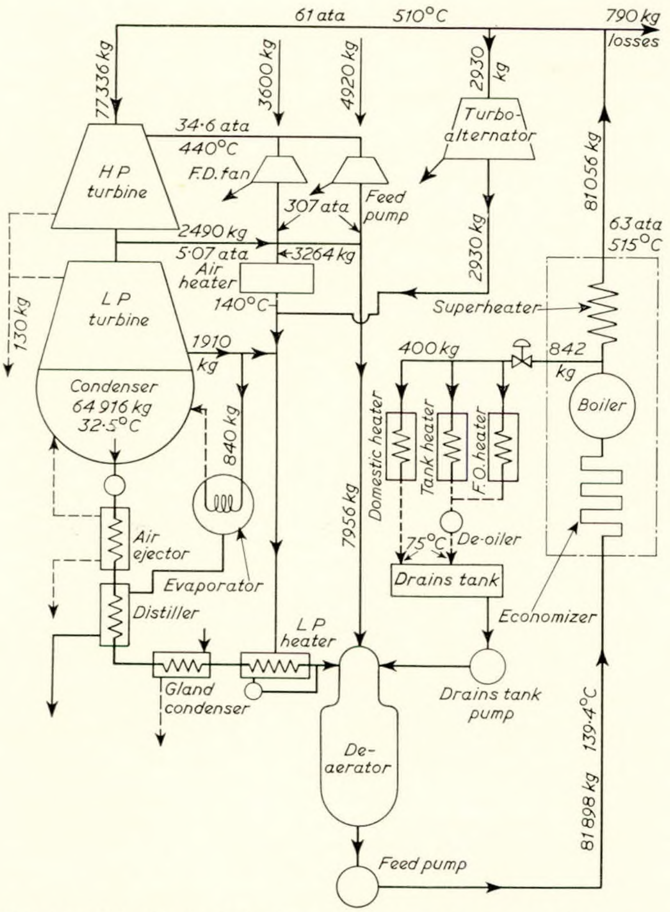
Mechanical cleaning of the large single boilers on merchant ships was not possible and therefore chemical cleaning was an accepted part of operation.

Commander Birkett had referred to "single shot" feed water treatment and the simplicity of this mode of operation. This had been used also in the author's company—the problems commenced if *p*H improvement was used to reduce system corrosion. The added alkalinity gained this way reduced the quantity of balanced chemicals required, resulting in reduced phosphate reserve, unless of course an adjusted higher phosphate mix was used for such systems.

On the question of deposits within the turbine and their absence on naval vessels, the author would submit that constant manoeuvring of these turbines would tend to wash these away as the heat drop across the steam path varied. The quoted figure of 1000 ppm total dissolved solids was much higher than the author would wish to operate with, even at 600 lb/in^2.

Mr. Cochrane's contribution on acid cleaning was most welcome since this was the side which tended to be neglected both in the commissioning and in the operational period. Wherever acid cleaning was used there was some element of risk and therefore anything that could be done to remove or reduce this risk was welcome.

Vacuum break with the use of nitrogen to reduce corrosion



Fuel rate 210·8 g/shp h. Calorific value 10 280. N.B.W.R. 2·41 kg/shp h.
Sea temperature 24°C. Shaft horsepower 28 000. Vacuum 722 mm.
Electrical load 405 kW. Boiler efficiency 88·5 %

FIG. 20

within the systems during shut-down periods had been noted but the author was sure that the cost involved was, for the marine industry, prohibitive.

The author particularly welcomed Mr. Cochrane's comment on the two-step process of acid cleaning of boilers in service. Copper was obviously being transported into the boiler but this was very rarely taken into account when acid cleaning was carried out.

The comments made on the pre-planning of acid cleaning prior to commissioning made eminent sense—the author sincerely hoped that this would become the rule rather than the exception for the future. For future designs, specifications should carry requirements for such pre-planning, also for the additional venting and draining points within the system to facilitate acid cleaning both prior to commissioning and during service.

The author sympathized with Mr. Hayden's plea for feed-back of information for past designs. This essential commodity was one all designers earnestly wished for but unfortunately rarely got.

The gas air heater yearly repair figure had been quoted in reply to Mr. Brownlie. Information on operating costs for the latest boiler designs were not as yet available.

There was no criticism made of the boiler which was illustrated when it was stated to be sensitive to excess air variations. He believed, as Mr. Hayden pointed out, that in any boiler of this configuration if the flame envelope was too long there would be a variation in the super-heater characteristic. The point made in the paper was really meant to illustrate the requirement for close combustion control.

Burners not burning right back at the tip could be troublesome and to avoid this the author's company did specify individual ignitors. Flashing off from an adjacent burner was not a recommended method of working.

Mr. Hayden had made some interesting comments about extended commissioning times of land installations and related this to over-complexity of instrumentation and controls. Over-complexity was something which in the author's view should be avoided in any system, probably more so on board ship. In fairness, however, he felt compelled to give his opinion that a correctly designed and fully commissioned alarm and control system would reduce rather than prolong the commissioning process. This had recently been demonstrated on a ship out of the U.K. where the trials had been carried out in a most controlled manner with all design figures being met at will. This had been a most encouraging experience for the author and his colleagues illustrating as it did the result of close co-operation between builder, his various sub-contractors and the owner's technical staff.

Mr. Owen had raised the point of possible over-torque on overlapping interlocked propellers. This forward thinking on futuristic plant was illustrated by Professor Jung in his contribution.

The author had had no experience with such plant and had to admit that such a problem had not been considered to date. However, he would venture the opinion that if such plant was to be applied to large tankers it would not present the same number of occasions for possible over-torque as on the class of vessel to which Mr. Owen referred. In view of this, power reductions on large helm variations could not constitute any measurable loss in service speed and therefore such a solution would obviously be acceptable.

Mr. Jakeman's comments on the proposed deletion of bypass relief valves on the lubricating oil filters were relevant and valid if no other precautions were taken. Where differential pressure alarms and low lubricating oil pressure engine shut-down features were incorporated, having separate sensing points, the author felt justified in omitting the bypass relief arrangement.

On occasions relief bypasses had been brought into operation on start-up due to the relatively high viscosity of the oil causing high differential pressures and the valves not reseating again. This possible contamination of the system against the fact that sudden chokage had not and should not occur with a clean system, and double protection, i.e. alarm and then shut-down if it did, brought about the specified elimination referred to by the author.

Mr. Lawrie made three very important points in assuring good operation of boilers. Well-placed sight holes within the furnace, individual ignitors for burners where control by cascading was used and improved gas sampling methods.

The first two points the author accepted without qualification other than to endorse them since he considered these to be essential for good boiler operation.

The third point was equally valid but unfortunately more difficult to achieve. However, if low excess air figures were to be sought without all the attendant problems that inadequate combustion would bring, some means must be found to overcome these difficulties in gas sampling.

The author was grateful to Mr. Lawrie for highlighting these points.

Dr. Gilbert's comments on the protection of main condenser and auxiliary cooler materials were most welcome. Confirmation from such an authority on the subject that one was at least working in the right direction was always encouraging.

On the subject of copper pick-up, the figure of 30 lb per 1000 days operation did in actual fact relate to a plant using hydrazine as an oxygen scavenger. As Dr. Gilbert pointed out there was no action by the ammonia in the absence of O_2. With hydrazine reserves showing in the boiler one could be sure that O_2 was not present in the boiler and therefore not present in the steam flow to the condenser. Vacuum systems, however, were always difficult to keep tight and therefore there was always the danger of some O_2 presence in the condenser due to leakage which would facilitate ammonia attack. It was on this basis that his company took the next exploratory step of introducing hydrazine into the cross-over pipe of the turbine since O_2 could not exist in its presence.

Marine Engineering and Shipbuilding Abstracts

No. 1, January 1969

Method of Cleaning Underwater Hulls Afloat

Research has shown that the commencement of fouling on a ship's hull takes place when the ship is stationary, i.e. in port, and continues when the relative movement of plate surface in relation to the water does not exceed about two knots.

The extent of fouling varies from ship to ship at any given time but, on average, a gradual speed loss of one knot may be experienced on a large tanker over a period of 12 months after drydocking and painting.

The curve of speed loss is not a straight line, but on a one knot loss over 12 months the average is about 0·5 knot.

Esso's 250 000-tonners currently under construction will have an average speed in service, over the loaded and ballast passages, of 16½ knots, when clean, or expressed another way, will steam 396 miles in 24 hours.

Some three years ago, Jersey Marine Research Programme became interested in the basic concept of SCAMP, the Submerged Cleaning and Maintenance Platform. This was seen as a vehicle which could attach itself to the underwater surface of the hull, could move in a controlled manner over this surface at varying depth and could be used for carrying out such services as surface cleaning and removal of fouling, underwater painting, survey by closed-circuit television and possibly for closure of sea inlets and other underwater maintenance requirements.

During 1966–67, Marine Research Programme funds were applied to the principal design of the vehicle, particularly with regard to the manner in which it could be clamped to the hull surface and at the same time allow controlled vertical or horizontal movement.

The shell or canopy of the Scamp is about 6 ft in diameter and 16 in in height, with centres of buoyancy and of gravity adjusted vertically and horizontally on the ventral axis. It has a slight positive buoyance in salt water, in order to float to the surface and is transported to the working locations by towing behind the work-boat.

The central impeller creates the pressure differential for clamping to the hull. Turning is by traction wheels and the traction/steering wheel is located at the forward end. The three cleaning brushes give a cleaning swathe of about 5 ft. Forward movement speed is designed for 1 ft/sec against a tidal force equivalent to a four-knot tide.—*Shipbuilding and Shipping Record, 23rd and 30th August 1968, Vol. 112, pp. 262–263.*

Research on Ships' Main Hull Structure

A broad survey has been made of recent research and work still in progress on the response of ships' main hull structure, with the main emphasis on warship structures. New methods are becoming available or are being proposed for both the longitudinal bending of the ship box girder and the local response of its stiffened plate panels. At the present time, the outstanding problem areas include the following:

1) Determination of the ultimate load-carrying of stiffened plate panels under either axial load alone or combined lateral and axial loads.
2) Computer programmes for three-dimensional elastic analysis of the common types of ship structure, with emphasis on fairly approximate treatments. The requirement is for either particular programmes for particular types of problem or programmes to generate the data for using an existing general three-dimensional analysis programme.
3) Study of the elastic response of double bottom structures. This problem is of more concern to merchant ship designers.
4) Realistic analysis and design methods for plate panels with small permanent set, under combined lateral and axial loading. This is the most important outstanding problem for warship designers.
5) Data on the static and fatigue strength of structural connexions. At present, the greater lack of knowledge is on fatigue strength.

At the present time, wide differences exist in the type of designs adopted, warship designers preferring a very elaborate and expensive structural layout costing perhaps £700/ton for the fabricated structure, whereas merchant ship designers use much more simple and sturdy construction costing typically £100/ton. The most important problem is to persuade the ship designers and the merchant ship classification societies that they can depart with confidence from their present semi-empirical and rule of thumb design procedures. Once analysis is accepted as the normal design process, meaningful optimization studies can be carried out, aimed particularly at producing minimum cost structures. For any realistic design optimization studies, cost data are required to be much more detailed than is normally available at the present time. An average figure of the cost per ton for all merchant ship construction or for all warship construction in a particular yard is not sufficiently detailed to sort out the relative merits and economics of various stiffener spacings. The provision of the right sort of costing information is possibly the most difficult aspect of ship optimization studies, requiring patient co-operation between the shipbuilder and research worker.

There is another more immediate and more obvious pay-off from ship structural research. This is by enabling designs having unconventional structural features or designs in unconventional materials to be successfully tackled. Unconventional structures include the now common problem of the open deck container ship and the proposed hinged ship structure.

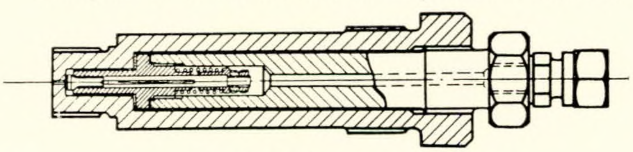
Despite the lack of any sensational successes from ship structural research up to the present time, there are important short-term and long-term dividends to be gained which together make this research an essential cost effective activity for a technically advanced shipbuilding nation.—*Clarkson, J., Shipping World and Shipbuilder, June 1968, Vol. 161, pp. 936–938.*

Latest Doxford Cylinder Lubrication System

For some years now a timed lubrication system has been in use on Doxford engines, based on that described in a paper presented before CIMAC in Copenhagen in 1962. This system has one pump per engine piston delivering a relatively large charge once per cycle through a distributor to each in turn of several lubricator quills. The resultant accurate control of quantity and timing has been found to give very good results, particularly when the pistons are fitted with suitable oil spreader rings and the quills are placed in the part of the cylinder liners away from the combustion zone. However, accidental timing errors can result in the oil being injected into the cylinder and thereby becoming ineffectual.

All J-type engines have been fitted with eight lubricator quills per piston. The original prototype was fitted with a small pump and distributor unit, each distributor point delivering to two quills through a Y-junction. These quills were of the differential needle type, basically similar to the fuel injection valves used in automotive engines but with much lighter springs, and were placed fairly close to the combustion belt. In the early days of testing it was found that combustion pressure acting on the upper cylinder quills tended to hold the valves open and to fill the lubrication system with gas. This was thought to be due to connecting two quills to each distributor point and additional lubricators were fitted to provide a separate unit for each piston. The modification resulted in a considerable improvement but there was still some gassing at high loads.

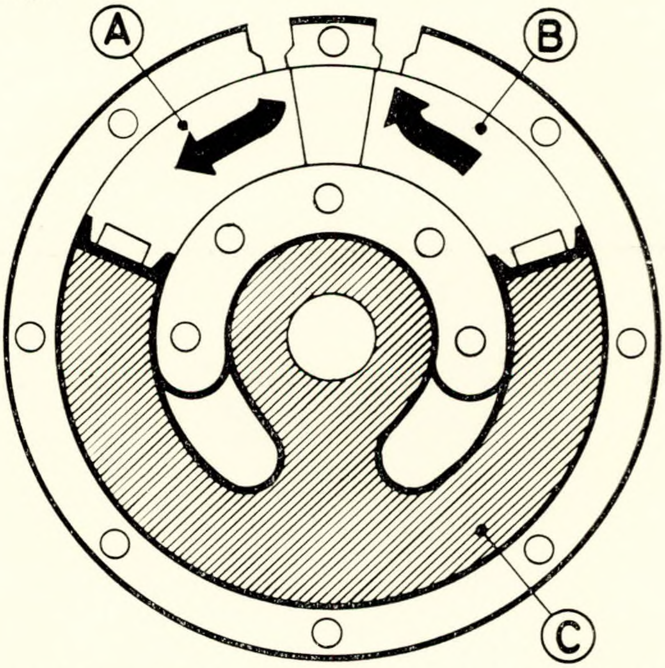
The quill valve shown was developed as a result of a number of experiments. In this case the valve is of the poppet type and opens towards the cylinder so that gas tends to keep the valve closed. This type of valve completely cured the gassing problem. The quills were subsequently moved to a lower pressure area of the cylinder and it is possible that the original valves would have been satisfactory, but the new type were no more difficult to produce than the old and had the additional advantage of obviating the very slight external leakage which could occur along the spindles of the older valve after a period of service.—*Marine Engineer and Naval Architect, July 1968, Vol. 91,* pp. 258–259.



Cylinder lubrication quill

New Hydraulic Actuator

A new hydraulic actuator, designed and developed by Associated Cargo Gear AB, Sweden, is now in production and being supplied for the remote control of valves on board ship, as well as for use on land. Known as the ASCA actuator 90, it is an hydraulic torque device of compact and rigid design, without any exposed reciprocating parts which can be made dirty, corroded or damaged. This ensures that there are no leakages in the sealing elements which could cause functional disturbance or oil loss. Prototype actuators have been installed in the cargo pump room of the oil tanker *Kungalaund* and have given very satisfactory performance. Over 200 of these actuators have been sold to Japan for use on board ships.



A and B are filled with oil. When pressure is applied to A, piston C is turned anti-clockwise and oil in B returns to line. Reverse procedure gives clock-wise rotation. Torque—335–14 200 ft/lb, working pressure—1420–2140 lb/in², swept volume—12·2–165 in³

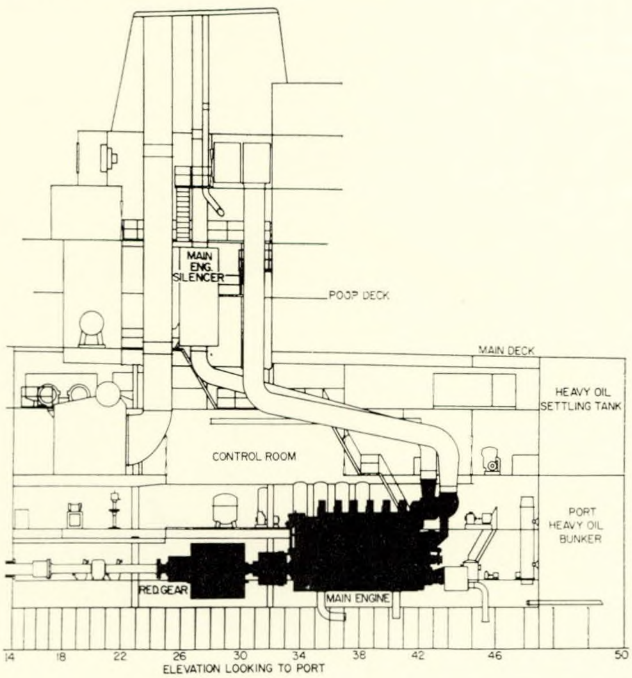
As will be noted from the accompanying sketch, there is only one moving part—the one-piece shaft with its bow shaped square piston. This piston runs in a ring-shaped channel in the fixed actuator housing, without being in metallic contact with the channel walls. At each end of the piston there is a floating sealing device which prevents oil from leaking past the piston. A dividing plate separates the channel into two separate chambers.

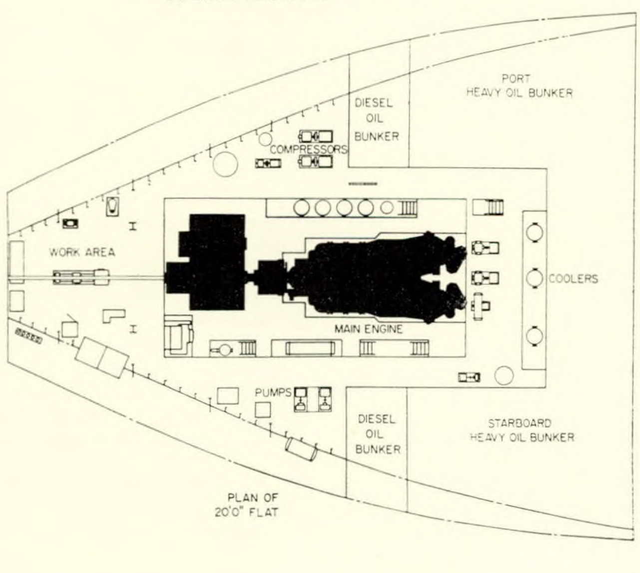
The piston shaft is mounted in SKF bearings, the working end being fitted with a keyway and the other with a square end for emergency operation and additional torque lever or position indicator, etc. The design is such that there is no metallic sliding contact between operating surfaces. The sealing elements are mounted in bayonet sockets and are free to move horizontally and vertically, thereby guaranteeing an equal sealing pressure.

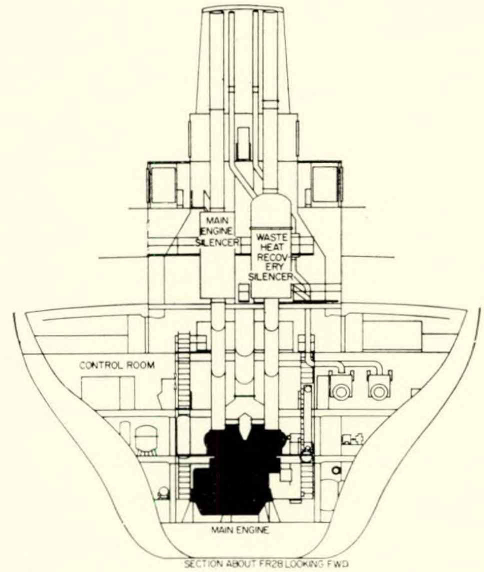
The sealing elements are the only parts exposed to wear and these can easily be changed after removing the actuator cover. The actuator housing is made from pressure-tight cast iron and the shaft and piston from nodular iron or cast steel. —*Shipping World and Shipbuilder, July 1968, Vol. 161, p. 1058.*

U.S. Tankers with Diesel Engines

The four 34 000 dwt motor tankers ordered by Falcon Tankers Inc., from Ingalls Shipbuilding, a division of the marine group of Litton Industries, Pascagoula, Mississippi, will be the first major U.S. ships ordered since the war to have U.S. Diesel engines: each is to be propelled by a 12-cylinder direct-reversing Fairbanks/Morse engine of 15 000 bhp at 450 rev/min.







Engine room plans for motor tankers

Design work and studies of engine applications for the four tankers were undertaken by Marine Consultants and Designers.

The Model 38A20 engine is the latest design of Fairbanks Morse who claim it as the most powerful Diesel engine for its size ever to be produced. Rated at 1250 bhp/cylinder at 450 rev/min, these opposed-piston engines came into production early in 1966 and are offered in 6 and 9-cylinder in-line versions and in 12 and 18-cylinder vee configuration. Principal characteristics are:

No. of cylinders	12
Brake horsepower	15 000
Rev/min	450
Finished weight of engine, lb ...	288 000
Cylinder arrangement	45° vee
Lower piston speed, ft/min ...	1612
Upper piston speed, ft/min ...	806

Direct-reversing, engine with heavy fuel burning equipment and bridge controls.

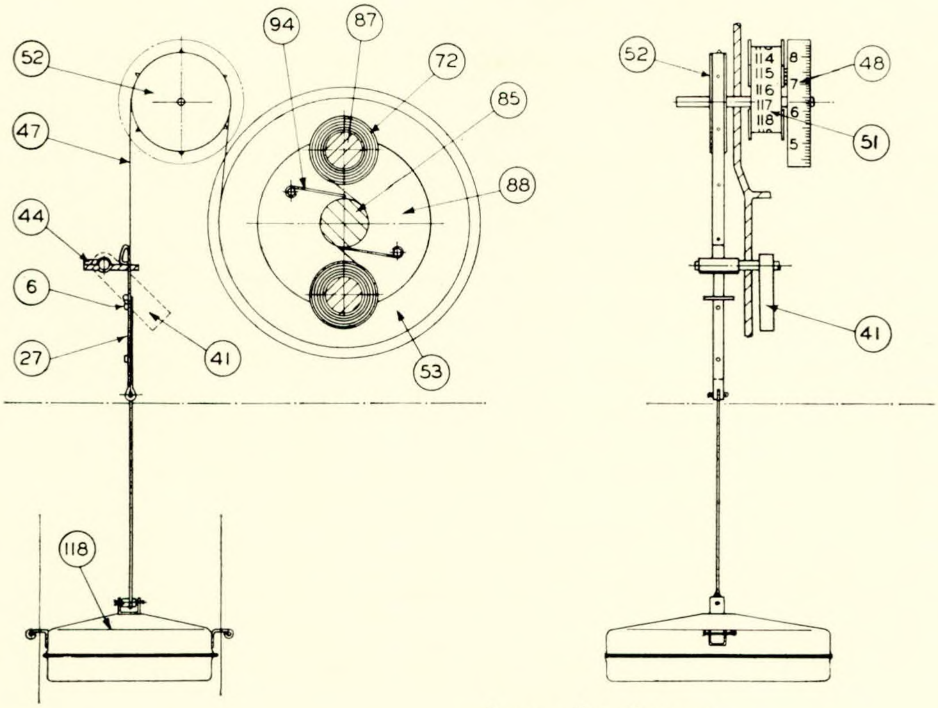
With a weight of 288 000 lb (129 tons approx.) for 15 000 bhp, it is contended that this engine is from one-half to one-quarter of the weight of European slow-speed Diesel engines of equivalent power, thus offering appreciable operating economies.

In each ship, the 12-cylinder engine will drive a fixed-blade propeller. The machinery arrangement is shown on the accompanying plans, from which it will be seen that the engine has attached pumps for lubricating oil, jacket-water and sea water circulation. Fairbanks Morse are supplying the complete propulsion system, including reduction gearing, couplings, monitoring equipment and remote controls.—*The Motor Ship, September 1968, Vol. 49, pp. 266–267.*

Cargo Oil Tank Gauge

A cargo oil tank level gauge has been designed and developed by Whessoe Ltd., offering a number of advantages to tanker owners.

One of the main advantages of the new gauge is freedom from maintenance. A factory-sealed negator motor unit prevents spring damage from high sulphur crude oils, and spring replacement, which is by exchange of a factory-sealed unit, is easily effected. The gauge will measure accurately and continuously the contents of tankers during loading, discharging and ballasting. It may also be used for the periodical



6) screws
27) float connector
41) counterweight
44) float hanger
47) tape
48) counter drum
51) spring strip
52) sprocket wheel
53) sealed drum
72) springs
85) power hub
87) storage drum
88) plate
94) stops
118) float

Cargo oil tank gauge

measurement of bunker contents, and is designed to accept double and single-synchro transmission.

The mechanism for maintaining constant tape tension at the float is contained within a sealed drum together with the means for controlling the rate at which the float will fall freely when the gauge is put into operation. Springs fitted inside the drum keep the tape under constant tension at the float, over the full gauging height. This drum is filled with silicon fluid which acts as a viscous damping medium and lubricant; the damping automatically increasing or decreasing with change of speed, so that during normal movements of the gauge the amount of damping is negligible, but when the gauge is released and allowed to fall freely, damping increases automatically to maintain the rate of fall at a safe level.

Movement of the tape as it passes over a sprocket wheel turns the counter drum, shown on the drawing, which in turn operates through a geneva mechanism, the graduated spring strip. The combination of figures on the graduated strip and the counter drum provides a readout. All counter parts are contained within a sealed oil-filled compartment.

When the gauge is not in use, the float is secured close underneath the gauge by means of a lock-up arrangement. This operates automatically when the float is raised to its full extent. The float is raised and released by a detachable crank which also embodies a reduction gear to prevent it from being raised too quickly, a device to prevent over-winding and a clutch to prevent any damage should the crank be inadvertently turned in the reverse direction.—*Shipping World and Shipbuilder, October 1968, Vol. 161, p. 1612.*

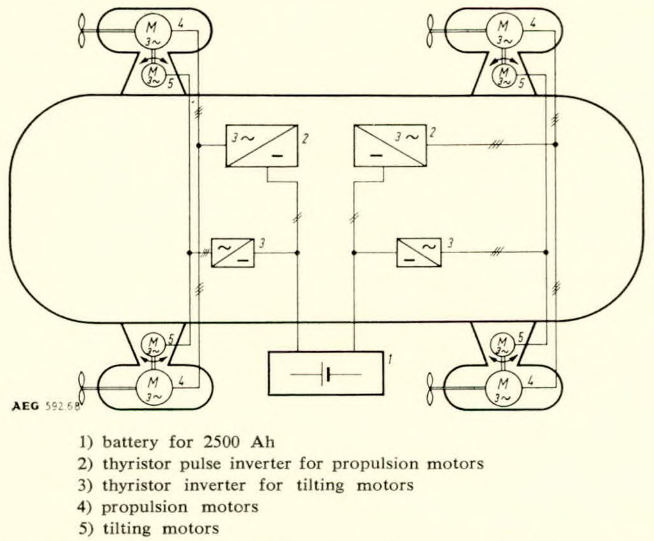
Propulsion System of Bathyscaphe

A new propulsion and control system was developed and built by AEG-Telefunken in co-operation with the Pleuger-Unterwasserpumpen company for the PX-15 research bathyscaphe built by Dr. Piccard (Lausanne) for the Grumman Aircraft Engineering Corporation. For the electric drive system, the specification demanded that the water filled, three phase, squirrel cage induction motors should be fed from a battery.

The propulsion system of the PX-15 bathyscaphe consists of four individual units. Each unit consists of a Pleuger submersible motor and a tilting gear with an auxiliary motor. The Pleuger submersible motors are water filled, eight pole, squirrel cage motors with an output of 25 lb/sec each at 720 rev/min. The water filling of the motor lubricates the soft rubber bearings, cools the winding and also serves as a support medium against the water pressure during diving.

The power source is a battery arranged in the keel of the bathyscaphe. This battery has a capacity of 2500 amp/h at an average voltage of 304 and forms a d.c. voltage source which feeds the three phase, squirrel cage motors via inverters. The inverters are arranged for a variable output voltage and frequency, each serving two motors. The switchgear installed allows any desired inverter/motor combination.

The four motor outriggers can each be tilted through 360°. The tilting shaft is driven via a worm gear by a Pleuger



1) battery for 2500 Ah
2) thyristor pulse inverter for propulsion motors
3) thyristor inverter for tilting motors
4) propulsion motors
5) tilting motors

Arrangement of propulsion and tilting motors and power supply system for bathyscaphe submersible motor with an output of 0·5 lb/sec at 1700 rev/min. These motors are also fed from the battery via inverters.

The inverter converts the battery voltage into a three phase a.c. voltage. For the motors, the voltage must be varied along with the frequency, and it must therefore be possible to vary the output voltage of the inverter. Because of the wide speed setting range the pulse method was used for the voltage variation in the inverter.

The speed of the motors is varied by altering the frequency of the inverter. This principle of frequency control solves the problem of speed adjustment for the propulsion drive without a tachogenerator. An electronic limit-value device prevents the motor slip from becoming excessive. The motor voltage is adjusted by a control circuit specially provided for the purpose. To improve the shape of the motor current curve, the voltage regulator operates with infraposed current regulation.—*Dworski, M. and Michel, M., AEG-Telefunken Progress, 1968, No. 2, pp. 51–53.*

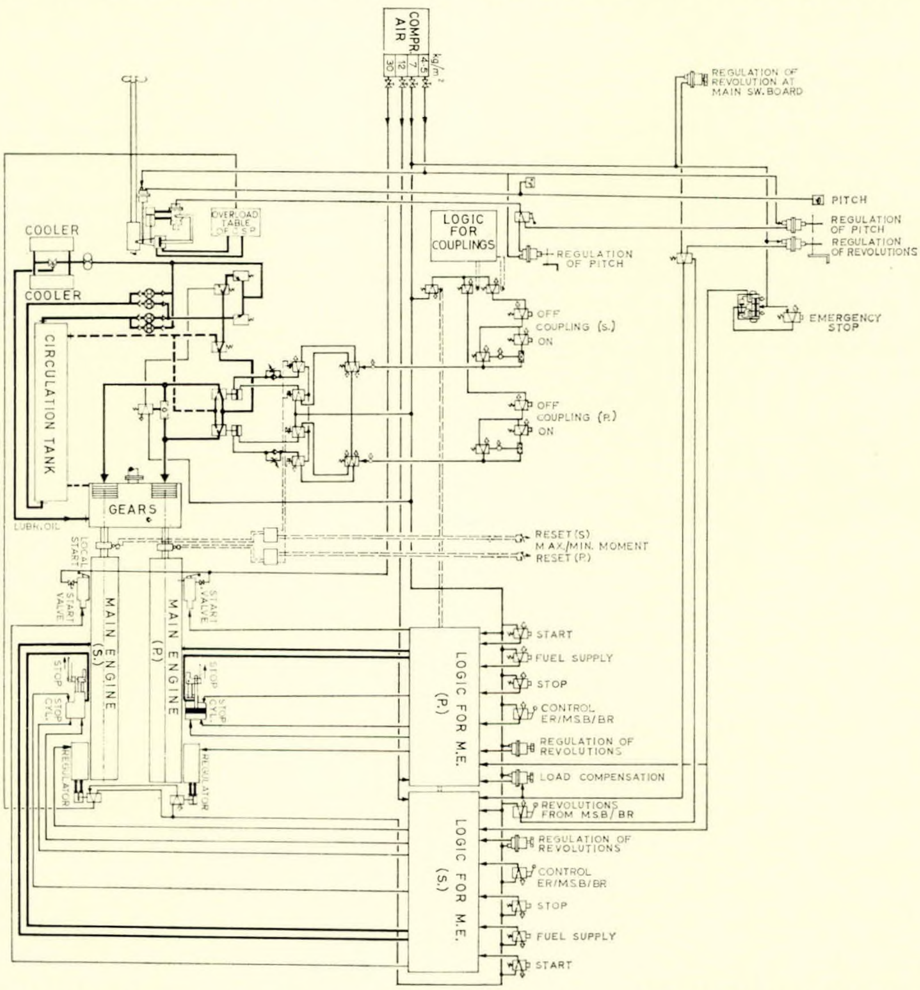
Large Refrigerated Liner

The first of two 487 000 ft³ refrigerated liners, *San Joaquin Valley,* has been delivered to the Swedish shipping company Rederiaktiebolaget Nordstjernan. This ship, one of the largest fruit carriers in the world, was built by Oy Wärtsilä Ab Turku Shipyard in Finland. Special features of the ship include wide twin hatches in all holds but one, and a very comprehensive and advanced refrigerating system with a wide range of temperatures available, thus enabling a variety of fruit, fish and meat to be carried.

Principal particulars are:

Length, o.a.	505 ft 6 in
Length, b.p.	459 ft 4 in
Breadth, moulded	68 ft 10½ in
Depth, to upper deck	43 ft 9½ in
Depth, to second deck	35 ft 0 in
Depth, to third deck	24 ft 10 in
Depth, to fourth deck	15 ft 6 in
Draught, summer load line ...	28 ft 0¼ in
Deadweight at 8·54 m draught ...	7900 tons
Gross tonnage	9634·22
Net tonnage	5333·44
Machinery output	2 × 7440 bhp at 500 rev/min
Speed on 8·54 m draught with main engine output of 14 880 bhp	21 knots
Speed on banana draught ...	22 knots
Trial speed in ballast condition ...	23 knots
Cargo capacity, bale	487 840 ft³

The refrigeration plant comprises 10 independent refrigerant R22 circuits. Each circuit intended for one cargo space is composed of the following: cooling unit, evaporator unit, refrigerant piping, and electrical panel. In the 10 cooling units there are 28 compressors installed with a total compressor capacity at standard rating (+30/−15°C) of 1 350 000 kcal/h. Depending on the size of the cargo space concerned,



Schematic diagram showing remote control of main engine, reduction gear and KaMeWa propeller of large refrigerated liner each cooling unit incorporates two or three hermetic reciprocating compressors coupled in parallel.

A panel with all the electronic equipment for the automatic operation of the 10 refrigerant circuits, and for remote starting and stopping of fans and sea water pumps, is located in the control room.

The propelling machinery in *San Joaquin Valley* consists of two Wärtsilä-S.E.M.T.-Pielstick Diesel engines, each developing 7440 bhp at 500 rev/min. They drive the propeller shaft, which is equipped with a KaMeWa c.p. propeller, through couplings and a reduction gear. The elastic couplings are of Vulkan's make and the gear reduces the speed of the propeller shaft to 120 rev/min.

The machinery has been automated to such an extent that it can be operated without continuous watchkeeping, and the engine room may be left unmanned for periods of 16 hours. The propelling machinery is regulated from a control room. The necessary devices for the supervision of the main engines, e.g. alarms and indicators, etc., have also been arranged on the bridge.—*Shipping World and Shipbuilder, June 1968, Vol. 161, pp. 924–930.*

Desalinator

Means of producing fresh water in quantity are now essential in all ships except very short-sea traders. Much greater volumes of fresh water are needed nowadays for domestic services (and this often extends to sanitary services) than could be carried on board without sacrifice of cargo space and deadweight. Boiler make-up feed water also makes demands on space.

The Babcock desalinator is designed primarily to use Diesel engine jacket cooling water as a source of heat, but any other available hot water in the range 140° to 190°F (60° to 90°C) may be used. Alternatively closed exhaust from auxiliary system, bled steam or an electric element can be the source of heat. In the case of hot water this is passed through the tubes of the heating element in the lower part of the shell while sea water is passed through the condenser tubes in the upper part.

After leaving the condenser a small portion of the cooling water is metered into the bottom of the shell as feed water and the rest passes through an ejector which maintains a vacuum in the shell and also removes excess brine. The salt water in the shell is raised to about 115°F (46°C) at which temperature it boils under vacuum. The vapour produced rises through a separator and then condenses on the surface of the condenser tubes which are specially inclined to enhance the clearance of condensate from the tubes and to improve heat transfer efficiency.

A tray arranged beneath the condenser collects the condensate which is withdrawn and transferred to the storage tank by an integral pump. A monitoring device fitted on the discharge side of the pump ensures that only pure water reaches the storage tank and an electric diverter valve returns impure water to the unit during start-up or in the event of mal-operation. The instrument panel includes a flow meter to measure the quantity of fresh water produced.—*Marine Engineer and Naval Architect, July 1968, Vol. 91, p. 256.*

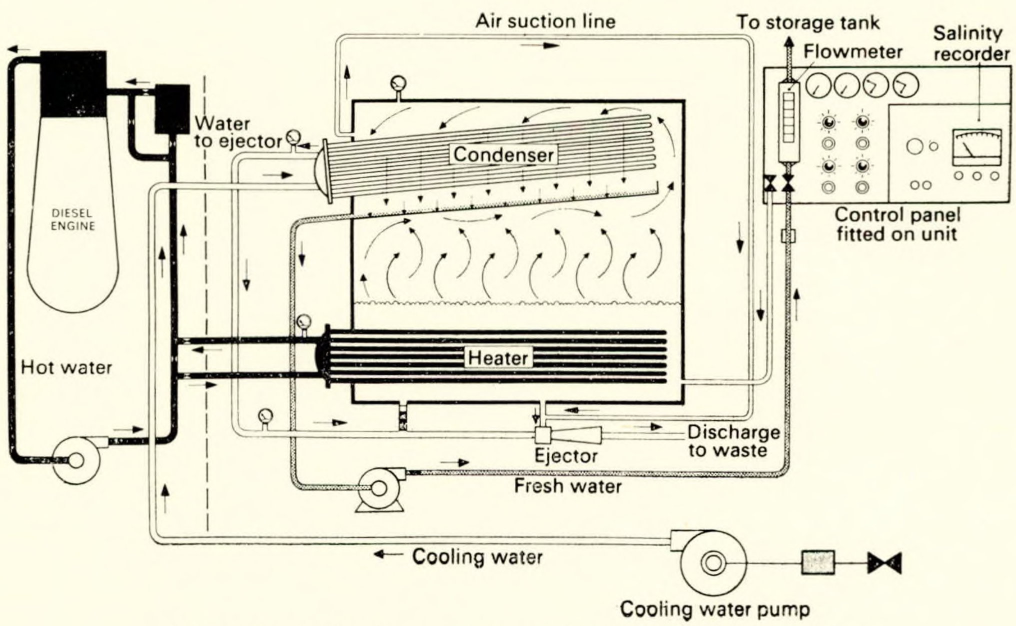
Hydraulically Operated Fire Fighting Platform

With supertankers ever increasing in size, the task of fire fighting becomes more and more difficult. In particular the problem of projecting a jet of foam on to a tanker deck, especially when the vessel is in the unladen condition, has thrown special focus on to the importance of the height of the monitor units.

The new Merryweather Major dual purpose monitor, able to deliver water or foam, is capable of throwing foam a distance of over 200 ft in a stream exceeding 100 ft in height and can handle 5000 gal/min. Designed to augment the performance of the monitor is a hydraulically operated extending platform capable of withstanding the severe stresses associated with the operation of a large capacity monitor under marine conditions.

The platform comprises a specially designed Simon Snorkel platform with additional engineering and foam equipment.

The twin boom Snorkel unit mounted with the platform gives a maximum working height of about 45 ft above the turntable mounting. Safety rails are incorporated as well as the monitor mounting and working space for the operator. The cage is kept horizontal by means of a special linkage and each boom can be raised and lowered independently as well as simultaneously. The turntable can rotate continuously



Connexions in desalinator—primary heat circuit shown in black in either direction. All platform movements are normally directed by the operator in the cage through a simple set of hand controls, though duplicate controls are fitted on the turntable for remote operation if required. For emergency rescue or lifting facilities the platform is capable of lifting 1500 lb (seven average people). During normal towing and berthing duties the platform is hydraulically folded and stowed in a position ensuring the lowest centre of gravity and minimum windage.—*Shipbuilding and Shipping Record, 23rd and 30th August 1968, Vol. 112. p. 257.*

21½-knot Cargo Liner

Although containerization is now a subject of prime importance in the various cargo liner trades and many of the major shipping companies are planning or putting into service ships built specifically for the carriage of containers, not all ship owners are following this trend. One such company is the East Asiatic Co., of Copenhagen, which operates a large number of ships in the Far East trade. However, containerization has influenced the design of the latest A-class general cargo liner, *Atrevida*, recently delivered to East Asiatic from Nakskov Skibsvaerft, Nakskov, Denmark.

Principal particulars are:

Length, o.a.	167·06 m
Length, b.p.	155·00 m
Breadth, moulded	24·76 m
Depth, to upper deck	13·30 m
Depth, to second deck	10·12 m
Depth, to third deck	7·19 m
Draught in open condition ...	8·55 m
Corresponding dwt	10 880
Draught in closed condition ...	9·90 m
Corresponding dwt	14 200
Gross register, tons	8930
Net register, tons	5129
Capacity of holds, including deep tanks (grain)	721 000 ft^3
Capacity of refrigerated holds ...	84 000 ft^3
Service speed	21–22 knots
Main engine	
Maker	Burmeister and Wain
Type	1274–VT2BF–160
Number of cylinders	12
Maximum continuous output ...	19 800 bhp
Corresponding rev/min	119

Built to the requirements for the highest classification of Lloyd's Register, the vessel is of the open/closed-shelterdeck type with four continuous decks, a forecastle and a fairly long poop, being principally designed for the owners' liner trades and arranged for the carriage of general and refrigerated cargoes, vegetable oils and latex and with provision for containers when required.

Experience gained in the previous ships of this class with their well-proven automation and remote control systems and many running hours in the unmanned state have led to a few minor modifications being carried out—mainly in pipework systems—on the installation fitted in *Atrevida* but basically it is the same arrangement as that fitted to the previous East Asiatic Co. vessels. Thus out of a total crew complement of 36 the engine room department accounts for 11 men comprised of four senior engineers, three junior engineers, one electrician and three motor men. The additional senior engineer carried on this ship will perform the duties of a refrigeration engineer since a larger refrigeration plant is installed.—*The Motor Ship, May 1968, Vol. 49, pp. 61–65.*

Chesapeake Log System

The Chesapeake log system operates on an electro-magnetic principle wherein a linear voltage proportional to speed is generated within an underwater sensor assembly and is numerically displayed with distance travelled on bulkhead or panel mounted instrumentation.

The sensor assembly, or rodmeter, consists of a fared strut, the extremity of which is inserted into the sea through a hull-mounted sea valve, or in smaller vessels, is affixed to the hull. The working part of the rodmeter consists of a fibreglass boot in which a coil that generates a magnetic field in the sea is encapsulated. Sensing elements are contained on this boot assembly across which a voltage is induced when the magnetic field is cut by a conductor, in this case the water passing by the sensing elements.

The log rodmeter signal increases linearly with increasing speed and does not require mechanical to electronic transformation; it has been proved to be accurate from speeds of −9 knots to well over +40 knots.

For reliability, the shipboard electronic unit is constructed entirely from solid state electronic devices. There are no moving parts, bellows, pitot tubes, etc.—*Shipbuilding and Shipping Record, 9th August 1968, Vol. 112, p. 193.*

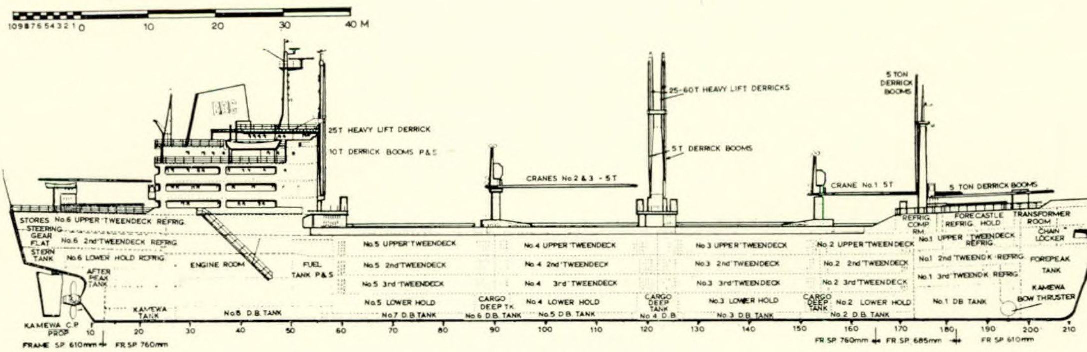
Ships' Stabilizers

Fins and tanks as stabilizing means are complementary.

The fin stabilizer provides the most efficient and effective means of stabilizing a vessel travelling at its normal speed in a seaway and there is no technical limit to the power that can be built in: it is purely economic.

The tank stabilizer is the most efficient and effective way of stabilizing the vessel at rest, or at slow speeds, since the power of the tank stabilizer is unaffected by ship's speed. There is, however, in this case a technical limit due to the loss of GM caused by free surface effects. In many ships this is about 2° to 3°.

In general a tank stabilizer is less effective than a fin stabilizer when the ship is moving at top or normal speed,



21½-knot cargo liner

but the tank stabilizer, however, has an economic advantage over the fin stabilizer in respect of cost.

With two complementary systems there are clear advantages if both can be operated in combination. Research work in this field indicates that this can be done. A combination system offers all the advantages of the systems individually at a price obviously greater than the tank system, but probably about that of the fin system.—*Rorke, J., Shipbuilding and Shipping Record, 9th August 1968, Vol. 112, pp. 185–188.*

Solid State Electronic Log

An advantage of the all solid-state marine log introduced by the Plessey Marine Systems Division is that the instrument can discern between forward and reverse motion relative to the surrounding water.

The log employs the electromagnetic principle and uses a probe in which coils and electrodes are encapsulated below the ship's hull. This generates an a.c. magnetic field in the surrounding sea water. The flow of water relative to the ship's hull acts as a moving conductor and an e.m.f. is generated proportional to speed. The e.m.f. is sensed by two pairs of electrodes and transmitted to the main display unit, where it is converted to digital indication of ship's speed and distance travelled.

This principle produces dependable, accurate and linear measurement of the ship's speed. Wide use of reliable, solid state components including integrated circuits has resulted in an instrument having no moving parts in the measurement system. The need for routine lubrication and maintenance of such parts has therefore been removed. Interference from cathodic protection is minimized by using corrective methods.

The system electronics are monitored by a built-in checking device which gives a warning on the main display unit if a system fault occurs. The equipment is built on the modular principle, enabling repairs to be carried out on a replacement basis.—*Shipbuilding and Shipping Record, 9th August 1968, Vol. 112, pp. 192–193.*

American Express Cargo Liner

Delta Argentina, the first of a series of five, has been handed over to her owner, Delta Steamship Lines, of New Orleans. The shipbuilder for all five vessels is Ingalls Shipbuilding Corporation of Pascagoula, a division of Litton Industries.

The shell butts and seams are welded throughout. The lower bilge strake is ABS Grade C normalized steel. A rounded gunwale connexion is provided for the mid-ship half length which is formed by rolling an 8-in radius in the outboard edge of the main deck stringer plate. Sheer and stringer strakes are ASTM-A517 steel, the use of this high strength material permitting an appreciable reduction in topside weight. It is believed that *Delta Argentina* represents the first modern large ship built in an American shipyard in the last 20 years which is 100 per cent welded and without any rivets whatsoever in the hull structure.

An impressed current cathodic protection system supplied by Englehard Industries is provided. The system consists of two reference electrodes, six guarded anodes, shaft slip ring device, complete control system, indicators and power supply as required for a complete automatic system.

The propulsion equipment for each ship consists of a General Electric high-pressure turbine and a low-pressure turbine, installed side-by-side and connected by a steam cross-under. Each is separately coupled to the pinions of a double-reduction gear unit.

The total available energy in the steam is divided about equally between the two turbines when operating at full load so that each performs roughly the same amount of work. For astern operation, a reversing element is included in the forward end of the low-pressure turbine. Openings are provided in the casings for the extraction of steam as required by the plant.

If either turbine becomes inoperative for any reason, the cross-under piping between the turbines can be changed to permit emergency operation of the working turbine.

The vessel is equipped with two vertical bank, single set, battery arranged boiler units of Babcock and Wilcox manufacture. The economizer is of B. and W. stud tube design. It is of the continuous loop type, arranged in the uptake after the last row of boiler generating tubes. In addition to the economizer, steam air heaters of the Aerorin type are fitted.—*Shipbuilding and Shipping Record, 7th June 1968, Vol. 111, pp. 790–795.*

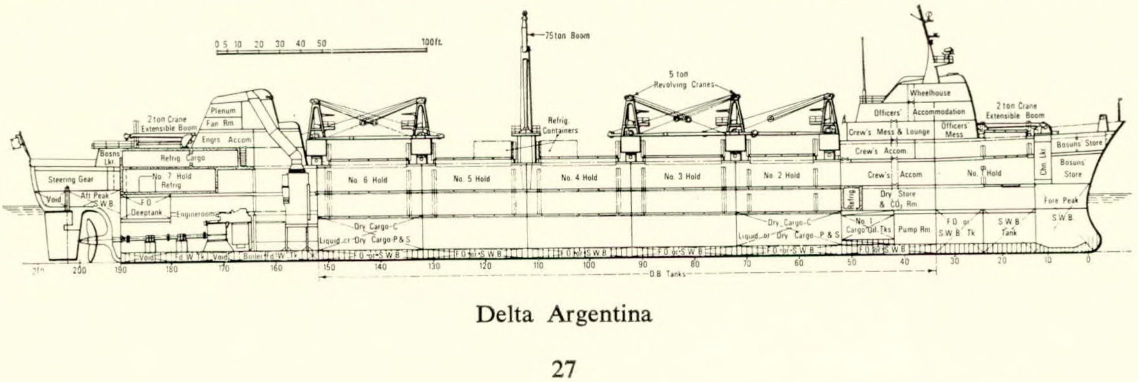
Omega Navigation System

After 15 years of research and development by the United States Navy, the Omega navigation system is now technically ready for operational use by ships and aircraft, both commercial and military.

The system will continuously provide position anywhere in the world and in all weathers, and the operation of the receiver is quick, simple, and reliable. Its demonstrated reliability is between one to two miles root mean square. The commercial version of the U.S. Navy type AN/SRN-12 Omega receiver, under contract production by Northrop Nortronics of California, is constructed of the same components and to the same high standard as the naval equipment. The power requirement is 115 V single-phase 60 Hz, and a 10 ft whip antenna is used.

The new Omega 1 receiver, operating on 10·2 kHz, measures the phase difference between signals received from any pair of transmitting stations ashore. Two, or three, intersecting lines of position then establish the position which is automatically displayed in digital form on the front panel of the receiver. Skywave corrections from U.S. Navy Oceanographic Office chart tables are then applied, and corrected lines of position are plotted to produce the position fix on the Omega chart for the area. Typical time needed for the complete operation from observation to final fix is about one minute.

The Omega system of relative nagivation, with stabilized



Delta Argentina

shore stations transmitting on very low frequencies and each with a range of 6000–8000 miles, provides fully worldwide coverage even in oceans remote from the usual radio aids, and under weather conditions which may render celestial observation impossible. Complete global coverage can be achieved with only eight such shore stations, and is its principal advantage over other systems: more than 100 Loran stations serve only about one-fifth of the earth.—*Shipbuilding and Shipping Record, 9th August 1968, Vol. 112, pp. 189–190.*

Israeli-owned Bulk Carrier

Har Addir is the largest ship in the rapidly expanding Israeli merchant fleet and the first ship to be built in the U.K. for Cargo Ships "El-Yam" Ltd., which is Israel's largest privately owned shipping company. The ship is operated by El-Yam Bulk Carriers (1967) Ltd., and is managed by the Maritime Overseas Corporation, New York, whose European affiliate is the Maritime Overseas Co., London.

Principal particulars are:

Length, o.a.	809 ft 0 in
Length, b.p. on 42 ft w.l. ...	776 ft 6 in
Breadth, moulded	104 ft 0 in
Depth, moulded	63 ft 0 in
Summer load draught	47 ft $5\frac{1}{2}$ in
Corresponding deadweight ...	77 250 long tons
Total cargo capacity (approx.) (grain)	3 000 000 ft^3
Heavy fuel capacity (approx.) ...	159 000 ft^3
Ballast capacity (approx.) including Nos 4 and 8 holds	1 659 000 ft^3
Service speed (approx.)	16 knots

In general layout the ship is a conventional bulk carrier with sloping hopper tanks between the tank top and shell and sloping saddle tanks between the shell and deck. There is a rather unusual feature, however, in that the designers have been able to obtain two-compartment sub-division due to the careful disposition of longitudinal side bulkheads in Nos 2 and 8 holds and have, therefore, been allowed B—100 per cent (Class A freeboard) under the 1966 Load Line rules.

It is believed that *Har Addir* is the first normal type bulk carrier to be assigned a draught associated with the Class A freeboard. The effect of this is that the ship can carry a deadweight of 76 902 long tons on a draught of 47 ft $3\frac{1}{2}$ in and in the near future this will be increased to 77 250 long tons at 47 ft $5\frac{1}{2}$ in. It is worth noting that a bulk carrier of the size of *Har Addir* would normally obtain B—60 per cent freeboard with one-compartment subdivision and the deadweight would be about 73 700 long tons on a draught of 45 ft 9 in. The two-compartment subdivision of *Har Addir* has, therefore, given the owners the advantage of carrying 3550 tons extra.

Har Addir is equipped with a bridge/engine control system supplied by Richardsons Westgarth (Instrumentation and Controls) Ltd., which allows the navigating officers to have direct control of engine speed and direction, provided that the engine room staff have switched over to "bridge" from the engine room control position.

A standard Harland and Wolff - Burmeister and Wain engine of the 884 VT2BF-180 design is installed. This is rated at 16 800 bhp at about 110 rev/min and it will operate on fuel of up to 3500 sec. Redwood No. 1. An electrically driven air blower of Sirocco design is fitted on the back of the engine to act as a standby in case of failure of one or both of the Brown Boveri turbochargers.—*The Motor Ship, July 1968, Vol. 49, pp. 195–198.*

Large French Tanker

At the time of her commissioning the 115 450 dwt *Dauphine*, built by Chantiers de l'Atlantique for Société Française de Pétroliers, was the largest French-flag tanker. Only three days later she was deposed from this position by the 213 000 dwt *Magdala*.

Built under survey and to the requirements of Bureau Veritas and American Bureau of Ships (B.V. class ✠ I 3/3 L1.1 (Petroleum in bulk) A and CP-F.60-H.R.), *Dauphine* is of conventional longitudinally-framed construction employing high tensile steel for the deck and bottom and their associated stiffeners, as well as for the top and bottom strakes of longitudinal bulkheads, the axial deck girder and the central bottom girder.

The cargo range is sub-divided into four centre and five each port and starboard wing tanks of which No. 3 on each side is reserved for water ballast.

Principal particulars are:

Length, o.a.	902 ft 3 in
Length, b.p.	859 ft 2 in
Breadth	133 ft 10 in
Depth	64 ft 8 in
Draught, maximum	49 ft 3 in
Deadweight, corresponding ...	115 450 tons
Cargo volume	4 668 592 ft^3
Clean ballast volume	942 341 ft^3
Gross register	59 958 tons
Net register	37 016 tons

Propulsive power is provided by a 10-cylinder Atlantique-B. and W. 84.VT2 BF. 180S developing 22 800 bhp at 114 rev/min turning a 31-ton four-bladed Novotone propeller, manufactured by Fonderies Phoceennes, to give the vessel a trial speed of 16·9 knots on a 41 ft 10 in draught.

Steam requirements at sea are met by an Atlantique waterwall tube exhaust gas boiler which is of sufficient capacity to drive the turbo-alternator and to supply all necessary heating devices including that for the heavy fuel. In the event of this supply falling short of requirements one of the two Saacke rotary burners of the main Foster Wheeler "D" type watertube boiler, manufactured by Chantiers de l'Atlantique and having an output of 37·4 tons/h of steam at 220 lb/in², fires automatically to meet the demand. The burner flame is watched by a photo-electric cell system and an Askania automatic heat regulation device is fitted.—*Shipbuilding and Shipping Record, 14th June 1968, Vol. 111, pp. 826–827.*

Propellers for Large Tankers

The increasing size of tankers continues although the limits for some of the world's seaways are reached. Further studies of tankers above 500 000 dwt are performed and one of the problems that must be solved is the powering and propulsion of the large vessels.

The service speed of large tankers is today 16 to 17 knots and at the present time the maximum power that is available from a single Diesel engine or steam turbine is about 50 000 shp. This means that the upper limits of single screw tankers are in the range of 250 000 to 320 000 tons depending on the propeller rotation when using the power as criterion. The weight of the propeller for these vessels will be in the range of 60 to 100 tons and with a diameter of 8 to 11 m.

Although there is no limit to the size of the propeller from a manufacturer's point of view, special problems will arise in producing castings of satisfactory quality and the equipment required will be very expensive when making propellers of 100 tons or more. Further, the large propeller weights introduce additional problems concerning shafting and bearing design as well as difficulties with handling and transport.

Furthermore it is a well known fact that the propulsive efficiency of large ships decreases as the ship size and power increase. This is attributable to the fact that the shaft rev/min has remained at approximately 110 to 120, except for some steam turbine installations, and the ship speed has been kept within small limits. From propeller charts it is seen that the increase of power without an increase in speed and change in rev/min decreases efficiency. To increase efficiency, an increase in the propeller diameter and a reduction in rev/min is necessary. The question in this connexion is how to suppress the reduced propulsive efficiency and avoid the difficulties with the increasing propeller size.

The combined propeller with the nozzle system offers the possibility of obtaining satisfactory propulsive efficiency with a reasonable propeller diameter. Several model tests have shown that a power saving of 5 to 15 per cent is possible by the nozzle-propeller system and with the optimum diameter 12 to 14 per cent less than the conventional propeller. If no nozzle is used but rev/min decrease from approximately 110 to 80, power reduction will be about 8 per cent. But even for the nozzle-propeller a reduction of rev/min together with increased propeller diameter will increase efficiency. If the nozzle-propeller is used with an approximate 80 rev/min, the power saving will be in the order of 20 per cent.—*European Shipbuilding, 1968, Vol. 17, No. 4, pp. 51; 66.*

Large Passenger Car Hydrofoil Ferry

The Supramar PT150, ordered from the Norwegian boatbuilders Westermoen Hydrofoil A/S, Mandal, by the Gothenburg-Fredrikshavn Line in August 1966 has now been delivered. Named *Espressan*, the new vessel has entered her owners' Sweden-Denmark ferry service.

This hydrofoil is a seagoing vessel capable of operation as a passenger or passenger/car carrier and meets the requirements of all the major classification societies. As *Espressan* is operating an international route, the regulations of SOLAS 60 have also been complied with.

The PT 150 is provided with two foils in tandem arrangements. The rear foil system, which is of the submerged air stabilized type built in accordance with Schertel-Supramar requirements, consists of the lift generating part and two vertical struts which are connected to the transom; the rudders are located at the trailing edge of the struts and the propellers below the foil. The bow foil is of the Schertel-Sachsenberg type with an additional pitch control; it is further provided with hydraulically-operated flaps which facilitate take-off and can also be used for turns, small course corrections and adjustment of flying height. The bow foil, together with its supporting elements, consists of a rigid frame structure. Both foils are of hollow high tensile steel construction.

Seating is provided on two levels for a total of 250 passengers; alternatively the layout can be altered for the vessel to carry 150 passengers and eight motor vehicles, or eight tons of palletized cargo, loaded onto the main deck by way of an hydraulically-operated ramp aft.

The propulsion installation of the PT 150 comprises two 20-cylinder vee-form turbocharged and intercooled Maybach MD 1081 Diesel engines, each continuously rated at 3400 bhp at 1740 rev/min with a fuel consumption of 0·38 lb/bhp-h, driving the propellers through Zahnradfabrik BW 1500 HS 18 reverse-reduction gear-boxes with built-in thrust bearings.—*Shipbuilding and Shipping Record, 13th September 1968, Vol. 112, p. 331.*

Japanese Nuclear Ship

Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI), recently concluded contract agreements with the Japan Nuclear Ship Development Agency (JNSDA), for the construction of the first Japanese nuclear-powered vessel.

This nuclear-powered ship will be built at IHI's Tokyo Shipyard and completion is scheduled for March 1972. It is expected that the hull of this vessel will be completed in 1970. Following installation of the nuclear reactor, after ascertaining safety and making various other tests, she will be delivered to JNSDA to make Japan the fourth nation in the world to have a nuclear-powered merchant vessel, the others being U.S.A., U.S.S.R. and West Germany.

This nuclear-powered ship is designed as an experimental vessel for the purpose of training crew members while carrying cargoes. She will be operated by 59 crew members and 20 others conducting experimental work.

Principal particulars are:

Length	426 ft 6 in
Breadth	62 ft 4 in
Depth	43 ft 4 in
Gross	8350 tons
Deadweight	2400 tons
Service speed	16·5 knots
Maximum speed	17·0 knots

One indirect cycle water moderated and water cooled type nuclear reactor, with a thermal output of 36 MW, will be installed on the ship. This will generate steam to drive a 10 000 hp steam turbine and provide the ship with a maximum speed of about 17 knots.

Even when the reactor accidentally stops, the ship can be safely operated with an auxiliary boiler.

To assure the maximum safety of the personnel around the reactor in case of accidents, it is installed in a 32 ft 10 in diameter high-tensile steel container. In addition, the outside of the container is wrapped in layers of shielding material—heavy concrete, lead and polyethylene.

Due consideration is also paid to hull construction in order to protect the reactor from collision, stranding or fire. Special attention has been paid to the area around the reactor room where there are sturdy partitions for foundering prevention and for shock-absorption.—*Shipbuilding International, August 1968, Vol. 11, pp. 48–49.*

German-built Gas Carrier for Dutch Owners

The gas-carrier *Antilla Cape* built by the Bremen yard of A. G. Weser was recently delivered to Scheepvaartmaatschappij Volharding N.V., Willemstad/Curaçao. The ship is intended for the transport of L.P.G. (propane, propylene, butane, etc.) as well as ammonia and has a capacity of about 30 000 m^3. She is the biggest ship for the transport of liquid gases, built by A. G. Weser. *Antilla Cape* has a length of 173·80 m, breadth of 25·80 m, depth of 17·10 m and draught of approximately 10·25 m. The vessel is powered by a Sulzer-Diesel engine with an output of 13 200 hp which gives the ship, in loaded condition, a trial trip speed of approximately 17·5 knots. The engine room of the vessel is fully automated and controllable from the bridge.

The cargo will be transported at atmospheric pressure and boiling temperature of about −50°C in four self-supporting insulated liquid-gas tanks. The liquid-gas tanks are manufactured of a special steel having sufficient tensility at the low temperatures of the cargo gases.

On the liquid-gas tanks a total of eight deep well cargo pumps are located enabling the vessel to be discharged within 12 hours. To avoid losses of the cargo by heating and evaporation, a reliquefying plant has been installed. By means of this plant the evaporating gases will be reliquefied and returned to the cargo tanks. If necessary, the pressure and temperature of the cargo can be lowered by this plant. Furthermore, the loading of the vessel will be possible without a gas return line to the shore connexion. The loading operation can be carried out in 18 hours. The gases displaced during the filling of the tanks will be reliquefied by the plant.

The tanks and pipelines of the ship's gas plant are protected by relief valves. For cleaning the liquid-gas tanks and piping an inert gas generator unit has been installed.—*Holland Shipbuilding, August 1968, Vol. 17, p. 63.*

Improved Oil Burner Performance

A suspended flame register halves loss coefficients by aerodynamic shaping of the inlet, diffuser and throat sections; a burner nozzle with a 20:1 turn-down ratio and no atomizer fouling is achieved by reshaping the atomizer tip. An exit swirler with an aerofoil shroud ring reduces draught loss by up to 20 per cent.—*Engineering and Boiler House Review, March 1968, Vol. 83, p. 88; Fuel Abstracts and Current Titles, September 1968, Vol. 9, p. 61.*

Temperatures at Lubricated Rolling/Sliding Contacts

A numerical method for the prediction of oil-film and metal surface temperatures is given for the case of lubricated rolling contacts with sliding. Near-Hertzian conditions occurring in gear discs and cams are considered and the temperature distributions, viscosity variations and heat partition values are calculated for a range of operating conditions. An asymmetry in the heat generation across the oil film is indicated.—*Manton, S. M., O'Donoghue, J. P. and Cameron, A., 1968, I.Mech.E. Paper P41/68.*

Fuel Oil Ash Deposition in Naval Boilers

The compact design is responsible for enhanced fouling rates. Location in the boiler and position on individual tubes were important in deposit composition. The deposit consisted of an innermost layer of corrosion product overlayed with further oil ash deposit. The rate of vapour deposition was independent of excess air but increased with increasing surface temperature. The nature of the deposit was unaffected by the excess air level but strongly dependent on surface temperature.—*Brown, T. D. and Ritchie, H. J., Jnl. Institute of Fuel, August 1968, Vol. 41, pp. 322–329.*

Theoretical and Experimental Study of Ship-roll Stabilization Tanks

This paper summarizes the development of a quasi-linear theory for rectangular-type anti-rolling tanks and presents results of the ensuing experimental investigation. Theoretical and experimental studies are compared. Experimental findings indicate that the anti-roll tank is a non-linear control element over its practical range of operation.—*Chu, W. H., Dalzell, J. F. and Modisette, J. E., Jnl. Ship Research, September 1968, Vol. 12, pp. 165–180.*

Low-speed Controllability of Ships in Wind

Aerodynamic and hydrodynamic data for the Marine class vessel were used to formulate a mathematical model representing the dynamic behaviour of ships in wind. The ship in bow wind tends—even without an auto-pilot system—to maintain its original course. Beam wind creates greater difficulties, although the use of an adequate auto-pilot increases the region of stability in wind of certain velocities. An increase in rudder size is shown to improve controllability in wind significantly.—*Eda, H., Jnl Ship Research, September 1968, Vol. 12, pp. 181–200.*

Research and Development in Colour Radiography

Recent research and development efforts directed toward the production of radiographs in colour is discussed. The relative merits of the use of different colour films is presented and some of the specific techniques used to produce colour radiographs are described. Comments on the application of colour radiography to inspection problems are included, together with a comparison with black-and-white radiographic techniques.—*Beyer, N. S. and Staroba, J. S., Materials Evaluation, August 1968, Vol. 26, pp. 167–172.*

Cholesteric Crystals for Nondestructive Testing

Cholesteric liquid crystals are compounds that go through a transition phase in which they possess the flow characteristics of a liquid while retaining much of the molecular order of the crystalline solid. Since liquid crystals have the ability to reflect irridescent colours, dependent upon the temperature of their environment, they may be used to project a visual colour picture of minute thermal gradients associated with material discontinuities. The author examines their utilization in nondestructive bond inspection.—*Brown, S. P., Materials Evaluation, August 1968, Vol. 26, pp. 163–166.*

Higher Order Wave Theory of Ships

The condition of the surface wave is considered on the free surface itself instead of the mean free surface, by the use of a co-ordinate transformation, together with the scheme of a systematic expansion in a small parameter,. Thus a higher order ship wave theory is developed. The most common practical case of a slender ship with an almost flat bottom is especially treated in detail.—*Yim, B., Jnl Ship Research, September 1968, Vol. 12, pp. 237–245.*

Digital Draught Indicator

A new digital draught indicator features a four-digit numerical read-out, a density corrector, remote central control box and the ability to share more than one draught station per control box read-out. Basically a pneumatic electric digital instrument, the unit permits a safe and rapid means of determining a vessel's exact draught. The indicator incorporates a sea water density corrector because, without it, an error of three per cent would incur which would give a 4-in error maximum over a 40-ft draught.—*Maritime Reporter/Engineering News, September 1968, Vol. 30, p. 44.*

World's Largest Tug

The world's largest and most powerful tug has been ordered by Bugsier Shipping and Salvage Co. The new tug is a 275-ft craft, powered by twin Diesel engines rated at a combined 16 000 hp. *Oceanic* is being built for the purpose of rendering assistance to supertankers. The 16 000 hp of *Oceanic* will enable the tug to travel 22 knots when running free. Her bunker capacity is 1250 tons which gives her a cruising radius of 20 000 miles.—*Maritime Reporter/Engineering News, September 1968, Vol. 30, p. 44.*

Detection of Material Discontinuities with Liquid Crystals

The inspection capabilities and limitations of liquid crystals applied after various joining methods have been used are discussed and a comparison made between these materials and conventional techniques. In addition, a brief description is given of the properties of liquid crystals from the standpoint of their applicability to nondestructive testing.—*Woodmansee, W. E. and Southworth, H. L., Materials Evaluation, August 1968, Vol. 26, pp. 149–154.*

Lubrication Requirements of a Modern Diesel Engine

Every engine manufacturer must determine the lubrication requirements and make service recommendations for the engines they produce. This paper is a general discussion of a method used to determine lubrication requirements for Diesel engines. It shows laboratory experience gained in single and multi-cylinder engines and field experience obtained from both proving ground and user tests before lubrication recommendations are finalized.—*McLain, J. A., Lubrication Engineering, June 1968, Vol. 24, pp. 254–261.*

Fatigue Properties of Repair Welded Cast Steel

The investigation is concerned with large weld volumes of 90–130 in^3 in heavy castings. Such welds of average soundness contain pores, while the castings always contain micro-shrinkage cavities. The large majority of the fatigue cracks starts at these defects. The expected endurance limit for defect-free welds was found to be higher than that for castings of the same tensile strength. On the other hand, the notch effect of pores was larger than that of micro-shrinkage cavities of the same size.—*de Kazinczy, F., British Welding Jnl, September 1968, Vol. 15, pp. 447–450.*

Evaluating Adhesives for Hydrofoils

This programme evaluated a wide range of adhesives for bonding different overlay materials to various substrates in an effort to find a combination applicable to hydrofoils operating at speeds up to 90 knots. Specimens appearing most promising in standard laboratory tests were tested as hydrofoil units in a water tunnel and on a rotating arm.—*Lehman, A. F. and Trepel, W. B., Materials Research and Standards, September 1967, Vol. 7, pp. 383–389; Applied Mechanics Reviews, June 1968, Vol. 21, p. 605.*

Calculation of the "Squatting" of a Hydrofoil Craft Taking Off from a Lift Surface

An investigation is made of the uncontrolled longitudinal motion of a hydrofoil craft incorporating both aerofoils and hydrofoils at bow and stern, on the transitional sections of its path. The motion is regarded as quasi-steady; i.e. all characteristics at any instant depend only on altitude, pitch angle and speed. Calculation of the relationship between altitude, angle of pitch and the forward speed is performed by the method of successive approximation.—*Rudomanov, V. I., Gidroaerodinamika Nesuschikh Poverkhnostey; Kiev, Nauk. Dumka, 1966, pp. 223–229; RZM 1967, No. 7, Rev. 7B 218; Applied Mechanics Reviews, June 1968, Vol. 21, p. 654.*

Pulsations in Intake and Exhaust Manifolds of Piston Engines

Various combinations of pipes and surge volumes are analysed for resonances. The authors make the usual simplifying assumptions on one dimensional flow without losses or reflexions and assume isotropic processes. This is applied to internal combustion engines under additional simplifying assumptions such as average constant cylinder volume. The authors indicate that engine efficiency can be appreciably increased or decreased by tuning or de-tuning the intake and exhaust piping system.—*Fiala, E. and Willumeit, H. P., Motortechnische Zeitschrift, April 1967, Vol. 28, pp. 144–151; Applied Mechancis Reviews, July 1968, Vol. 21, p. 731.*

Rolling Contact Fatigue Crack Initiation in a 0·3 per cent Carbon Steel

The results of detailed examination of the specimens from a number of pitting experiments carried out over some years on a particular combination of steels indicate that the pre-pitting crack was initiated by asperity interactions.—*Dawson, P. H., 1968, I.Mech.E. Paper P4/69.*

Metallurgical Aspects of Bearing Failures

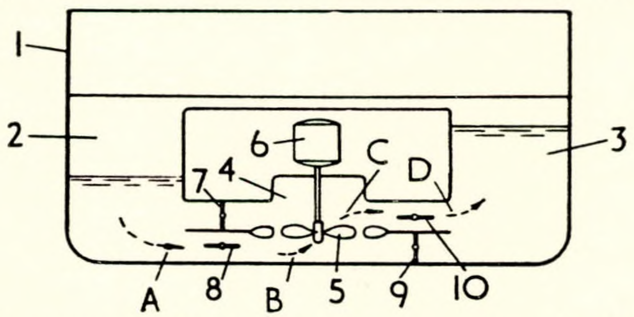
When rubbed against a steel pin simulating swarf in a bearing, phase transformations in carbon and nickel steel journals have been shown to form a protective hard surface layer, preventing failure. Under similar conditions in a three per cent Cr-Mo steel transformations did not occur, allowing metal transfer, carburization and eventual failure of the journal. These could be prevented by the selection of certain oils.—*Burns, K. W., 1968, I.Mech.E. Paper P40/68.*

Patent Specifications

Active Tank Stabilizer

The active tank stabilizer envisaged has two tanks partially filled with liquid and a channel system interconnecting their lower regions. A propeller is mounted in the channel system to drive liquid between the tanks, valves controlling the direction of flow of liquid from one tank to the other. A roll-sensing system controls the operation of the valves to achieve the stabilizing effect. The tanks and the channel system are so arranged as to provide a liquid system with a resonant frequency substantially corresponding to the highest roll frequency likely to be experienced. The hull of the vessel is shown at (1) and it is provided with tanks (2) and (3), having their lower regions interconnected by a channel system (4). The latter is divided into upper and lower channels by a horizontal partition with a central opening containing propeller (5), driven by motor (6).

The upper channel has two valves (7) and (10) of which valve (7) is shown closed and valve (10) is shown open. The lower channel has valves (8) and (9), of which valve (8) is shown open and valve (9) is shown closed. The propeller (5) draws liquid from the lower channel and discharges it into



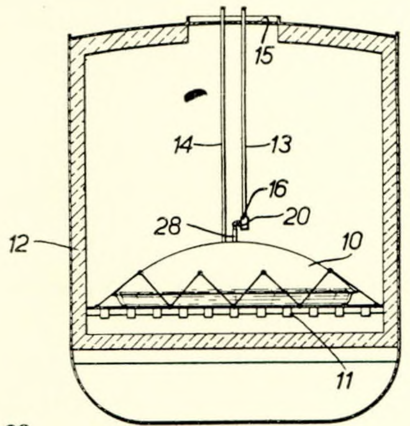
the upper channel. With the valves arranged thus, the direction of liquid flow between the two tanks is as shown by arrows. To reverse the direction of flow between the tanks, valves (8) and (10) are closed and valves (7) and (9) are opened.—*British Patent No. 1 123 393 issued to Muirhead and Co., Ltd. Complete specification published 14th August 1968.*

Ballast Arrangement for Tank Ships

This invention relates to a ballast arrangement for tank ships and more particularly to the prevention of contamination of the cargo tanks by ballast water or the contamination of the ballast water by any residue in the tank.

The cargo tank illustrated in Figs 1 and 2 contains a

FIG. 1.



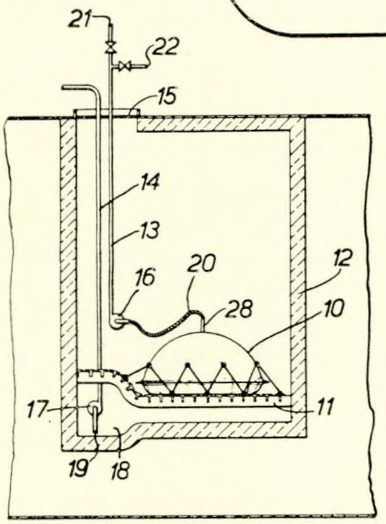


FIG. 2.

collapsible ballast bag (10) which is supported on a grating (11). The particular installation described is designed for carrying liquid butane and therefore the cargo tank is provided with thermal insulation (12) in order to reduce heat transfer. The heat transfer tends to occur to the greatest extent through the sides and base of the tank because these are in contact with the cold liquid cargo and also with the sea outside the vessel. For this reason it is conventional to avoid apertures in the walls and floor of the tank and therefore the ballast pipe (13) and the cargo pipe (14) pass through a hatch (15) situated in the roof. Since the depth of the tank is greater than the barometric height, the tank also contains the ballast pump (16) and the cargo pump (17); and these are supported by their respective pipes (13) and (14).

The cargo pump (17) is situated near the bottom of the tank in the sump (18). The ballast pump (16) is connected to the ballast bag (10) by means of a non-collapsible hose (20). At deck level the ballast pipe (13) branches to provide an air inlet (21) and a water inlet (22).—*British Patent No. 1 126 785 issued to British Petroleum Co. Ltd. Complete specification published 11th September 1968.*

Hatch Cover for Cargo Vessels

This invention relates to a new system of hatches for the holds of vessels which uses semicircular or sectoral covers which open and close by means of rotational movements in a horizontal plane. The system consists of a circular or semicircular coaming, the diameter of which may be slightly smaller than the beam of the vessel. Over this coaming rotates a first cover which is semicircular or sectorial in shape with sufficient space left around its outer rim for the accommodation of rolling gear and watertight joints. Over this rotates a second cover which is also semicircular or sectoral in shape and designed to cover the area of hatch opening not already covered.

Both the first and second covers are provided with rollers which allow them to rotate smoothly on circular tracks installed on the top of the coaming and on the upper surface of the first cover respectively. Watertightness is achieved by a series of seals and clamps which are distributed around the entire periphery of the first cover and the curved edge of the second. Each roller is surmounted by a spring-loaded elevator so that when the clamps are tightened the covers are pulled down against the action of the springs and a seal is made between the two covers or cover and coaming.

In Fig. 1, a plan view of the deck is shown with seven circular hatch openings (1) to (7). In Fig. 2, several possible positions of the hatch covers are shown from fully closed, as in (1') to one hatch fully open as shown in (5') and (7').

In Figs 1 and 2, (8) designates the longitudinal bulkhead which divides each of the circular hatchways (1) to (7) into two halves. (9) represents a series of vertical tanks for ballast, liquid or grain cargo and (10) a watertight bulkhead separating two adjacent holds while (11) shows a small hatchway allowing access to the vertical tanks (9).—*British Patent No. 1 126 282 issued to Cargocover S.A. Complete specification published 5th September 1968.*

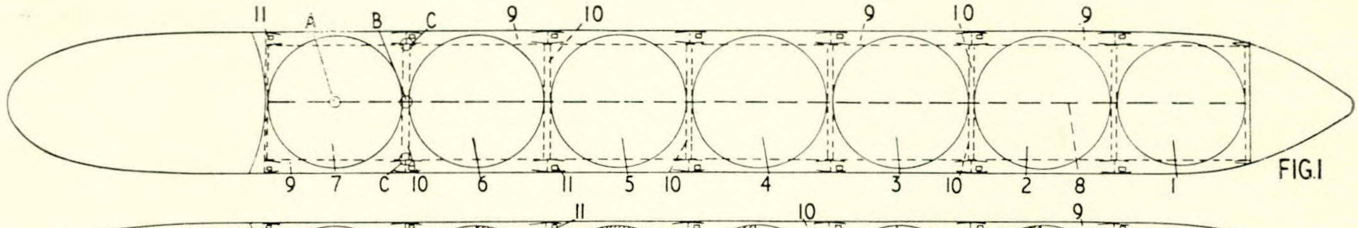


FIG.1

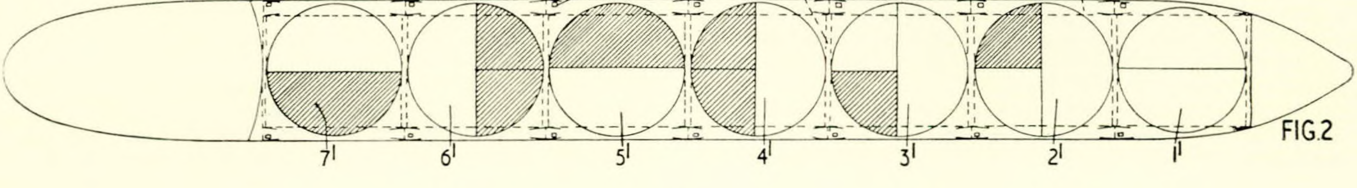


FIG.2